"The sound of affect": Age differences in perceiving valence and arousal in music and their relation to music characteristics and momentary mood

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Abstract

Throughout life, music plays an important role in individuals' everyday affective experiences. Previous findings suggest that preferences for, and perceptions of, music with distinct affective qualities might differ for individuals from varying age groups. To date, however, evidence from age-comparative studies across adulthood is rare and little is known about the mechanisms that contribute to age differences in music perception. In an age-heterogeneous sample ranging from adolescence to old adulthood (*n* = 50; 12–75 years), we investigated differences in affect perceptions of 147 sounds and 465 songs of various musical styles and dates of origin, as well as the respective roles of music characteristics and participants' current mood. Results indicate significant age-differential perceptions of valence and arousal in music, but not in sounds. Moreover, several music characteristics and the participants' current mood explained significant differences in the perception of affective qualities of music between listeners of different ages. These findings contribute to the understanding of age differences in affect perceptions in the auditory domain and the specificity of music, in particular. They also have implications for the use of music as experimental stimuli, which requires particular sensitivity to potential problems of age fairness and comparability.

Keywords: Affect perception, age differences, music, musical feature analysis, current mood, music and emotion, sounds

Music has been referred to as the “language of emotion” and its power to communicate and induce diverse emotional states has been addressed and explored extensively (e.g., Juslin & Sloboda, 2010; Lundqvist, Carlsson, Hillerson & Juslin, 2009). Several studies indicate that emotional perceptions of music are guided by individuals’ preferences as well as their momentary needs and goals (e.g., Laiho, 2009; Schaefer & Sedlmeier, 2010). Thus, when individuals listen to a piece of music, for example, by the Beatles or Bach, some find it peaceful, whereas others hear a melancholy undertone. Of course, to a certain degree, the perception of how pleasant, sad, angry, or cheerful a song seems, depends on its characteristics, such as whether it is in major or minor mode or whether it is fast or slow (e.g., Husain, Thompson, & Schellenberg, 2002). At the same time, the perception of the song’s affective quality also depends on characteristics of the listener. For example, it has been shown that current mood states can influence the perception of the affective quality of music in a mood-congruent manner (e.g., Vuoskoski & Eerola, 2011). That is, one may be more likely to perceive joy in a given piece of music the more joyful one feels at that moment. Previous research suggests that individuals’ age may play a particularly decisive role in this regard. For example, older adults were shown to perceive sad or scary music as less sad or scary, respectively, compared to younger people, while the perception of happy or peaceful music did not differ by age (e.g., Lima & Castro, 2011).

So far, however, the interdependency between music-inherent and person-related characteristics and the listener’s age remain unclear. Thus, the present study addressed two open questions: (a) Are objective music characteristics such as mode or tempo differentially relevant for listeners from various age groups as cues guiding their perception of affective qualities in music? (b) Does listeners’ current mood contribute to how they perceive affect in music, and does this association differ by age? The present research thus contributes to the understanding of differences in the perception of affective qualities in music and extends relatively rare previous findings by investigating the role of music and listener characteristics in individuals of various ages. The overarching aim of the present study was to add new insights into affect perceptions in music specifically and as compared to other auditory sounds. The findings are also relevant for experimental designs using musical stimuli, in particular when seeking to use music in samples including individuals varying in age, where the issue of stimulus equivalence across the investigated age groups is of particular importance to ensure age fairness of the study approach.

Age-related Differences in Affect Perception

The way affective qualities of various different types of stimuli are perceived seems to differ between individuals from different age groups (e.g., Carstensen et al., 2011; Riediger & Rauers, 2014). This is evident in age-related differences in the attribution of affect to music (e.g., Lima & Castro, 2011) as well as to visual stimuli, such as facial expressions (e.g., Ebner & Johnson, 2009) or pictures (e.g., Isaacowitz, Wadlinger, Goren, & Wilson, 2006). A meta-analysis across stimuli of different modalities (e.g., facial expression, speech prosody) showed that while the recognition accuracy for specific negative emotions (e.g., angriness, sadness) decreased with age, the recognition accuracy for other emotions, such as happiness and surprise, did not differ between individuals in various age groups (Ruffman, Henry, Livingstone, & Phillips, 2008). The few studies using music as stimuli are in line with these findings, indicating an age-related decrease in the recognition accuracy for negative emotions (fear, sadness), and comparably stable recognition of positive emotions (happiness, peacefulness) across different age groups (Laukka & Juslin, 2007; Lima & Castro, 2011).

Although the underlying mechanisms are not yet fully understood, there are strong indications that motivational changes in processing emotional information might be responsible for age-related differences in the perception specifically of negative emotions (e.g., Carstensen, Isaacowitz, & Charles, 1999). Investigations of age-heterogeneous samples covering the age range from adolescence to old age, for example, found a higher prevalence of pro-hedonic affect regulation motivation (of wanting to enhance or maintain positive affect or to avoid negative affect) among older adults, whereas contra-hedonic motivation (of wanting to enhance or maintain negative, or to dampen positive affect) was most prevalent among adolescent participants (Riediger, Schmiedek, Wagner, & Lindenberger, 2009; Riediger, Wrzus, & Wagner, 2014). These and other studies showed that older adults not only aspire to, but also experience, more positive affective states in everyday life than do younger individuals (e.g., Carstensen et al., 2011; Kessler & Staudinger, 2009; Riediger & Rauers, 2014).

The Specificity of Music as Compared to Other Auditory Stimuli

Previous studies on affect perceptions in non-musical sounds indicate similarities in the emotional processing of acoustic and visual cues (pictures and natural environmental sounds; Bradley & Lang, 2000) but also indicate differences in the processing of different types of acoustic stimuli (music and environmental sounds; Gomez & Danuser, 2004). In comparison to sound ratings, music affect perceptions varied equally across the two-dimensional space, whereas the negatively valent low-arousal area was underrepresented for sounds (Gomez & Danuser, 2004). In addition, a much stronger relationship between respiratory variables and affective ratings were obtained for music, which might indicate a higher emotional engagement in listening to music as compared to sounds (Gomez & Danuser, 2004). Although much evidence suggests music's high importance in serving everyday emotional functions in individuals of different age groups (e.g., Bonneville-Roussy, Rentfrow, Xu, & Potter, 2013; Laukka, 2007; Saarikallio, 2011), to our knowledge, no study has yet explored age-related differences in the affective perception of music in comparison to sounds. In the present study, we assumed that everyday music perceptions might be particularly affected by age-differential motivations and person characteristics such as momentary mood. Hence, we investigated whether differences in perceiving affective information in music are related to differences in currently experienced mood in individuals of varying age.

Valence and Arousal as Dimensional Affect Characteristics

The present study investigates differences in the perception of affective qualities of music. Dimensional affect models propose that affective states vary in both valence (i.e., how pleasant versus unpleasant they are), and arousal (i.e., how activating or deactivating they are; Russell & Barret, 1999). Although further modifications and additions on the two-dimensional valence-arousal plane have recently been discussed (e.g., Roda, Canazza, & de Poli, 2014), the majority of previous research suggests that affective qualities in music can be characterized reliably with regard to valence and arousal (e.g., Den Brinker, van Dinther, & Skowronek, 2012; Vieillard et al., 2008). Results from multidimensional scaling of emotional dissimilarity judgment data in music, for example, revealed a good fit with the two-dimensional approach of valence and arousal (Bigand, Vieillard, Madurell, Marozeau, & Dacquet, 2005; Eerola & Vuoskoski, 2010; Vieillard et al., 2008).

Further evidence suggests that both dimensions are especially relevant for understanding age differences in affect perception. For example, Keil and Freund (2009) reported differences in the extent to which individuals from different age groups differentiate between valence and arousal in their evaluations of affective picture stimuli. Whereas younger individuals' valence ratings were independent of the stimuli's arousal level, older adults tended to rate low-arousal pictures as generally pleasant and high-arousal pictures as generally unpleasant (e.g., Gruehn & Scheibe, 2008; Keil & Freund, 2009).

The Role of Music Characteristics for Affective Music Perception

Various studies aiming to define variables that are relevant for adults' affect attributions to music have focused on music characteristics (e.g., Leman, Vermeulen, De Voogdt, Moelants, & Lesaffre, 2005; Schubert, 2004). Although the features included in studies of Western music slightly differ, various indicators are robust in their prediction of attributions of valence and arousal to music, for example, tempo and mode (e.g., Hunter, Schellenberg, & Schimmack, 2008; Husain et al., 2002; Van der Zwaag, Westerink, & Broek, 2011). While a high tempo and a major mode are associated with positive valence (i.e., happiness), a lower tempo and a minor mode are associated with negative valence (i.e., sadness; e.g., Husain et al., 2002).

Furthermore, other studies point towards additional music characteristics and their predictive value for the perception of valence and arousal in music. For example, higher levels of loudness and timbre (the sound color, often described as light/dark or warm/cold) have been identified as reliable predictors for the perception of high arousal (e.g., Coutinho & Dibben, 2013; Ilie & Thompson, 2006; Schubert, 2004). A higher level of timbre and event density (musical events in the course of time as indicated by the frequency of harmonic change and or pulse) were significant predictors for the perception of negative valence (e.g., Eerola, 2011; Leman et al., 2005; Yang & Chen, 2011). In sum, evidence suggests that the attribution of affect to music can be partly predicted by a combination of the respective music piece's structural characteristics (Leman et al., 2005). Acoustic feature analyses thus yield information that help clarify these potential influences on the perception of music (e.g., Coutinho & Dibben, 2013; Weninger, Eyben, Schuller, Mortillaro, & Scherer, 2013).

Recent findings suggest that musical preferences change across the lifespan (Bonneville-Roussy et al., 2013, Bonneville-Roussy & Stillwell, Kosinski, & Rust, 2017), and that these changes might be related to changes in preferences for music-inherent attributes (Bonneville-Roussy & Eerola, 2017). For example, with older age, individuals preferred music with rough timbre and unstable loudness dynamics less (Bonneville-Roussy & Eerola, 2017). Bonneville-Roussy and Eerola (2017) suggest changes in hearing tolerance (i.e., toward high pitch and intensity) and emotion regulation motivation (i.e., preference toward positive affect) as possible explanations for age-differences in preferred music-inherent characteristics. Further results substantiate that music preferences can be guided by age-differential emotion regulation motivations (Cohrdes, Wrzus, Frisch, & Riediger, 2017). Thus, a comprehensive investigation of both music- as well as person-related factors for the explanation of age-related differences in music perceptions might add substantial knowledge, as already proposed in theoretical music preference approaches (e.g., LeBlanc, 1982; Hargreaves, Miell, & MacDonald, 2005).

Based on these and other findings (e.g., Bonneville-Roussy et al, 2017; Saarikallio, 2011) suggesting non-linear age effects in music preferences and perceptions throughout life, we examined linear as well as quadratic age effects in the present study. In addition, research shows that perceptions of music are positively related to the listener's familiarity with, and liking of, a specific musical style and its typical characteristics. These characteristics seem to play an important role in emotionally engaging the listeners with music (e.g., Pereira, Teixeira, Figueiredo, Xavier, Castro, & Brattico, 2011; Van den Bosch, Salimpoor, & Zatorre, 2013) and are therefore included as control variables in the present study.

The Role of Current Mood for Affective Music Perception

Momentarily experienced mood states have been associated with affect-congruent biases in evaluations of affective qualities in different stimuli (for a review, cf. Rusting, 1998). Although the role of current mood might vary with the type of emotional processing, the *feelings-as-information model* postulates that (affective) evaluations result from relying on one's mood as a source of information (Schwarz, 2001). Also, evaluations of affective qualities in music have been linked to the listener’s current mood. For instance, young adults perceived music as being in congruence to their momentary mood (Vuoskoski & Eerola, 2011).

Age-comparative research, however, suggests age-related differences in this regard. Younger and older adults, for example, were found to differ in their visual attention towards emotional information after mood induction (Isaacowitz, Toner, Goren, & Wilson, 2008). While younger adults generally showed a mood-congruent attentional bias, older participants showed mood-congruent attention to positive stimuli after induction of a positive mood, but mood-incongruent attention to positive stimuli after induction of negative mood (Isaacowitz et al., 2008). This finding substantiates assumptions of age-related differences in information processing related to currently experienced mood and serving affect regulation.

To the best of our knowledge, however, respective age-comparative evidence from music research is still lacking. To fill this void, one aim of the present study lies in the extension of previous findings on age-related processing biases in the visual domain by investigating age-related differences in current mood and their potential effects on the perception of affective qualities in auditory music stimuli.

Rationale of the Present Study

The present study aims to investigate age-related differences in affective music perceptions and the explanatory roles of both music and person characteristics. Second, the present study explores whether affective evaluations of auditory stimuli are specific to music as compared to other sounds.

Age differences in affective music perceptions. In line with previous research, we assumed that listeners varying in age would differ in their perceptions of the affective quality of music (e.g., Laukka & Juslin, 2007). More precisely, in *Hypothesis 1* (H1), we expected perceptions of music to be more positive and less arousing in older age. Additionally, we explored whether age effects occur for perceptions of valence and arousal in a non-musical control task from the auditory domain (*Exploratory Question*; EQ).

Age-moderations between music characteristics and affective music perceptions. It is still open whether individuals with differing age vary in their interpretation of music characteristics as cues for the perception of musical valence and arousal. Based on recent findings on music-inherent preferences (Bonneville-Roussy & Eerola, 2017), we expected loudness and timbre as well as measures indicating a high level of dynamic change or event density (e.g., deviation in loudness, timbre, harmonic change, pulse clarity) as relevant features also for the investigation of age-related differences in affective music perceptions. Hence, we hypothesized that the age of participants moderates the relationship between music characteristics such as loudness, timbre and event density, and the perception of affective qualities in music in *Hypothesis 2* (H2).

Age-moderations between current mood and affective music perceptions. Since part of the differences in valence and arousal perception in music may arise from person characteristics such as the currently experienced mood, we examined whether the age of the listener moderates the relationship between currently experienced mood and the perception of valence and arousal in music. In *Hypothesis 3* (H3), we expected in accordance with previous findings on visual stimuli (e.g., Isaacowitz et al., 2008), a mood-congruent perception of affective qualities in music in adolescents and young adults and a mood-incongruent perception of affective qualities in music when experiencing negative affect at older ages.

Method

Sample and Procedure

Fifty musical laypersons (50% female) participated in a computer-assisted music evaluation study from September to November 2011 at the laboratory of the Max Planck Institute for Human Development in Berlin, Germany. Men and women were equally distributed with n = 10 each across five age groups (12–17 years, *M* = 14.30, *SD* = 1.49; 18–29 years, *M* = 22.20, *SD* = 2.90; 30–44 years, *M* = 36.60, *SD* = 4.72; 45–59 years, *M* = 52.30, *SD* = 3.30; 60–75 years, *M* = 68.60, *SD* = 4.79) and had a mean age of 38.80 years (*SD* = 20.26 years). A non-significant result from a χ^2-Test ($p > .05$) confirms the assumption that the age of participants is equally distributed across the age range. Thus, the age of participants is used as a linear variable in the analyses.

As part of a larger assessment protocol, participants listened (individually through headphones) to 381 sounds and 465 songs in their full length (mean duration of songs = 3.41 minutes, *SD* = 0.85; mean duration of sounds = 1.42 minutes, *SD* = 0.64). Sounds and songs were presented in randomized order, and for two hours at a time. To rate all sounds and songs, participants attended seven testing sessions in total. These sessions were conducted within a period of four weeks and with age-homogeneous groups of two to four participants. After each song/sound, participants indicated on 7-point rating scales (-3 to 3/0 to 6) their familiarity with, liking of, as well as the levels of valence and arousal of the respective song/sound. Participants also completed a demographic questionnaire including musical expertise, a hearing ability test, a cognitive information-processing speed test, and a verbal intelligence test. At the beginning and end of each session, participants indicated their current mood. After the last testing session, participants received a reimbursement of 135 EUR (approximately $ 152). The study was approved by the ethics committee of the Max Planck Institute for Human Development in Berlin, Germany.

On average, the musical experience of the sample was relatively low regarding their musical knowledge (“I possess substantial musical knowledge,” $M = 2.86$, $SD = 1.49$) and musical practice (“I can play an instrument/several instruments well,” $M = 2.39$, $SD = 2.46$), whereas their interest in music was relatively high (“I am interested in music”, $M = 4.67$, $SD = 1.36$) as indicated on a seven-point rating scale ranging from 0 (do not agree at all) to 6 (agree totally). Musical experience and interest did not correlate significantly with the participants' age (knowledge $r_{age} = -.27$, $p = .06$; practice $r_{age} = -.14$, $p = .34$; interest $r_{age} = -.19$, $p = .17$).

To ensure that ratings were not distorted by potentially impaired hearing, we excluded people with hearing devices or diagnosed hearing impairments. In addition, the hearing ability of all participants was measured simultaneously for both ears based on the Hughson-Westlake procedure (Carhart & Jerger, 1959). All hearing scores were within normal ranges according to audiometric hearing thresholds, with $M = 5.7$ dB ($SD = 4.83$) for 250 Hz, $M = 7.1$ dB ($SD = 4.82$) for 500 Hz, $M = 1.0$ dB ($SD = 6.46$) for 1000 Hz, $M = 9.1$ dB ($SD = 8.14$) for 2000 Hz and $M = 7.8$ dB ($SD = 6.53$) for 3000 Hz and as compared to age peers from other study samples (e.g., Goodman, 1965; Wiley, Chappell, Carmichael, Nondahl, & Cruickshanks, 2008).

Moreover, participants showed normal cognitive skills within the expected age-appropriate ranges, as measured with a cognitive information-processing speed test (SDT; Lang, Weiss, Stocker, & von Rosenbladt, 2007) and with a verbal intelligence test (MWT-A; Lehrl, Merz, Burkard, & Fischer, 1991): cognitive information-processing speed, *M* = 52.82, *SD* = 10.60, Min = 36; verbal knowledge, *M* = 30.54, *SD* = 3.11, Min = 22 (see Lehrl et al., 1991; Sheridan et al., 2006).

Music and Sound Selection

Previous findings highlight the importance of subjective meaning and age-relevance of stimuli when investigating age-related differences in affect perception and recognition (e.g., Gruehn & Scheibe, 2008; Riediger, Voelkle, Ebner, & Lindenberger, 2011). Hence, we included music of several styles and dates of origin to accommodate potential age-related differences in the familiarity with, and liking of, various musical styles. As an auditory control task asserting the same claim of age-fairness, we included a selection of non-musical sounds with a comparably high variance in date and place of occurrence as well as in levels of valence and arousal.

Music selection. With the aim to maximize variance in valence and arousal of to-be-rated music pieces, three members of our research team with a professional music background (several years of music education and musical practice) searched suitable music pieces using the online platforms *allmusic.com*, *last.fm*, and *musicovery.com* as sources. The selection procedure was guided by the following criteria: (1) clear assignment to one of eight musical styles (classical, jazz, pop, rock, heavy metal, electronic, hip hop/RnB, folk/country), (2) distinct affective quality (i.e., no large changes in affective quality within a given song), and (3) diversity of release dates. To avoid possible biases between vocal and instrumental pieces, we included vocal music only. Each of the selected songs was assigned to one of the four quadrants of the affect circumplex model (Russell & Barrett, 1999): quadrant A = negative valence & high arousal (*n* = 117 songs), quadrant B = positive valence & high arousal (*n* = 117 songs), quadrant C = negative valence & low arousal (*n* = 114 songs), quadrant D = positive valence & low arousal (*n* = 117 songs).[1]

The final music selection consisted of 465 songs in total, that is, about 60 songs belonging to each of the eight musical styles and varying in publication date from 1607 to 2009 for classical music and from 1940 to 2011 for the other musical styles (see Supplemental Material A, Tables S1 to S8 for the complete song lists).

Sound selection. By systematically searching through sound databases and online resources (International Affective Digitized Sounds, IADS by Lang & Bradley, 2007; Hoerspielbox: http://www.hoerspielbox.de/frameset.htm, Brickfilms: http://brickfilms.com/resources, Salamisounds: http://www.salamisound.de, Freesound: http://www.freesound.org/index.php, and Audiyou: http://www.audiyou.de/index.html), three other members of our research team pre-selected 381 sounds with either affective or neutral content (e.g., screaming, laughter vs. making coffee, duck quacking). In line with the present study's rationale on examining affective stimuli, we report results regarding the subset of the 147 affective sounds only. Similar to the songs, sounds were selected if they met the criterion of distinct affective quality as rated on a seven-point rating scale from -3 (very low) to 3 (very high) and assigned to one of the four quadrants of the affect circumplex model.

Measures

Perception of valence and arousal in songs and sounds. After listening to each song/sound, participants indicated the perceived valence and arousal of each song/sound (see perceived vs. felt affective responses to music; Gabrielsson, 2002) using bipolar scales ranging from -3 (heavy/dark and calm/relaxing, respectively) to +3 (light/bright and agile/activating, respectively). Scale anchors were selected based on expert ratings from our research group (N = 14)[2].

Familiarity and liking of songs and sounds. Furthermore, participants were asked to rate each song/sound regarding liking ("How much do you like this song/sound?") on a 7-point Likert scale from 0 (not at all) to 6 (totally) and regarding familiarity ("How often have you heard this song/sound before?") from -3 (never) to 3 (very often).

Annotation of music characteristics. We determined indicators of various objective song characteristics that have been related to perceptions of music valence and arousal (e.g., Leman et al., 2005). These indicators are summarized in Table 1 and described in more detail in Supplemental Material B. They include characterizations of each song with regard to its mean and variance of tempo, mode, loudness, timbre (the sound color as indicated by the spectral centroid and spectral inharmonicity), or event density (as indicated by harmonic change and pulse clarity). Indicators were obtained for each of the 465 songs using the annotator software Sonic Visualiser (Cannam, Landone, Sandler, & Bello, 2006) and the corresponding Vamp plugins (see also the Vamp plugins user documentations at http://vamp-plugins.org). Descriptive statistics for each indicator averaged across songs per quadrant are shown in Table S9 (see Supplemental Material B).

(Insert Table 1 about here)

A random sample drawn from all automatically annotated music characteristics was monitored by the first author to assess measurement reliability. Due to a high level of discrepancy in the automatized tempo and mode, calculations of the Sonic Visualizer were replaced by music experts' assessments. Eight music experts from the Department of Music at the Max Planck Institute for Empirical Aesthetics in Frankfurt/Main, Germany (mean age = 32.27, *SD* = 5.30; 46.70% female) determined each song's tempo (in bpm) and mode (major/minor). Based on their own musical style expertise, each expert rated approximately 60 songs assigned to one of the eight musical styles. All experts held a degree in musicology (at least masters' level) and reported a high level of distinct knowledge of music (M = 5.27, SD = 0.88) on a scale from 0 (not at all) to 6 (totally), as well as a relatively high level of musical practice with M = 2.83 hours per week (SD = 2.72), across M = 20.53 years in total (SD = 5.41), and on average 13.67 years of music education (SD = 5.04).

Participants' current mood. At the beginning and end of each session, participants indicated their current mood using 12 items selected from different mood self-report measures (Hampel, 1977; Roecke, 2006; Watson, Clark, & Tellegen, 1988). The scale included three items each to indicate positive valence and high arousal (PV–high = lively, elated, cheery), positive valence and low arousal (PV–low = joyful, pleased, satisfied), negative valence and high arousal (NV–high = frustrated, irritated, angry), and negative valence and low arousal (NV–low = gloomy, down-hearted, sad). Response options ranged from 0 (not at all) to 6 (totally). Internal consistencies of subscales were α = .86 for PV–high, α = .86 for PV–low, α = .83 for NV–high, α = .83 for NV–low. In view of our aim to investigate effects of the current mood on the perception of valence and arousal in music, we included the mood states assessed at the beginning of each session in the analyses reported below.

Results

Age-related Differences of Affect Perceptions in Music and Non-Musical Sounds

Age-related differences in affective sound perceptions. To differentiate between music-specific and general auditory age effects in the perception of valence and arousal (EQ), we first analyzed affective ratings of non-musical sounds from a control task. We calculated two multiple linear regression analyses (*lm* function from the *car* package in R statistics; Fox & Weisberg, 2011) to predict the within-person averaged levels of valence and arousal ratings of sounds. The age of participants and the quadratic age term were entered as predictors as well as the familiarity with, and the liking of songs as control variables.

Both models explained a significant proportion of variance in the dependent variables, with $F(4,49) = 202.57$, $p < .001$, $R^2 = .36$ for valence, and $F(4,49) = 310.07$, $p < .001$, $R^2 = .43$ for arousal. Neither age nor age squared predicted valence (age: β = –.06, $p = .39$, quadratic age: β = .05, $p = .46$) or arousal perceptions of non-musical sounds (age: β = .08, $p = .21$, quadratic age: β = –.07, $p = .26$). The familiarity with sounds was a non-significant predictor for the perceived level of valence (β = .02, $p = .17$), but a significant positive predictor for arousal (β = .03, $p = .02$). Liking of sounds was a significant positive predictor for the perception of valence (β = .35, $p < .001$) and a significant negative predictor for arousal (β = –.43, $p < .001$) in sounds.

Age-related differences in affective music perceptions. In analogy to the sound analyses, we conducted two multiple regression analyses on the within-person averaged levels of perceived valence and arousal with age as well as the quadratic age term as indicators. The within-person centered levels of familiarity with, and liking of, songs were included as control variables. In line with H1, we assumed that with older age, individuals perceive music as more positive and less arousing.

Contrary to the sound ratings, both the linear age effect (β = –.25, $p <. 001$) and the quadratic age term (β = .28, $p < .001$) were significant predictors of the perceived valence ($F(4,49) =199.01$, $p < .001$, $R^2 = 0.18$, Figure 1a). That is, the level of perceived positive valence slightly decreased from adolescence on and increased again with older age (U-shape). In addition, songs were perceived as more positive with greater familiarity with (β = .02, $p = .04$), and liking of songs (β = .16, $p < .001$). Again, and other than for non-musical sounds, age (β = .67, $p <. 001$) and the quadratic age term (β = –.57, $p <. 001$) were significant predictors of the perceived arousal ($F(4,49) = 215.14$, *p* < .001, R^2 = 0.19, Figure 1b). In other words, the perceived level of arousal slightly increased from adolescence on but decreased again in older age (inverted U-shape). Songs were perceived as less arousing with greater familiarity (β = –.09, *p* < .001) and as more arousing with a greater liking of songs (β = .15, *p* < .001).

(Insert Figure 1 about here)

Associations Between Music Characteristics, Current Mood, and Music Affect Attribution Differ by Age

In the present research, we were interested in whether individuals varying in age might differ in their interpretation of music characteristics and the role of their momentary mood as a cue when attributing affect to music. To answer this question, we used crossed random-effects regression analyses (Baayen, Davidson, & Bates, 2008) and investigated potential age interactions of the associations between music characteristics (H2) and current mood (H3) on perceived affective music qualities.[3] The statistical approach of crossed random-effects models is similar to that of multilevel models except that it allows for independent sources of variances for persons and items (e.g., Judd, Westfall, & Kenny, 2012). In the present study, each person rated each song so that song ratings were crossed within each person, and person ratings were crossed within each song. Moreover, song ratings and current mood ratings were nested within persons across the seven different testing sessions. Thus, we specified songs and persons as crossed random-effects (by-person and by-song adjustments to the intercept) that both were also nested within sessions (by-person and by-song adjustments to the slope for sessions). We conducted separate analyses for testing H2 and H3 with two different models each predicting the (1) valence and (2) arousal ratings per song: The first set of analyses calculated the proportion of significant variance explained from *z*-

standardized music characteristics (H2; Table 2) and the second set of analyses from the within-person centered current mood (H3; Table 3). In all analyses, we included the liking of, and familiarity with, each song (grand-mean centered) as predictor variables on the song level as well as the participant's age (grand-mean centered; linear and quadratic effect) on the person level. We also included the cross-level interaction between age and music characteristics in the first analyses (Table 2), and the person-level interaction between age and current mood in the second analyses (Table 3).

Participants' hearing ability correlated significantly with age, $r = -.75$, $p < .01$ and had no effect on the perception of valence and arousal when age was included in the same model. Therefore, we excluded hearing ability from the following results. Detailed information on the perceived valence and arousal as well as the liking and familiarity of each song is given in the Supplemental Material A. Summarized results of age-related differences with regard to the liking and familiarity of varying musical styles are provided in the Supplemental Material C.

(Insert Table 2 about here)

Music characteristics. Results from the crossed random-effects analysis on the perceived level of valence and arousal show that a significant proportion of the variance was predicted by specific music characteristics, as expected (see Table 2): The mode of music, as well as the tempo, pulse clarity, mean loudness, variation (*SD*) in loudness, median spectral centroid, and the median spectral inharmonicity were significant predictors of both valence and arousal. The variability (*SD*) in the spectral centroid as well as the frequency of harmonic change only explained a significant additional proportion of variance for the valence dimension.

As shown in Table 2 and predicted in H2, crossed random-effects analyses also revealed significant interactions of specific music characteristics with age. A major mode, higher tempo, and lower spectral centroid were more strongly associated with perceptions of positive valence in older adults (Fig. 2). Furthermore, a major mode and a higher tempo were more strongly associated with perceptions of high arousal in older and middle-aged than in younger individuals (Fig. 3). Against H2, we found no significant moderations of age between loudness or measures indicating event density and affect perceptions.

(Insert Figures 2 and 3 about here)

Current mood. In H3, we predicted that listener's age would moderate the relationship between the currently experienced affect[4] and the perceived level of valence and arousal in music. As shown in Table 2, results revealed that the more participants had reported negative valence and low-arousal mood (NV–low) at the outset of the testing session, the more they perceived the music pieces they listened to during the session as positive. Moreover, and as expected, age moderated the relationship between NV–low and the perceived valence of the music: While for middle-aged and older adults, experiencing NV–low was associated with a higher tendency to perceive music as more positive, the opposite was the case for the youngest participants in the investigated age range (Fig. 4a). Region-of-significance analyses revealed that the association between NV–low and the perception of music valence was significantly positive in participants older than 46 years, and significantly negative in participants younger than 32 years of age.

The more individuals had reported positive or negative mood with high arousal at the beginning of the session (PV–high or NV–high), the more they perceived high arousal in the music. In line with H3, there was also a significant age moderation of the association between NV–high and the arousal level perceived in music: The younger participants were, the stronger the associations between NV–high and perceptions of high arousal in music were (Fig. 4b). Region-of-significance analyses revealed that the association between NV–high and the perception of arousal in music was significantly high in participants younger than 31 years, and significantly low in participants older than 50 years of age.

(Insert Figure 4 about here)

Post-hoc Statistical Power and Sample Size Analyses

With regard to the small sample size of the present study, we conducted post-hoc power analyses calculating the statistical power for the probability that the found effects from current mood on valence and arousal perceptions (Table 3) are significant based on n =100 Monte Carlo simulations with the help of the R statistics package *SIMR* (Green & McLeod, 2016). Analyses revealed that the test power exceeded the recommended threshold of 80 % for the following effects: NV-low on valence perceptions (power = 1.00; 95 % CIs = 0.96;1.00), NV-low × Age interaction on valence perceptions (power = 1.00; 95 % CIs = 0.96;1.00), NV-low × Age quadratic interaction on valence perceptions (power = 0.94; 95 % CIs = 0.87; 0.98), PV-high on arousal perceptions (power = 1.00; 95 % CIs = 0.96; 1.00), NV-high × Age interaction on arousal perceptions (power = 0.97; 95 % CIs = 0.91; 0.99), NV-high × Age quadratic interaction on arousal perceptions (power = 0.97; 95 % CIs = 0.91; 0.99). One exception is represented by the effect from NV-high on arousal perceptions with 0.57 test power (95 % CIs = 0.47;0.67) going below the recommended threshold. Hence, we calculated the appropriate sample size to achieve a test power of 80 % with the *powerCurve* function in *SIMR* (Green & McLeod, 2016). Analyses revealed that a sample with n = 70 would be appropriate to determine the found effect from current mood (within-person clustered, see Table 3) on affective music perceptions with a recommended statistical power of 80 % and with an error probability of less than 5%.

Moreover, results revealed satisfactory power of the present study, by showing that an n of approximately 220 songs would have been sufficed with the present sample size of participants to detect the found effects from music characteristics (within-songs clustered, see Table 2) on valence and arousal perceptions at the recommended 80 % level and with an error probability of less than 5%.

Discussion

Participants from an age-heterogeneous sample spanning the age range from adolescence to old age evaluated 465 songs in eight different musical styles and with varying dates of origin as well as 147 affective sounds as a different auditory control task in terms of their perceived levels of valence and arousal. They also indicated their current mood before evaluating the songs and sounds. Objective music characteristics were determined with the help of annotator software and music expert ratings. This information was used to investigate the predictive value of music and person characteristics as to how individuals in various age groups perceive valence and arousal in music.

Age-related Differences in Affective Perceptions of Non-Musical Sounds and Music

Individuals from varying ages did not differ significantly in affective perceptions of non-musical sounds. In contrast, affect attributions to music did differ by age. Accordingly, results indicate the specificity of music to make age-differential perceptions of affect apparent as compared to other auditory stimuli. This finding is new and needs to be elaborated in more detail. One explanation might be the high relevance and functional use of music in guiding emotional experiences in the everyday lives of individuals across the lifespan (e.g., Laukka, 2007; Saarikallio, 2011). Future studies could address open questions on how to explain these age-differential perceptions of affect in music by relating them to current age-relevant (affective) motivations more specifically.

In line with H1, we expected older individuals to perceive music as more positive and less arousing than younger individuals. Results indicated a quadratic age-related trend of perceiving positive valence and low arousal in music: Adolescents and older adults tended to perceive music as more positive on average than young and middle-aged adults did (U-shaped function). These findings are in line with research demonstrating an age-related increase in pro-hedonic motivation across adulthood (e.g., Carstensen et al., 2011; Riediger et al., 2009), but stand in contrast to previous observations of a comparatively higher propensity to contra-hedonic orientation in adolescents than in adults of older ages (cf. Riediger et al., 2009, 2014). Exploring the reasons underlying these age differences in the perception of musical valence thus remains an interesting open question to be addressed in future studies.

Regarding perceptions of musical arousal, we found that middle-aged adults tended to perceive higher average levels of arousal in music than did adolescents and older adults (inverted U-shaped function). The adolescents' perceptions of comparatively low levels of arousal in music may have to do with being in a phase of life that is characterized by a temporary increase in sensation-seeking tendencies, as has been observed in various life domains including media preferences (e.g., Arnett, 1994; Larson, 1995). As a consequence, adolescents may have a higher threshold for perceiving stimuli as arousing. For older adults, the comparatively low average propensity to ascribe arousal to music may reflect an affect-regulatory strategy to avoid high arousal, which has been found to be increasingly aversive (Keil & Freund, 2009) and increasingly difficult to recuperate from with higher age (Wrzus, Mueller, Wagner, Lindenberger, & Riediger, 2014). Again, these considerations remain speculative at this point, and further investigations are necessary to reveal the reasons for the observed age differences in participants' tendencies to perceive arousal in music. In sum, results underscore that merely investigating younger and older adults would obscure the non-linear age associations observed in the present study and highlight the importance of including adolescents and middle-aged adults when investigating perception of affect in music from a developmental perspective.

The Age-differential Role of Music Characteristics for Perceiving Affect in Music

In line with previous research, we found objective music characteristics such as the tempo, mode, and timbre (sound color as indicated by the spectral centroid or inharmonicity) to be significant predictors of the perceived level of valence and arousal in music (e.g., Leman et al., 2005). In addition, results of the present study show that measures of variability (i.e., the standard deviations of loudness and the spectral centroid) increase the explained variance in the affective perception of music beyond musical characteristics averaged per song. This pertains especially to the valence dimension, which has been more difficult to explain by basic musical characteristics so far (cf. Eerola, 2011). The more variable the loudness and timbre of songs were, the more they were perceived as negatively valenced and highly arousing. These findings are related to research on musical complexity as a psychoacoustic dimension and its influence on the perception of emotional qualities in music. Indeed, previous research in this domain suggests that music's perceived complexity, as determined by the variability (number of changes) or the degree of redundancy, for example in harmonic or melodic progression, is significantly related to the attribution of negative valence and high arousal to music (e.g., Balkwill & Thompson, 1999).

A new finding of the present study is that individuals in various age groups differ not only in their perception of valence and arousal in music, but also in the way they rely on specific music characteristics when judging the affective quality expressed by music (H2). A major mode, higher tempo and lower timbre were more strongly associated with perceptions of positive valence in older individuals. Moreover, a major mode and a higher tempo in music were more strongly associated with perceptions of high arousal especially in middle-aged but also in older as compared to younger individuals. Results can partly be interpreted in line with recent indications of age-related differences in hearing tolerance toward specific sound qualities such as the timbre (Bonneville-Roussy & Eerola, 2017). In the present study, higher levels of timbre were associated with lower levels of valence with increasing age, which could be explained by a higher vulnerability due to hearing loss and might also lead to lower preference ratings due to motivations of negative valence avoidance. Contrary to previous findings on music preferences, indications of dynamic change or event density were not significantly related to the age of participants while the tempo and mode played a particular role for the explanation of age-related differences in affective music perceptions.

Accordingly, findings seem also reasonable when taking differences in familiarity with musical styles into account (see also results reported in Supplemental Material C). For example, older adults showed a higher familiarity with classical and jazz music, while younger individuals were more familiar with popular music styles (e.g., pop, electronic), which differ in the use and combination of music characteristics (e.g., Bonneville-Roussy & Eerola, 2017). Structural analyses of popular songs across the last decades showed that current popular music is characterized by a more ambiguous mode, often breaking with conventional tempo associations, and may thus also have more ambiguous emotional connotations (cf. Schellenberg & Scheve, 2012). In conclusion, the interpretation of musical characteristics in the attribution of musical affect could differ by age as a result of higher levels of familiarity with musical styles, based on expertise and culturally learned indicators of affect (see also Balkwill & Thompson, 1999). Thus, one key task for future research lies in the longitudinal investigation of differences in the perception of affective qualities in music to clarify its development across adulthood as well as interrelationships between familiarity with musical style and the interpretations of music characteristics as indicators of affect in music.

The Age-differential Role of Current Mood for Perceiving Affect in Music

In addition, results from the present study support the hypothesis H3 that older adults differ from younger individuals in the influence of currently experienced mood on perceived levels of valence and arousal in music. The more older individuals reported NV–low, the more positive their perceptions of music were, as expected. This was the case for younger individuals too, but to a lesser extent. Furthermore, our results suggest that older adults perceived a higher level of arousal in music when reporting NV–high than did middle-aged and young adults. In other words, with regard to negative valence, younger individuals' perception of affect in music was mood-congruent, while that of older adults was mood-incongruent, which is consistent with H3 based on findings from previous research on the processing of negative pictures (e.g., Isaacowitz et al., 2008). In contrast, both younger and older participants showed a rather mood-congruent perception of positive valence in music. For arousal perceptions, mood-congruency effects also differed depending on the participants' age and were most pronounced among the youngest participants of the present sample (aged 30 years and younger). Overall, findings demonstrate that perceptions of affect in music differ depending on characteristics of the piece itself as well as characteristics of the listener as proposed by theoretical approaches to music perception and evaluation (e.g., LeBlanc, 1982; Hargreaves, Miell, & MacDonald, 2005) and particularly highlights age-differential perceptions.

Implications for Future Studies with Music as Experimental Stimuli

The present findings demonstrate that the individuals from varying ages perceived the *same set* of musical stimuli differently with regard to the songs' valence and arousal. In addition to the understanding of factors relating to perceptions of affect in music, our results also have ramifications for the use of music as experimental stimuli or affect-elicitors in age-heterogeneous samples. In particular, researchers using musical paradigms should be highly sensitive to the issue of age fairness and age comparability, which need to be established before running such studies. Results presented in the Supplemental Material may be instrumental in this regard. Despite the average perceptual differences, we found various songs that were perceived homogeneously across the entire examined age range and may therefore lend themselves as stimuli to be used in age-comparative studies (cf. Supplemental Material A).

Limitations

Although the current study used a very large number of songs (n = 465) and sounds (n = 147), which were rated by the same age-heterogeneous sample, it also possesses some limitations. The sample size was relatively small (N = 50), which restricts the generalizability of the present findings to other populations and may also have played a role in limiting the significance of potential effects of current mood on affective music perceptions. The sample size to detect age-related moderations between music characteristics and affective perceptions in music was sufficient and represents a strength of the present study.

In addition, the cross-sectional design of the present study is a limitation as it renders impossible both unravelling of causality in the investigated associations and disentangling of cohort differences from factors associated with within-person change over time in the observed age differences. Future research should investigate changes in the perception of affective qualities in a broader sample, and follow individuals over time as they grow older.

Conclusions

This study provides evidence of age-related differences in affective perceptions in music but not in sounds and thus highlights the specificity of music. In addition, the present study shows that affective experience of music is associated with specific factors intrinsic to the music piece itself (such as its tempo or mode) and to the listener (such as age, momentary mood, and familiarity with musical style). The found differences in affect attributions to music thus highlight the involvement of several individual factors in the evaluation process and question more general approaches of affect *recognitions* (in terms of false and true). Results moreover provide information on a broad selection of music that can be encountered frequently in everyday life. Our study thus extends previous research, which has often relied on synthetically produced music examples or on limited selections from one musical style (e.g., instrumental, film music), only. In addition to the insights these findings provide for better understanding of affect perception in music, they also have important implications for researchers planning to use music as experimental stimuli in age-comparative studies. The present research underscores that careful selection of musical pieces and styles is essential in order to achieve an age-fair investigation of research questions.

Supplemental Material

Tables and figures/audio files with the index “S” are available as Supplemental Online Material, which can be found attached to the online version of this article at http://msx.sagepub.com.

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Michaela Riediger is now Chair of the Department of Developmental Psychology at the Center for Lifespan Developmental Science at the Friedrich Schiller University Jena, Germany and Caroline Cohrdes is a Research Associate in the Mental Health Unit at the Department of Epidemiology and Health Monitoring at the Robert Koch Institute Berlin, Germany, as well as a Visiting Scientist at Center for Lifespan Developmental Science at the Friedrich Schiller University Jena, Germany. We embrace the values of openness and transparency in science (Schönbrodt, Maier, Heene, & Zehetleitner, 2015). We therefore report statistical power analyses, data exclusions (if any), and all procedures and variables concerning the current research question. There were no manipulations.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Endnotes

[1] The three team members selecting songs also pre-rated the perceived level of valence and arousal on a seven-point rating scale from -3 (very low) to 3 (very high). In order to test the consistency of ratings, 15% of them were thereafter double-coded by another member of our research team. The inter-rater reliability was $\kappa = .66$ for valence and $\kappa = .81$ for arousal. The inter-rater agreement in pre-selecting music by terms of affect perceptions was relatively low according to the valence dimension, but still satisfactory (values of $\kappa = .61$ to .80 indicate substantial agreement according to, e.g., Landis & Koch, 1979). This finding is in line with previous research indicating higher variability and less reliable predictability of perceived levels of valence in music as compared to arousal (e.g., Eerola, 2011). We do not consider this a problem for the present research, as the pre-selection and rating procedure merely served to compile a stimulus set of music pieces varying in date of origin, musical style, valence, and arousal. Other than that, these ratings did not play a role with regard to the findings presented here.

[2] Based on ratings from 14 members of our research team, we aimed to pre-select generally comprehensible and incisive labels for the valence and arousal scale anchors to be used for music evaluations in the main study. While listening to different affective music, we first collected several attributes describing both dimensions and finally selected attributes from the collection that were most frequently rated as appropriate.

[3] Assumptions on normality and homogeneity of residuals for regression analyses were tested with the help of histograms and q-q-plots indicating no violation.

[4] In the present study, the current mood across all sessions was predominantly PV–low (M = 9.09, SD = 3.70) and similarly PV–high (M = 10.07, SD = 3.62) but less NV–low (M = 1.27, SD = 2.06) or NV–high (M = 1.17, SD = 2.20). Correlations between

age and the currently experienced mood showed non-significant results for PV–low, PV–high and NV–low with *p*s > .05 but a significant negative correlation between age and NV–high (r_{age} = -.24, p <. 001).

Tables

Table 1.

Music Characteristics Related to Perceived Levels of Valence or Arousal: Corresponding Measures, Annotation Tools, and Selected References

Parameter	Measure	Indicator	Annotation	Reference
Harmonic change	Frequency	Valence	Vamp plugins, qm-tonalchange, tc function	Leman et al., 2005; Yang & Chen, 2011
Loudness	Mean, standard deviation	Arousal	Vamp plugins, libxtract, loudness	Bonneville-Roussy & Eerola, 2017; Coutinho & Dibben, 2013; Ilie & Thompson, 2006; Leman et al., 2005; Schubert, 2004; Weninger et al., 2013
Mode	Modal value, major/minor	Valence	Vamp plugins, qm-keydetector, mode, & expert ratings	Eerola, 2011; Leman et al., 2005
Pulse clarity	Autocorrelation coefficient of Inter-onset-intervals	Valence & Arousal	Vamp plugins, qm-onsetdetector, smoothed fd	Eerola, 2011; Zentner & Eerola, 2010

Table continues

Table 1 *(continued).*

Parameter	Measure	Indicator	Annotation	Reference
Spectral centroid	Median, Standard deviation	Arousal	Vamp plugins, spectralcentroid, linearcentroid	Bonneville-Roussy & Eerola, 2017; Coutinho & Dibben, 2013; Schubert, 2004; Weninger et al., 2013; Yang & Chen, 2011
Spectral inharmonicity	Mean, Standard deviation	Valence	Vamp plugins, libxtract, spectral inharmonicity	Bonneville-Roussy & Eerola, 2017; Eerola, 2011; Leman et al., 2005
Tempo	Beats per minute	Valence & Arousal	Vamp plugins, qm-tempotracker, tempo, & expert ratings	Bonneville-Roussy & Eerola, 2017; Coutinho & Dibben, 2013; Ilie & Thompson, 2006; Leman et al., 2005; Schubert, 2004; Weninger et al., 2013

Table 2.

Two Crossed Random-effects Analyses Predicting the Perception of (1) Valence and (2) Arousal From Music Characteristics and Interactions with Age and Age Quadratic, Controlling for Familiarity with, and Liking of Songs.

Parameters	**Valence**	**Arousal**
	Estimate [95% CI]	Estimate [95% CI]
Fixed effects		
Intercept	0.49** [0.42;0.56]	0.46** [0.39;0.52]
Age	1.22** [0.93;1.52]	-0.23 [-0.53;0.07]
Age^2	-1.08** [-1.38;-0.78]	0.31* [0.01;0.61]
Liking	0.13** [0.09;0.18]	0.15** [0.11;0.19]
Familiarity	-0.03 [-0.09;0.02]	-0.01 [-0.07;0.04]
Harmonic Change	-0.12** [0.08;0.16]	0.03 [-0.06;0.01]
M Loudness	0.62** [0.57;0.68]	0.08** [0.03;0.14]
SD Loudness	-0.26** [-0.31;-0.20]	-0.11** [-0.16;-0.06]
Mode	0.16** [0.08;0.25]	0.74** [0.66;0.81]
Pulse Clarity	0.06** [-0.10;-0.02]	0.07** [0.03;0.11]
Med Spectral Centroid	-0.11** [-0.16;-0.07]	0.13** [0.09;0.17]
SD Spectral Centroid	-0.08** [0.04;0.12]	0.02 [-0.01;0.06]
Med Spectral Inharmonicity	-0.16** [-0.21;-0.10]	0.17** [0.12;0.22]
SD Spectral Inharmonicity	-0.11** [-0.15;-0.07]	0.03 [-0.07;0.01]
Tempo	0.48** [0.43;0.52]	0.13** [0.09;0.17]
Age × Harmonic Change	-0.05 [-0.15;0.04]	0.02 [-0.08;0.11]
Age × *M* Loudness	0.08 [-0.06;0.21]	0.01 [-0.13;0.14]
Age × *SD* Loudness	0.05 [-0.08;0.18]	0.05 [-0.18;0.08]

Table continues

Table 2 *(continued)*.

Parameters	**Valence**	**Arousal**
	Estimate [95% CI]	Estimate [95% CI]
Age × Mode	0.27** [0.07;0.47]	0.34** [-0.54;-0.15]
Age × Pulse Clarity	0.08 [-0.02;0.17)	0.01 [-0.09;0.11]
Age × *Med* Spectral Centroid	0.11* [0.01;0.21]	-0.03 [-0.07;0.13]
Age × *SD* Spectral Centroid	0.05 [-0.05;0.15]	0.01 [-0.09;0.11]
Age × *Med* Spectral Inharmonicity	-0.08 [-0.22;0.06]	0.07 [-0.06:0.21]
Age × *SD* Spectral Inharmonicity	0.03 [-0.07;0.12]	0.06 [-0.04;0.16]
Age × Tempo	0.19** [0.09;0.29]	0.10* [-0.01;0.20]
Age^2 × Harmonic Change	0.05 [-0.05;0.14]	-0.02 [-0.11;0.08]
Age^2 × *M* Loudness	-0.10 [-0.23;0.04]	0.01 [-0.12;0.14]
Age^2 × *SD* Loudness	-0.05 [0.18;0.08]	0.02 [-0.11;0.15]
Age^2 × Mode	-0.29** [-0.49;0.09]	-0.34** [-0.54;-0.14]
Age^2 × Pulse Clarity	-0.07 [-0.17;0.03]	0.01 [-0.08;0.11]
Age^2 × *Med* Spectral Centroid	-0.07 [-0.17;0.03]	0.01 [-0.09;0.11]
Age^2 × *SD* Spectral Centroid	-0.04 [-0.14;0.06]	-0.01 [-0.11;0.09]
Age^2 × *Med* Spectral Inharmonicity	0.08 [-0.05;0.22]	-0.04 [-0.18;0.09]
Age^2 × *SD* Spectral Inharmonicity	-0.03 [-0.13;0.07]	-0.07 [-0.17;0.02]
Age^2 × Tempo	-0.22** [-0.32;-0.11]	-0.08* [-0.18;0.02]
Random effects		
Variance components (SD)		
Songs : sessions	0.78 (0.88)	0.64 (0.80)
Persons : sessions	0.21 (0.46)	0.22 (0.47)

Note. Results from crossed random-effects models were estimated using the *lme4* package from the R statistics software (Bates, Maechler, Bolker, & Walker, 2015). Significance levels for fixed effects were estimated using the *lmerTest* package (Kuznetsova, Brockhoff, & Christensen, 2017) with Satterthwaite's approximation for denominator degrees of freedom. Results from a likelihood ratio test (*anova* function provided by the *lmerTest* package based on Kenward-Roger's approximation) showed that the model with persons and songs specified as crossed random-effects nested within sessions has the right level of complexity for this data ($\chi^2 = 5780$, $p < .001$ for valence and $\chi^2 = 4978$, $p < .001$ for arousal) (see Baayen et al., 2008; Judd, Westfall, & Kenny, 2012). ** $p < .01$, * $p < .05$; see Table 3.

Table 3.

Two Crossed Random-effects Analyses Predicting the Perception of (1) Valence and (2) Arousal From Current Mood and Interactions with Age and Age Quadratic, Controlling for Familiarity with, and Liking of Songs.

Parameters	**Valence**	**Arousal**
	Estimate [95% CI]	Estimate [95% CI]
Fixed effects		
Intercept	0.38** [0.31;0.45]	0.15** [0.08;0.21]
Age	1.13** [0.86;1.40]	-0.34* [-0.62;-0.06]
Age^2	-0.99** [-1.28;-0.71]	0.45** [0.16;0.73]
Liking	0.27** [0.21;0.32]	0.24** [0.19;0.29]
Familiarity	-0.19** [-0.26;-0.13]	0.03 [-0.02;0.09]
PV–high	0.06 [-0.03;0.16]	0.18** [0.08;0.27]
PV–low	0.03 [-0.07;0.13]	-0.08 [-0.18;0.02]
NV–high	-0.03 [-0.11;0.04]	0.12** [0.04;0.20]
NV–low	0.14** [0.08;0.20]	-0.01 [-0.07;0.05]
Age × PV–high	0.13 [-0.36;0.62]	-0.34 [-0.84;0.15]
Age × PV–low	-0.17 [-0.67;0.33]	0.08 [-0.43;0.59]
Age × NV–high	-0.12 [-0.49;0.25]	-0.66** [-1.03;-0.29]
Age × NV–low	0.56** [0.22;0.89]	-0.07 [-0.41;0.27]
Age^2 × PV–high	-0.18 [-0.67;0.31]	0.24 [-0.26;0.73]
Age^2 × PV–low	0.21 [-0.31;0.73]	-0.02 [-0.55;0.51]
Age^2 × NV–high	0.01 [-0.39;0.42]	0.77** [0.36;1.18]
Age^2 × NV–low	-0.46** [-0.83;-0.09]	-0.03 [-0.40;0.34]

Table continues

Table 3 *(continued).*

Parameters	**Valence**	**Arousal**
	Estimate [95% CI]	Estimate [95% CI]
Random effects		
Variance components (SD)		
Songs : sessions	1.50 (1.23)	0.90 (0.94)
Persons : sessions	0.17 (0.41)	0.17 (0.41)

Note. PV–high = positive valence & high arousal, PV–low = positive valence & low arousal, NV–high = Negative valence & high arousal, NV–low = negative valence & low arousal. Results from crossed random-effects models were estimated using the *lme4* package from the R statistics software (Bates et al., 2015). Significance levels for fixed effects were estimated using the *lmerTest* package (Kuznetsova et al., 2017) with Satterthwaite's approximation for denominator degrees of freedom. Results from a likelihood ratio test (*anova* function provided by the *lmerTest* package based on Kenward-Roger's approximation) showed that the model with persons and songs specified as crossed random-effects nested within sessions has the right level of complexity for this data ($\chi^2 = 10506$, $p < .001$ for valence and $\chi^2 = 6859$, $p < .001$ for arousal; see Baayen et al., 2008; Judd, Westfall, & Kenny, 2012); ** $p < .01$, * $p < .05$.

Figure Captions

Figure 1. Correlation of within-person averaged ratings of (a) valence and (b) arousal across songs with increasing age. The regression line indicates the quadratic relationship. Valence and arousal were rated on a 7-point rating scale from -3 to +3.

Figure 2. Interaction plots showing significant effects of age and age squared with music characteristics, (a) mode, (b) tempo, (c) spectral centroid on the perception of valence in music. Age min = 12, mean = 39, max = 74. Valence and arousal were rated on a 7-point rating scale from -3 to +3. Error bars represent +/- 1 SE.

Figure 3. Interaction plots showing significant effects of age and age squared with music characteristics, (a) mode and (b) tempo, on the perception of arousal in music. Age min = 12, mean = 39, max = 74. Valence and arousal were rated on a 7-point rating scale from -3 to +3. Error bars represent ± 1 SE.

Figure 4. Significant interactions of age and age squared with the currently experienced level of (a) negatively valenced low-arousal mood on the perception of *valence* in music and (b) negatively valenced high-arousal mood on the perception of *arousal* in music. Age min = 12, mean = 39, max = 74. Valence and arousal were rated on a 7-point rating scale from -3 to +3. Error bars represent ± 1 SE.