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In the Ear of the Beholder: How Age Shapes Emotion Processing in Nonverbal Vocalizations

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It is well established that emotion recognition of facial expressions declines with age, but evidence for age-related differences in vocal emotions is more limited. This is especially true for nonverbal vocalizations such as laughter, sobs, or sighs. In this study, 43 younger adults ($M = 22$ years) and 43 older ones ($M = 61.4$ years) provided multiple emotion ratings of nonverbal emotional vocalizations. Contrasting with previous research, which often includes only one positive emotion (happiness) versus several negative ones, we examined 4 positive and 4 negative emotions: achievement/triumph, amusement, pleasure, relief, anger, disgust, fear, and sadness. We controlled for hearing loss and assessed general cognitive decline, cognitive control, verbal intelligence, working memory, current affect, emotion regulation, and personality. Older adults were less sensitive than younger ones to the intended vocal emotions, as indicated by decrements in ratings on the intended emotion scales and accuracy. These effects were similar for positive and negative emotions, and they were independent of age-related differences in cognitive, affective, and personality measures. Regression analyses revealed that younger and older participants' responses could be predicted from the acoustic properties of the temporal, intensity, fundamental frequency, and spectral profile of the vocalizations. The two groups were similarly efficient in using the acoustic cues, but there were differences in the patterns of emotion-specific predictors. This study suggests that ageing produces specific changes on the processing of nonverbal vocalizations. That decrements were not attenuated for positive emotions indicates that they cannot be explained by a positivity effect in older adults.

Keywords: ageing, emotion recognition, nonverbal vocalizations, brain deterioration, positivity effect

When interacting with others, we get information about their emotional states through multiple nonverbal cues such as facial expressions, body postures, touch, and voice. Interpreting these cues effectively is crucial for everyday interpersonal functioning. Emotion recognition competence is associated with personal and social adjustment (Carton, Kessler, & Pape, 1999; Hall, Andrzejewski, & Yopchick, 2009), and it mediates the ability to inhibit verbosity in communicative contexts (Ruffman, Murray, Halberstadt, & Taumoepeau, 2010) and to judge the appropriateness of social behaviors (Halberstadt, Ruffman, Murray, Taumoepeau, & Ryan, 2011). Current literature indicates that emotion recognition in nonverbal signals may change as we get older. A body of research, mostly on facial expressions, has reported age-related differences in recognition accuracy (e.g., Ruffman, Henry, Livingstone, & Phillips, 2008), gaze fixation patterns (e.g., Allard & Isaacowitz, 2008; Isaacowitz & Choi, 2011), and brain responses (e.g., Gunning-Dixon et al., 2003; Kisley, Wood, & Burrows, 2007; Williams et al., 2006). Although these changes can occur beyond general cognitive and sensory losses (e.g., Orbelo, Grim, Talbott, & Ross, 2005; Sullivan & Ruffman, 2004), the specific mechanisms that underlie them remain fiercely debated. Two caveats of the literature may be hindering progress. First, most research uses visual stimuli, much less being known about the auditory expression of emotions. Second, in some studies, it has been hypothesized that age-related effects vary with valence (e.g., Riediger, Voelkle, Ebner, & Lindenberger, 2011; Samanez-Larkin & Carstensen, 2011; Williams et al., 2006), but usually a single positive emotion (happiness) is compared with several negative ones. Here we examine how age shapes the recognition of a similar number of positive and negative emotions in voice, focusing on a

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specific kind of cues—nonverbal vocalizations (e.g., laughter, sobs, retching, or sighs). These nonlinguistic sounds are very unlike speech concerning the underlying articulatory mechanisms and acoustic features (Scott, Sauter, & McGettigan, 2010). They are a rich source of information in social settings—in what constitutes a primitive and universal form of communication (Sauter, Eisner, Ekman, & Scott, 2010) —that parallels the use of voice by other species (Belin, Fecteau, & Bédard, 2004; Scherer, 1995). We aim to refine our understanding of how age modulates emotion recognition, and to bring a developmental perspective to the study of nonverbal vocalizations.

Ageing and Emotion Recognition

It is well documented that advancing age is associated with decreased accuracy in the recognition of emotions portrayed in facial expressions (e.g., Calder et al., 2003; Isaacowitz et al., 2007; Lambrecht, Kreifelts, & Wildgruber, 2012; Mill, Allik, Realo, & Valk, 2009; Orgeta, 2010; Orgeta & Phillips, 2008; Williams et al., 2009). In a meta-analysis review of 17 data sets, mostly using forced-choice tasks, Ruffman et al. (2008) found that older adults (around 71 years of age) perform consistently worse than younger ones (24 years of age) for expressions of anger, fear, and sadness. The magnitude of the changes was smaller for happiness and surprise, and for disgust there was a trend for age-related improvements. That changes were smaller for happiness is difficult to interpret, though, because ceiling effects are often observed for this emotion (Calder et al., 2003; Isaacowitz et al., 2007; Orgeta, 2010; Sullivan & Ruffman, 2004; Williams et al., 2006). Stability for disgust is also not consistent across studies (Lambrecht et al., 2012; Mill et al., 2009). Thus, whether and how the magnitude of age-related decline differs across emotions remains to be established. Modalities other than faces are less explored, but available studies uncovered age-related decrements for body postures (Ruffman, Halberstadt, & Murray, 2009), lexical stimuli (Isaacowitz et al., 2007; Phillips & Allen, 2004), and visual scenes (St. Jacques, Dolcos, & Cabeza, 2010). Within the auditory domain, differences have been reported for emotion recognition in music (Laukka & Juslin, 2007; Lima & Castro, 2011a) and speech prosody (e.g., Mitchell, 2007; Mitchell, Kingston, & Bouças, 2011; Paulmann, Pell, & Kotz, 2008). These findings are suggestive of supramodal effects, although modality-specific changes seem to exist as well. For instance, in the aforementioned meta-analysis (Ruffman et al., 2008), declines for speech prosody (four data sets) and faces were comparable regarding anger and sadness, but decline for happiness was smaller in faces than in speech, and decline for fear was observed in faces but not in speech. Considering that visual and auditory stimuli engage distinct neural systems (e.g., Belin, Bestelmeyer, Latinus, & Watson, 2011; Scott, 2005), cross-modal specificities like these are to be expected. Specificities may exist even within the auditory modality, as different kinds of auditory emotional information rely on distinct neurocognitive mechanisms (Lima, Garrett, & Castro, 2013).

Mechanisms Underlying Age-Related Differences in Emotion Recognition

Cognitive and sensory losses are possible explanations for age-related effects in emotion recognition. Ageing is associated with deterioration in cognitive abilities (e.g., Grady, 2012; Hedden & Gabrieli, 2004; Salthouse, 2009) and in vision and hearing acuity (e.g., Caban, Lee, Gómez-Marín, Lam, & Zheng, 2005; Fozard & Gordon-Salant, 2001), with potential implications for higher order processes, such as speech and language (e.g., Benichov, Cox, Tun, & Wingfield, 2012; Peelle, Troiani, Grossman, & Wingfield, 2011). However, there is some evidence that these factors are relatively poor predictors of changes in emotion recognition in faces, speech prosody, and body postures (e.g., Mitchell, 2007; Orbelo et al., 2005; Ryan, Murray, & Ruffman, 2010; Sullivan & Ruffman, 2004). For instance, Lambrecht et al. (2012) found that decrements in the recognition of faces and speech prosody persist after partialing out differences in working memory, verbal intelligence, vision, and hearing (thresholds at frequencies between 125 and 8,000 Hz were covered). The role of these general factors for putative effects in nonverbal vocalizations has not been examined thus far.

Two more specific causal hypotheses have been debated in the literature. One highlights the role of brain decline in structures implicated in emotion processing, namely, in frontal and temporal lobes and/or in neurotransmitters (Cacioppo, Berntson, Bechara, Tranel, & Hawkley, 2011; Calder et al., 2003; Ruffman et al., 2008). Some emotions would undergo larger changes than others, because rates of brain deterioration differ across neural systems (e.g., Raz et al., 2005). For example, Ruffman et al. (2008) discussed in depth the possibility that deterioration in the cingulate cortex and amygdala underlies declines in the recognition of fear and sadness in faces, and that relative preservation of the basal ganglia underlies stability for disgust. The other hypothesis, grounded in the framework of the socioemotional selectivity theory, highlights the role of top-down regulatory processes. Because of reductions in perceived time horizons, advancing age would lead to increased prioritization of goals related to emotional well-being over gathering information and exploration, resulting in controlled efforts to direct cognitive resources toward positive information. The term “positivity effect” designates a relative preference for positive information over negative information at older ages (Carstensen & Mikels, 2005; Charles & Carstensen, 2010; Mather & Carstensen, 2005; Reed & Carstensen, 2012; Samanez-Larkin & Carstensen, 2011). Findings that age-related changes might be smaller for the recognition of happiness versus negative emotions are often interpreted within this framework (Laukka & Juslin, 2007; Lima & Castro, 2011a; Mill et al., 2009; Mitchell et al., 2011; Riediger et al., 2011). Williams et al. (2006) have argued for this account as well: Age-related decline in the recognition of fearful faces was predicted by increased activity in the medial prefrontal cortex (assumed to reflect enhanced regulation over negative input), whereas the stability in the recognition of happy faces was predicted by decreased activity in the same region. However, some caveats of these findings need to be considered: (a) because ceiling effects were found for happiness, it is difficult to discern whether the effects reflect real differences between emotions or the differential ease with which they were processed; (b) decrements in the recognition of fear were also predicted by structural reductions in the medial prefrontal cortex gray matter volume, a finding more compatible with a brain deterioration account; and (c) as in emotion research in general, only one positive emotion was examined, making it difficult to ascertain whether differences are happiness-specific or a general effect of valence. Investigating other modalities, and analyzing a diverse set of positive and negative emotions, will allow for a finer analysis of the roles of brain decline and top-down regulation for age-related effects in emotion recognition.

Recognizing Emotions in Nonverbal Vocalizations

Nonverbal vocalizations[1] communicate emotions as effectively as facial expressions and speech prosody. Schröder (2003) reported very high accuracy—81% on average—for the recognition of 10 emotion categories (admiration, threat, disgust, elation, boredom, relief, startle, worry, contempt, and hot anger) in vocalizations that included spontaneous nonverbal sounds, like laughter, and more conventionalized affect emblems, like "yuck." This study focused mostly on negative emotions, but nonverbal vocalizations are also effective at expressing a wide range of positive states. Sauter and Scott (2007) observed that vocal sounds communicating five positive emotions—achievement/triumph, amusement, contentment, sensual pleasure, and relief—elicit high recognition accuracy (70% on average) and consistent ratings. Other seldom-studied positive emotions can be perceived in vocalizations as well, such as awe, compassion, enthusiasm, and interest (Simon-Thomas, Keltner, Sauter, Sinicropi-Yao, & Abramson, 2009). Hence, as suggested by Ekman (1992), vocal expressions may be a unique tool for investigating the processing of positive emotions. It is also known that subjective behavioral responses to vocalizations can be predicted from the low-level acoustic features of the stimuli, as previously demonstrated for a different kind of vocal emotions—speech prosody (Banse & Scherer, 1996; Juslin & Laukka, 2001). In multiple regression analyses, Sauter, Eisner, Calder, and Scott (2010) observed that specific constellations of acoustic cues related to temporal aspects, amplitude, pitch, and spectral profile predict listeners' ratings for 10 emotions (achievement/triumph, amusement, contentment, sensual pleasure, relief, anger, disgust, fear, sadness, and surprise). Because their study was conducted on younger undergraduates, it remains to be determined whether the constellations of predictors are age dependent, and whether advancing age is associated a less efficient use of the acoustic cues. From a developmental standpoint, there is evidence that 5-year-old children can already recognize positive and negative emotions in vocalizations (Sauter, Panattoni, & Happé, 2012). Regarding changes across the adult life span, little is known. Ruffman and colleagues (Ruffman, Halberstadt, et al., 2009; Ruffman, Sullivan, & Winand, 2009; Ryan et al., 2010) tested younger and older adults with mixed sets of speech prosody stimuli and nonverbal vocalizations, and reported age-related decline for sadness and anger (no differences for happiness, disgust, fear, and surprise). However, these studies examined a maximum of two exemplars of nonverbal vocalizations per emotion, recorded by one or two speakers, making it difficult to rule out stimulus effects. Furthermore, combined results were analyzed and discussed for speech prosody and vocalizations, which means that domain specificities could not be not considered, and a single positive emotion (happiness) was included. Therefore, any specific effects of age on nonverbal vocalizations, and any modulating effect of valence, are to be determined.

The Present Study

We investigated age-related modulations in the recognition of nonverbal vocalizations. To examine possible valence-specific effects, a similar number of positive and negative emotions was included: achievement/triumph, amusement, pleasure, and relief; anger, disgust, fear, and sadness. The selected positive categories were suggested to correspond to distinct vocal emotions (P. Ekman, personal communication), and indeed they were previously shown to elicit high categorization accuracy and consistent ratings, unlike other categories such as contentment, pride, or love (Sauter, Eisner, Calder, et al., 2010; Sauter & Scott, 2007; Simon-Thomas et al., 2009). A multidimensional rating procedure was implemented in which participants rated how much each vocalization expressed the intended emotion as well as all the other emotions. This task is less prone to the responses biases that can affect forced-choice paradigms (e.g., Isaacowitz et al., 2007), and it provides a more comprehensive and complex understanding of how listeners perceive the stimuli (Riediger et al., 2011). To account for the potential role of general variables, we controlled for hearing loss, employed a battery of cognitive measures, and administered a personality inventory, as personality traits may shape emotion processing (e.g., Hamann & Canli, 2004). Additionally, we included measures of current affect, emotion regulation, and future time perspective; according to a top-down regulatory account on age-related differences in emotion recognition, emotion regulation and future time perspective would be the drivers of changes in performance on the emotion task. On the basis of the literature for other modalities (e.g., Ruffman et al., 2008), we hypothesized that age is associated with decrements in sensitivity to nonverbal emotion vocalizations, and that these decrements can be independent of general cognitive decline. If age-related differences are explained by top-down regulatory mechanisms toward positivity, then decrements should be attenuated for positive emotions compared with negative ones. If they are caused by other mechanisms, such as brain deterioration, there might not be a straightforward relationship between the valence of the emotion and the magnitude of the decrements. We measured vocalizations for a set of acoustic features and examined how younger and older participants' ratings could be predicted from these cues.

Method

Participants

A total of 86 participants took part in the study. Forty-three were included in the younger group (M age = 22, SD = 2.2; age range = 19 to 27 years), and 43 in the older group (M age = 61.4, SD = 7.9; age range = 47 to 83 years). All participants were living independently in the community and were in good general physical health. Exclusion criteria were major psychiatric and neurological illnesses (e.g., depression), current or recent intake of psychotropic

[1] Nonverbal vocalizations are often referred to as "affect bursts" (Scherer, 1994). We do not use this expression here because our vocal sounds do not always show the features denoted by the word "burst" (e.g., rapid onsets, intense expressions, very brief durations). Additionally, we examined vocal cues alone, not the co-occurrence of facial and vocal affect, as the original definition of affect burst implied.

medications, cognitive decline or brain damage (e.g., history of seizures or brain tumors), and hearing difficulties. Both younger and older participants reported having good hearing abilities, as indicated by the ratings provided in a scale from 1 (*very good hearing*) to 6 *(very bad hearing*; younger participants, $M = 1.8$, $SD = 0.6$; older participants, $M = 2.5$, $SD = 1$). Written informed consent was obtained from all participants. They received financial compensation for their time. The study involved a single individual experimental session lasting about two hours. As can be seen in Table 1, the two age groups were matched for education, gender distribution, and musical training.

Background Cognitive and Affective Measures

The results of background cognitive and affective assessments are also summarized in Table 1. These assessments included measures of hearing loss, general cognitive status, verbal intelligence, short-term and working memory, executive control, current affect, emotion regulation strategies, time perspective, and personality traits. A pure-tone audiometric screening test was completed, and participants were included only if they had thresholds equal to or lower than 30 dB HL in both ears, at the frequencies that are crucial for speech perception (500 Hz, 1,000 Hz, 2,000 Hz, and 4,000 Hz). To inspect general cognitive status, we used the Montreal Cognitive Assessment test (MoCA; www.MoCAtest.org; Portuguese version, Simões, Firmino, Vilar, & Martins, 2007). All participants scored ≥21 (maximum 30), which is within the normative range for the Portuguese population (normative study based on a sample of 650 cognitively healthy adults; Freitas, Simões, Alves, & Santana, 2011). Verbal intelligence and short-term and working memory were assessed, respectively, with the Vocabulary and Digit Span tests of the Wechsler Adult Intelligence Scale (Wechsler, 2008). Executive control was assessed with a Stroop task. Participants named colors as fast as possible in two conditions: a baseline condition, in which stimuli consisted of nonlinguistic letter strings (e.g., XXXX) printed in blue, pink, green or gray; and conflict condition, in which stimuli consisted of written words (azul, blue; rosa, pink; verde, green; or cinza, gray) printed in an incongruent ink color (e.g., the word azul, blue, printed in green ink), and participants named the color of the ink, independently of the word. The latencies in the baseline condition were taken as a proxy for processing speed (average reaction times, RTs, per item), and in the conflict condition they were taken as a proxy for cognitive control. As a measure of current affect, we used the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988; Portuguese version, Galinha & Pais-Ribeiro, 2005). To assess emotion regulation strategies, two questionnaires were used: the Emotion Regulation Questionnaire, which evaluates reappraisal and suppression (ERQ; Gross & John,

Table 1
Participant Demographic and Background Characteristics

Characteristics	Younger ($n = 43$)	Older ($n = 43$)	$F(1, 84)$	p
Education (years)	15.4 (1.7)	14.4 (2.9)	3.63	.06
Gender	22 F/21 M	30 F/13 M	—	.08
Musical training (years)	0.5 (1.3)	0.3 (0.9)	1.11	.3
Montreal Cognitive Assessment (/30)	27.4 (1.7)	26 (2.2)	11.24	< .001
Vocabulary WAIS-III (raw score,/66)	45.5 (7.7)	47.5 (7.1)	1.65	.2
Digit Span WAIS-III (raw number of digits recalled)				
Forward (/9)	6.2 (1.3)	6.1 (1.3)	0.03	.87
Backward (/9)	4.7 (1.1)	4.3 (1.1)	3.55	.06
Stroop test (naming latencies, s/item)				
Baseline	0.7 (0.1)	0.8 (0.1)	3.3	.10
Conflict condition	1 (0.2)	1.3 (0.3)	18.4	< .001
Positive and Negative Affective Scale				
Positive affect (/50)	26.7 (5.3)	31.3 (6.6)	12.58	< .001
Negative affect (/50)	13.3 (3.7)	11.2 (2.3)	0.23	.01
Difficulties in Emotion Regulation Scale				
Nonacceptance (/5)	2.1 (0.9)	2.6 (0.9)	5.31	.02
Goals (/5)	3.1 (0.7)	2.7 (0.7)	4.75	.03
Impulse (/5)	2.1 (0.5)	2.1 (0.5)	0.08	.77
Awareness (/5)	2.1 (0.6)	2.3 (0.6)	2.77	.10
Strategies (/5)	2.1 (0.7)	1.9 (0.6)	2.07	.15
Clarity (/5)	1.9 (0.5)	1.9 (0.6)	0.01	.94
Emotion Regulation Questionnaire				
Reappraisal (/7)	4.5 (1.1)	4.9 (1.0)	3.34	.07
Suppression (/7)	3.2 (1.2)	3.5 (1.1)	2.05	.16
Future Time Perspective Scale (/70)	52.2 (7.9)	39.5 (12)	33.36	< .001
NEO Five-Factor Inventory (raw score)				
Neuroticism (/48)	23.4 (7.8)	20.7 (5.3)	3.47	.07
Extraversion (/48)	31.2 (4.9)	29.1 (6)	3.03	.09
Openness (/48)	32 (6.7)	31.3 (4.7)	0.41	.53
Agreeableness (/48)	33.1 (5.8)	34.2 (4.5)	0.91	.34
Conscientiousness (/48)	32.8 (7.1)	35.4 (4.8)	4.2	.04

Note. Standard deviations are given in parentheses. M = male; F = female; WAIS-III = Wechsler Adult Intelligence Scale.

2003; Portuguese version, Machado Vaz, 2008), and the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004; Portuguese version, Coutinho, Ribeiro, Ferreirinha, & Dias, 2010), which covers six dimensions wherein difficulties may occur, such as difficulties in accepting negative emotional responses in oneself. Future time perspective (i.e., how much people perceive future time as being limited) was evaluated with the scale by Lang and Carstensen (2002). Finally, we used the NEO Five-Factor Inventory (NEO-FFI) to inspect personality traits (McCrae & Costa, 2004).

As can be seen in Table 1, younger and older participants differed in several measures. Older participants performed worse than younger ones on general cognitive status (MoCA) and executive control (Stroop conflict condition). They had also marginally worse working memory (backward digit span task). This is in agreement with literature on neurocognitive aging (e.g., Grady, 2012; Hedden & Gabrieli, 2004; Salthouse, 2009). Older participants reported less current negative affect and more positive affect compared with younger ones, a result consistent with previous studies (Mather & Knight, 2005). There were differences concerning emotion regulation as well: older participants reported struggling more than younger ones against the experience of negative emotions (DERS–nonacceptance), and engaging more easily in goal-directed behaviors (DERS–goals); they also reported using reappraisal marginally more often than younger participants (ERQ). Orgeta (2009) found an age-related decrease in difficulties in the goals dimension of DERS, and John and Gross (2004) and Yeung, Wong, and Lok (2011) found age-related increments in the use of reappraisal. As expected, future time perspective was higher for younger than for older participants. Finally, we found age-related differences in personality traits: Older participants showed a marginally significant decline in neuroticism, and an increase in conscientiousness (for similar effects, e.g., McCrae et al., 1999).

Stimuli and Experimental Task

The stimulus set included tokens from a recently validated corpus of nonverbal vocalizations (Lima, Castro, & Scott, 2013) and from a corpus used in previous studies (Sauter, Eisner, Calder, et al., 2010; Sauter & Scott, 2007). They consist of 80 brief vocal sounds, 10 tokens per emotion, without verbal content (emblems such "yuck" were not included). Eight emotions were investigated: achievement/triumph, amusement, (sensual) pleasure, relief, anger, disgust, fear, and sadness. The vocalizations were recorded by eight speakers—four women and four men (aged 27 to 43 years; four of them were Portuguese and four were British English). Illustrative scenarios were used as a basis for the recordings (see Appendix A). The validation procedures showed that these stimuli elicit high recognition accuracy, are rated consistently as communicating the intended emotions, and their acoustic attributes provide sufficient information to discriminate between emotion categories and to predict listeners' subjective responses (Lima, Castro, et al., 2013; Sauter, Eisner, Calder, et al., 2010). We piloted a large number of vocalizations on 20 participants (who did not take part in the main study; *M* age = 20 years), and selected the final set used in the current study so that (a) all emotion categories were matched for duration, categorization accuracy, and perceived intensity (confirmed by ANOVAs with these variables as dependent factors, and emotion categories as between-subjects factor, all $ps > .15$); and (b) positive and negative emotions did not differ in arousal ($p = .9$). We carefully controlled for these aspects to ensure that any differential effects of age across categories or valences could be attributed to age and not to stimulus' characteristics. The duration and affective features of the stimuli are depicted in Table 2. Our stimuli are acted emotion portrayals, not spontaneous vocalizations, because it is practically and ethically problematic to experimentally induce most of the emotional states we examined here. Additionally, acted portrayals have been considered to be a suitable tool for the study of emotional expressions (Scherer & Bänziger, 2010).

The 80 vocalizations were presented eight times in randomized order. On each presentation, participants rated on a 7-point scale, from 0 (*not at all*) to 6 (*very much*), how much the stimulus expressed one emotion only (the order of the emotion scales was randomized across participants). Thus, each vocalization was rated regarding the eight possible emotions, one at a time. Note that the ratings on different scales were independent of each other (for a similar procedure, e.g., Adolphs, Schul, & Tranel, 1998; Adolphs, Tranel, & Damasio, 2001; Sauter, Eisner, Calder, et al., 2010; Sauter & Scott, 2007). Before starting the task, the eight emotion labels were presented to the participants, accompanied by an appropriate scenario for each emotion, to ensure that they were adequately understood (see Appendix A). There were six practice

Table 2
Characteristics of the Nonverbal Emotion Vocalizations

Stimulus type	Duration (ms)	Accuracy (%)	Intensity (1–100)	Valence (1–100)	Arousal (1–100)
Positive					
Achievement	1018 (237)	80 (11.8)	75.3 (5.6)	86.9 (6.3)	87.6 (4.8)
Amusement	1000 (244)	91 (6.1)	74.3 (13.9)	81.9 (7.3)	77.4 (12.4)
Pleasure	1114 (177)	86.5 (14)	81 (7)	73.1 (5.9)	41 (8.7)
Relief	916 (226)	89 (6.6)	77.8 (9)	57.3 (5.6)	33.3 (6.8)
Average	1012 (225)	86.6 (10.6)	77.1 (9.4)	74.8 (12.9)	59.8 (24.8)
Negative					
Anger	1048 (170)	85 (12.9)	80.5 (8.9)	17.2 (5.1)	74 (8.7)
Disgust	920 (427)	91 (9.4)	80.2 (7.5)	17.6 (3.4)	52.8 (7.9)
Fear	914 (295)	79 (10.7)	74.2 (10.5)	26.6 (7.4)	68.7 (19.2)
Sadness	1083 (278)	87.5 (16.5)	73.4 (10.1)	15.8 (8)	41.8 (10)
Average	991 (304)	85.6 (13)	77.1 (9.6)	19.3 (7.4)	59.3 (17.5)

Note. Perceptual data are based on a pilot study with $N = 20$. Standard deviations are given in parentheses.

trials to familiarize participants with the rating scale and stimuli. The practice phase was also crucial to adjust the volume of stimulus presentation to a comfortable hearing level. All participants heard the stimuli via high quality headphones (Sennheiser HD 280 Pro), in a quiet testing room with low background noise level. Responses were collected using a seven-button response pad from Cedrus Corporation, model RB-730, attached to an Apple MacBook Pro computer running SuperLab 4.0.1 (Abboud, Schultz, & Zeitlin, 2006). On each trial, participants were presented with the stimulus while the emotion and the scale to be rated appeared on the screen. Participants could take breaks as they wished. There was no time limit, but they were encouraged to respond fast and intuitively. The task lasted from 45 min to 1 hr.

Acoustic Measurements

The 80 vocalizations were measured concerning acoustic cues related to temporal features, intensity, fundamental frequency (F0), and spectral aspects. A total of 12 parameters were extracted using Praat software (Boersma & Weenink, 2009): duration (ms); intensity mean and standard deviation (dB); number of amplitude onsets; F0 mean, standard deviation, minimum, maximum, and range (Hz); spectral center of gravity and standard deviation (Hz); and harmonics-to-noise ratio (dB). The results are presented for each emotion in Appendix B. F0 measures were based on a derived curve representing changes in fundamental frequency as a function of time (using a 75- to 1,000-Hz pitch range, autocorrelation method). The number of amplitude onsets gives an estimation of the number of "syllables" (separate perceptual centers) in a vocalization (Morton, Marcus, & Frankish, 1976). They were counted using an algorithm that detects local rises in the smoothed amplitude envelope (Cummins & Port, 1998; Scott, 1993). The signal of each vocalization was first band-pass filtered (Hanning filter centered at 2.2 kHz with a bandwidth of 3.6 kHz), full-wave rectified and smoothed (Hanning low-pass filter with an 8-Hz cutoff), and then the first derivative of the smoothed envelope was obtained. Onsets were defined as points in time at which (a) a defined threshold in the amplitude envelope was exceeded, and (b) the derivative curve had a positive value. Spectral center of gravity measures were computed on the basis of fast Fourier transformations. Harmonics-to-noise ratio corresponds to the degree of acoustic periodicity, and it was computed on the basis of a forward cross-correlation analysis for the voiced segments only.

Results

Age Shapes Emotion Ratings and Recognition Accuracy

Table 3 depicts the average ratings provided by younger and older participants on each of the eight emotion scales for each stimulus category (for ease of interpretation, raw ratings 0 to 6 were converted to 0 to 100). Both age groups rated all emotion categories higher on the intended scale than on all the other scales, as can be seen in diagonal cells in bold. Statistical support for this finding was obtained through a series of ANOVAs, one for each emotion category and age group (rating scales as repeated-measures factor), and by planned comparisons contrasting the ratings on the intended scale versus ratings on the seven remaining scales (for younger participants, main effect of category, $F[7, 294] = 150.26$ for achievement, 186.02 for amusement, 429.9 for pleasure, 374.4 for relief, 247.03 for anger, 1319.59 for disgust, 309.27 for fear, and 423.9 for sadness; for older participants, 80.81 for achievement, 65.46 for amusement, 72.54 for pleasure, 81.1 for relief, 66.58 for anger, 153.74 for disgust, 49.46 for fear, and 96.79 for sadness; all $ps < .001$; all planned contrasts were significant, $ps < .00001$; p values were corrected, both here and in the remaining analyses in which multiple comparisons were conducted). This is evidence that the vocalizations were successful at communicating the intended emotions to younger and older participants.

Table 3
Intensity Ratings (Scaled 0–100) and Derived Accuracy for Each Emotion Category As a Function of Age Group

Group/Emotion	Rating scale								Derived accuracy
	Achievement	Amusement	Pleasure	Relief	Anger	Disgust	Fear	Sadness	
Younger									
Achievement	**73 (1.7)**	29.8	10.8	29.9	0.3	0.2	0.1	0.1	65.3 (5.3)
Amusement	21	**64.1 (1.8)**	6.6	11.8	0.2	0.3	2	8.9	76 (2.8)
Pleasure	8.2	5.8	**73.6 (1.5)**	6.6	0.7	0.5	0.3	0.3	92.1 (1.7)
Relief	8.6	1.6	6	**71 (1.8)**	2.6	0.8	5.2	1.1	86.7 (2.8)
Anger	5.7	0.3	0.3	0.7	**67.4 (2)**	21	10.1	4.8	74.9 (3.4)
Disgust	0.6	0	0.4	0.6	8.9	**72.2 (1.5)**	2.1	0.9	91.2 (1.5)
Fear	4.6	0.7	0.6	6.1	2	6.9	**64.9 (1.9)**	13.9	77.2 (2.8)
Sadness	0.4	0.6	0.3	0.4	1.2	1.9	17.5	**67.1 (2)**	80.9 (2.9)
Older									
Achievement	**58.8 (2.6)**	21.9	27.6	42	6.1	4.2	6.5	2.1	41.2 (5.4)
Amusement	33.3	**51.1 (2)**	17.6	28.9	5.4	5	6.2	10.9	42.3 (5.3)
Pleasure	13.6	6.6	**53.4 (3.1)**	20.7	6.9	11.2	8	5.4	60.9 (4.7)
Relief	20	4.4	14.7	**56.5 (2.9)**	8.5	10.3	19.4	9	64.2 (4.7)
Anger	21.6	4.2	6.3	13.2	**51.3 (2.8)**	34.2	19.7	7.1	39.5 (4.5)
Disgust	7.7	2.9	3.7	6.6	14.8	**60.4 (2.8)**	12.9	4.7	74 (4.2)
Fear	17.1	5.3	12.6	18.9	11.7	15.7	**50 (3)**	23.4	49.5 (4.5)
Sadness	5.9	4.9	4	7.7	9.7	9.7	27.6	**57.9 (2.7)**	61.4 (5.1)

Note. Diagonal cells in bold show ratings on the intended emotion scale (standard errors in parentheses).

As hypothesized, there were clear differences between age groups: older participants provided significantly lower ratings (54.9) than younger ones (69.2) on the intended scales, as supported by an ANOVA, with ratings on the intended scales as repeated-measures factor, and age group as between-subjects factor (main effect of age, $F[1, 84] = 31.99$, $p < .001$, $\eta_p^2 = .28$). Age-related differences were significant for all emotion categories, positive and negative, with the exception of sadness (interaction Emotion × Group, $F[7, 588] = 2.07$, $p = .05$, $\eta_p^2 = .02$; post hoc Tukey's HSD [honestly significant difference] tests, $ps < .05$ for all emotions, except for sadness, $p = .27$).[2] It cannot be argued that older participants' lower ratings are a simple result of their being more conservative, that is, that they tended to use the lower values of the scales more often than younger participants: An analysis of the global ratings (averaged across all the scales for each emotion, intended and nonintended) revealed that they were similar across age groups or higher in older participants (similar for achievement/triumph, amusement, disgust, and pleasure; higher for anger, fear, relief, and sadness, $ps < .002$). Further evidence for the impact of age comes from accuracy data. Accuracy rates were derived from the raw ratings, based on the emotion scale that received the highest rating: When the highest of the eight ratings matched the vocalization's intended emotion, the response was considered correct; when it did not, the response was considered incorrect; and when the highest rating was provided to more than one emotion with identical magnitude (e.g., giving 6 for sadness and also for fear), the response was considered ambivalent (for a similar procedure, e.g., Adolphs, Damasio, & Tranel, 2002; Belin, Fillion-Bilodeau, & Gosselin, 2008; Gosselin et al., 2005; Lima & Castro, 2011a; Vieillard et al., 2008). Accuracy rates for each emotion and age group are displayed in the last column of Table 3 (for the sake of completeness, the confusion matrix is provided in Appendix C). Older participants were significantly less accurate (54.1% correct) than younger ones (80.6% correct), similarly for all emotions. This was confirmed by an ANOVA on arcsine transformed accuracy rates (main effect of age, $F[1, 84] = 48.87$, $p < .001$, $\eta_p^2 = .37$; interaction Age × Emotion, *ns*, $F[7, 588] = 1.35$, $p = .22$, $\eta_p^2 = .02$). When accuracy rates were corrected for possible response biases using unbiased hit rates, "Hu" (Wagner, 1993), older participants' decreased accuracy was replicated: .44 versus .75 for younger and older participants, respectively (main effect of age, $F[1, 84] = 55.66$, $p < .001$, $\eta_p^2 = .4$); differences were observed for all emotions, though for sadness they only approached significance (interaction Age × Emotion, $F[7, 588] = 2.13$, $p = .04$, $\eta_p^2 = .02$; post hoc Tukey's HSD tests, $ps < .001$ for all emotions, except for sadness, $p = .09$). Participants' gender did not impact on the aforementioned effects, as examined in additional ANOVAs including gender as between-subjects factor (ratings: main effect of gender and interaction Age × Gender, *ns*, $ps > .06$; derived accuracy: main effect of gender and interaction Age × Gender, *ns*, $ps > .5$; unbiased hit rates: main effect of gender and interaction Age × Gender, *ns*, $ps > .4$].

There were also age-related differences in the ratings provided on the nonintended scales (see Table 3, rows). This was examined in a series of ANOVAs, one for each emotion category, with ratings on the nonintended scales as repeated-measures factor (seven scales), and age as between-subjects factor. Older participants provided generally higher ratings than younger ones on the nonintended scales (main effects of age, $F[1, 84] = 6.58$ for achievement, 13.14 for amusement, 16.75 for pleasure, 16.75 for relief, 22.63 for anger, 14.07 for disgust, 22.7 for fear, and 10.95 for sadness; all $ps < .01$). This effect was not uniform across scales, though: The interaction Age × Scale was significant for all emotion categories, except for fear, $p = .06$ (interactions Age × Scale, $F[6, 504] = 6.64$ for achievement, 4.73 for amusement, 4.55 for pleasure, 3.49 for relief, 5.25 for anger, 4.82 for disgust, and 18.94 for sadness; all $ps < .01$). Post hoc Tukey's HSD tests revealed that, for achievement vocalizations, older participants' ratings were higher than younger ones' on the pleasure and relief scales; for amusement, they were higher on the achievement, pleasure, and relief scales; for pleasure, on the relief and disgust scales; for relief, on the achievement, disgust, and fear scales; for anger, on the achievement, relief, disgust, and fear scales; for disgust, on the achievement and fear scales; and for sadness, on the achievement, pleasure, relief, anger, and fear scales (all $ps < .05$). A qualitative analysis reveals that the pattern of older participants' higher ratings on the nonintended scales may reflect similarities between emotion categories along three broader dimensions: valence, arousal, and acoustic features. Many of the nonintended scales on which older participants provided higher ratings are of the same *valence* as the intended scale: pleasure and relief scales for achievement vocalizations; achievement, pleasure, and relief scales for amusement vocalizations; achievement scale for relief vocalizations; disgust and fear scales for anger vocalizations; and fear scale for disgust and sadness vocalizations. The same holds for *arousal* (see Table 2 for details about vocalizations' arousal): disgust scale for pleasure and relief vocalizations; achievement scale for anger vocalizations; and pleasure and relief scales for sadness vocalizations. As for *acoustic* similarities, older participants provided higher ratings on the fear scale for relief vocalizations, and these two emotions are similar for duration, intensity mean, and F0 minimum (see Appendix C); they also provided higher ratings on the relief scale for anger vocalizations, which are similar for intensity standard deviation and F0 standard deviation; and they provided higher ratings on the achievement scale for disgust (similar F0 standard deviation, and F0 maximum, and F0 range) and sad vocalizations (similar F0 standard deviation, F0 minimum, and spectral center of gravity).

To further explore if there were age-related differences in the weighting of positive and negative information in vocalizations, we collapsed the set of ratings provided to all positive emotion categories, and to all negative ones, and submitted them to an ANOVA with valence as repeated-measures factor (positive, negative) and age group as between-subjects factor. Older adults provided higher ratings (main effect of age, $F[1, 84] = 9.16$, $p = .003$, $\eta_p^2 = .1$), but this was similarly observed for positive and negative vocalizations (interaction Age × Valence, *ns*, $F[1, 84] = 0.18$, $p = .67$, $\eta_p^2 = .00$), that is, a selective preference for positive information in older adults was not found.

[2] Although in the analyses of ratings age differences for sadness were not significant, in the derived measure of accuracy, they were. Therefore, there is not enough evidence in our data set to argue that age-related effects were not general across emotions.

Potential Moderators of Age-Related Differences in Emotion Recognition

We examined whether the relationship between age and emotion recognition is statistically explained by individual differences in background measures, namely, in cognitive abilities, personality traits, and in emotion regulation.[3] The method proposed by Preacher and Hayes (2008) to assess mediation involving multiple simultaneous mediators was used. Age was the independent variable, and performance on the emotion task was the dependent variable (ratings on the intended scales averaged across all emotions). As potential mediators we entered the background measures for which there were age-related differences, either significant or marginally significant ($p \leq .07$, see Table 1): education, general cognitive status (MoCA), backward digit span, executive control (Stroop, conflict condition), current negative and positive affect (PANAS), emotion regulation (DERS, nonacceptance and goals; ERQ, reappraisal), future time perspective, and personality (NEO-FFI inventory, neuroticism and conscientiousness). The indirect effects of age on emotion recognition, that is, mediated effects, were estimated using a bootstrapping procedure (20,000 resamples). Age-related differences on ratings were not reduced after partialing out variability on the set of potential mediators as a whole: the total effect coefficient ($\pm$ *SE*) was $-.0257 \pm .0042$ ($t[84] = -6.0957$, $p < .001$), and it did not differ from the direct effect coefficient, $-.0231 \pm .0075$ ($t[84] = -3.0684$, $p = .003$), as indicated by the 95% CI [−.0167, .0113] of total indirect effects, with a point estimate of −.0026. A closer look at separate potential moderators revealed that none of them had a significant influence on the relationship between age and emotion recognition, 95% CI: education [−.0061, .0001], cognitive status [−.0049, .0040], backward digit span [−.0025, .0039], executive control [−.0063, .0050], current negative affect [−.0054, .0016], current positive affect [−.0025, .0067], DERS–nonacceptance [−.0063, −.0006], DERS–goals [−.0052, .0014], ERQ–reappraisal [−.0004, .0054], future time perspective [−.0073, .0064], NEO-FFI–neuroticism [−.0033, .0027], and NEO-FFI–conscientiousness [−.0013, .0032]. These analyses indicate that age-related differences in the recognition of vocal emotions are not reducible to variability in the measures of general cognitive abilities, emotion regulation, or personality.

Age-Related Differences in the Acoustic Predictors of Emotion Ratings

Previous studies on speech prosody and nonverbal vocalizations showed that, in younger participants, the acoustic features of the stimuli are significant predictors of subjective emotion ratings (Banse & Scherer, 1996; Juslin & Laukka, 2001; Lima & Castro, 2011b; Lima, Castro, et al., 2013; Sauter, Eisner, Calder, et al., 2010). We conducted multiple regression analyses to determine whether these findings generalize to older participants, and to explore whether age-related effects in emotion recognition were echoed in differences in the acoustic predictors of subjective responses. One standard (simultaneous) multiple regression analysis was conducted for each emotion scale and age group, taking the acoustic cues for the 80 vocalizations as predictors, and the ratings provided for each of the 80 vocalizations on that scale as dependent variable (averaged across the 43 participants in each age group). To keep the set of independent variables small and to avoid collinearity, we excluded as much as possible acoustic features that were highly intercorrelated ($r > .6$). The following variables were included: duration; intensity mean and standard deviation (dB); number of amplitude onsets; F0 mean and standard deviation; spectral center of gravity; and harmonics-to-noise ratio (F0 minimum, maximum and range, and spectral standard deviation were excluded). The main findings are presented in Table 4 in terms of beta weights and proportion of variance explained by the acoustic measures (adjusted R^2). Apart from amusement, all models were significant, indicating that younger and older participants' ratings could be reliably predicted on the basis of vocalizations' acoustic features. Why results for amusement were not significant is not straightforward, though it is possible that our model did not have power enough to attain significance for this emotion; previous similar analyses yielded significant results (Lima, Castro, et al., 2013; Sauter, Eisner, Calder, et al., 2010), but they were based on larger stimulus sets ($N = 100$ in Sauter et al. and $N = 121$ in Lima et al.; here, $N = 80$). As can be seen in Table 4, participants' ratings were driven by many cues, and the specific combination of cues reaching significant beta weights was unique for each emotion.

Concerning possible age differences, these analyses unveiled two main findings. First, the general predictive strength of acoustic features was similar in younger and older participants: The explained variance was .285 for younger and .284 for older participants, on average. Thus, younger and older participants were equally efficient and consistent in using the low-level acoustic properties of the stimuli to guide subjective emotion ratings. Second, there were differences across age groups in the emotion-specific patterning of significant predictors, suggesting that they weighted some cues differently (see the pattern of significant beta weights in Table 4). Specifically, for pleasure vocalizations, duration and amplitude onsets were significant predictors of ratings in older but not in younger participants, and F0 mean was significant in younger but not in older ones; for relief, spectral center of gravity and harmonics-to-noise ratio were significant predictors for younger but not for older participants; for anger, duration was significant for older but not for younger participants; for disgust, intensity mean was significant for younger participants but not for older ones; for fear, F0 mean was significant for older but not for younger participants; finally, for sadness, F0 mean and standard deviation were significant predictors of older participants' ratings but not for younger ones'. The fact that younger and older participants were equally efficient in using the vocalizations' acoustic features suggests that these differences in the weighting of predictors may not be caused by sensory difficulties alone. Furthermore, a sensory account would predict general problems (observed across all emotions) in the use of specific acoustic cues (e.g., F0 mean), which we did not find. For instance, F0 mean was a weaker predictor of responses in older participants versus younger ones in the ratings of pleasure, which would suggest a less fine-grained use of this cue, but the very same cue was a stronger predictor in older participants versus younger

[3] It has been pointed out that cross-sectional mediation analyses may provide limited answers to questions about temporal ordering and causal structure of behavioral change (Lindenberger, von Oertzen, Ghisletta, & Hertzog, 2011; Raz & Lindenberger, 2011). However, here we focus on statistical mediation only—that is, "mediation" is solely considered in terms of the amount of age-related variance in emotion recognition that is explained by differences in other variables.

Table 4
Summary of Results of Multiple Regression Analyses for Each Rating Scale (Rows) Against Acoustic Cues (Columns)

	Acoustic cue								
Group/Emotion	Duration	Int_M	Int_{SD}	Amp Onsets	$F0_M$	$F0_{SD}$	$Spectral_{COG}$	H/N_{RATIO}	Adj R^2
Younger									
Achievement	−.01	.31*	.14	−.06	.24*	.16	.21**	.5*	.43*
Amusement	−.02	.34**	.19	.25**	.1	.1	.07	.0	.03
Pleasure	.13	.01	−.14	−.11	−.23*	−.08	−.25*	.37*	.52*
Relief	.07	.15	−.22**	−.39*	.53*	−.01	−.29*	−.4*	.35*
Anger	.19	.45*	.11	−.1	−.31*	.09	.16	−.4*	.20*
Disgust	−.14	−.32*	−.02	−.01	−.41*	.34*	.43*	.24	.18*
Fear	−.12	−.07	.4*	.01	.19	−.36*	.01	.01	.27*
Sadness	−.04	−.41*	−.14	.39*	.11	−.17	−.11	−.03	.30*
Older									
Achievement	.05	.39*	.22**	−.06	.28*	.08	.25*	.35*	.38*
Amusement	−.03	.33**	.25	.3*	.1	.05	.05	−.02	.03
Pleasure	.19*	.17	.01	−.18*	−.06	−.08	−.18**	.42*	.52*
Relief	.12	.24	−.07	−.37*	.54*	−.04	−.2	−.21	.33*
Anger	.22*	.51*	.18	−.09	−.3*	.05	.14	−.48*	.24*
Disgust	.0	−.13	.0	−.06	−.39*	.32*	.37*	.02	.14*
Fear	−.03	−.09	.28*	−.03	.27*	−.37*	.02	−.17	.28*
Sadness	−.04	.4*	−.13	.36*	.22*	−.26*	−.17	−.09	.35*

Note. Values represent beta weights; adjusted R^2s are also shown. Int = intensity; Amp = amplitude; COG = center of gravity; H/N = harmonics-to-noise; Adj = adjusted.
* $p < .05$. ** $p \leq .07$.

ones in the ratings of fear, suggesting that older participants can use it just as well younger participants do. Thus, it is plausible that the age-related differences in the weighting of cues reflect higher-order processes to a significant extent.

Discussion

This study examined how age shapes emotion recognition in nonverbal vocalizations. Five main findings were revealed. First, older adults were less sensitive than younger ones to the intended vocal emotions, as indicated by decrements in ratings on the intended emotion scales and categorization accuracy. Second, decrements were not modulated by valence—they were similar for positive and negative emotions. Third, there were age-related differences in the pattern of ratings on the nonintended emotion scales. Fourth, the impact of age on emotion recognition was not a result of differences in measures of general cognitive abilities, emotion regulation, current affect, and personality traits. Fifth, variability in the low-level acoustic features of vocalizations predicted with similar strength subjective ratings in younger and older participants, but there were differences across groups regarding the pattern of predictors for each emotion. These findings are discussed in the following paragraphs.

Age Shapes Emotion Recognition in Nonverbal Vocalizations

Although age-related declines are extensively described for the recognition of facial expressions (e.g., Ruffman et al., 2008), relatively fewer studies were conducted in the auditory domain. Importantly, these were focused on speech prosody (e.g., Mitchell et al., 2011; Paulmann et al., 2008), leaving other kinds of auditory emotion cues largely unexplored. Here we went a step further, showing, for the first time, that there are clear age-related effects in how we perceive nonverbal vocal sounds such as laughter. These vocalizations, unlike speech prosody, are devoid of linguistic information, and they involve specific production mechanisms (Scott et al., 2010). We found decrements for all emotions, which indicate a general reduction in the recognition of these emotional sounds. Decrements for anger and sadness are a fairly robust finding in the literature on other modalities (Ruffman et al., 2008), which is mostly based on forced-choice paradigms, and decrements for fear are also often reported, both for facial expressions and speech prosody (Calder et al., 2003; Laukka & Juslin, 2007; Paulmann et al., 2008; Mill et al., 2009). The present study extends these findings to a different expressive channel and to a different method—a multidimensional rating procedure. With respect to disgust, although relative age invariance is frequently observed, particularly in the case of facial expressions (Ruffman et al., 2008; but see Lambrecht et al., 2012), we observed decline. It is possible that modulations for this emotion are more apparent in the auditory versus visual domain. In agreement with this hypothesis, declines have been repeatedly found for disgust in another auditory channel—speech prosody (Lambrecht et al., 2012; Lima & Castro, 2011b; Paulmann et al., 2008). As for positive emotions, some studies reported smaller effects or stability for happiness in facial expressions (Calder et al., 2003; Ruffman et al., 2008; Sullivan & Ruffman, 2004; Williams et al., 2006) and speech prosody (Laukka & Juslin, 2007; Mitchell et al., 2011), and on the basis of this finding, it was suggested that age-related changes might depend on valence. However, happy facial expressions are often associated with ceiling effects, and this may have masked age-related effects in previous work. Furthermore, conclusions regarding valence can hardly be made when a single positive emotion is examined. Capitalizing on the fact that nonverbal vocalizations are effective at communicating diverse positive emotions (Sauter & Scott, 2007; Simon-Thomas et al., 2009), we conducted the first ageing study including a varied set of rarely studied positively valenced emotion categories and found decrements for all of them—achievement/triumph, amusement, pleasure, and relief. Additionally, differently from the majority of previous research, the vocalizations were piloted and carefully selected in order to avoid ceiling effects and to increase comparability between categories and valences.[4] With such a well-controlled and varied set of stimuli, decrements were still similar for positive and negative emotions. This is clear-cut evidence that, for nonverbal vocalizations, valence does not play a role in moderating age-related modulations. We did not cover the full range of positive vocal emotions (e.g., awe, compassion, enthusiasm), and thus it is possible that decrements do not generalize for all positive emotions. However, the fact that they exist for the four emotions analyzed here excludes a general effect of valence.

Strikingly, differences were observed in how younger and older participants rated the nonintended emotional properties of vocalizations as well: For all stimuli categories, except for fear, older participants provided higher ratings than younger ones in several of the nonintended scales. It is notable that these differences were equally obtained for positive and negative emotion categories. They may reflect similarities between intended and nonintended emotions in terms of broader dimensions, specifically valence, arousal, and acoustic features. These dimensions of similarity have been suggested to explain the distribution of emotion categorizations for speech prosody (Banse & Scherer, 1996) and music (Laukka, Eerola, Thingujam, Yamasaki, & Beller, 2013). Thus, compared with younger participants, older participants provided relatively lower ratings on the intended scales, but they provided relatively higher ratings on emotionally or acoustically related nonintended scales. These results point to the possibility that the boundaries between specific emotion categories are sharper for younger than for older participants. From a methodological perspective, they indicate that a complete understanding of age-related modulations benefits from taking into account both how the intended and the nonintended emotions are perceived. This is not easily captured by conventional forced-choice paradigms (for a review on the advantages of multidimensional rating tasks, see Riediger et al., 2011). Although in forced-choice tasks, increments in "errors" are a direct side effect of decrements in accuracy, this is not the case in our task, as ratings on the intended and nonintended scales are independent of each other. Therefore, older participants' higher ratings on the nonintended scales are likely to reflect true differences in how multiple emotional qualities were perceived in the same stimulus (they are not just a side effect of decrements on the intended scales).

What Explains Age-Related Differences in Emotion Recognition?

Even though older participants performed worse than younger ones in measures of global cognitive status and executive control, these differences did not account for age-related effects in how vocalizations were recognized. This finding converges with previous studies on facial expressions and speech prosody, in which it was observed that differences in emotion recognition may occur beyond general cognitive decline (e.g., Mitchell, 2007; Orbelo et al., 2005; Ryan et al., 2010; Sullivan & Ruffman, 2004). In agreement with the available literature, younger and older participants also differed regarding current affect (e.g., Mather & Knight, 2005), future time perspective, emotion regulation (Orgeta, 2009; Yeung et al., 2011), and personality (McCrae et al., 1999). Notwithstanding, none of these measures proved to be associated to age-related effects in the experimental task. Finding that emotion regulation and future time perspective are not linked to performance in emotion recognition suggests that our results cannot be interpreted within the framework of the socioemotional selectivity theory, which assumes that reductions in time horizons and top-down regulatory mechanisms (toward positivity) underlie changes in emotion processing (e.g., Carstensen & Mikels, 2005; Charles & Carstensen, 2010; Reed & Carstensen, 2012; Samanez-Larkin & Carstensen, 2011). In fact, several aspects of our results speak strongly against this account: Age-related decrements were not attenuated for positive emotions, older participants' higher ratings on the nonintended scales were not biased toward positive emotion categories, and when the complete range of ratings provided for positive and negative vocalizations was compared across groups, older participants did not show disproportionate higher responses for positive information, that is, there was no evidence for an age-related shift in preferences for positive input. A preference for positive information in older adults has been found in the context of emotion experience (e.g., Carstensen, Pasupathi, Mayr, & Nesselroade, 2000), as well as for memory and attention (e.g., Mather & Carstensen, 2005), but it does not seem to extend to emotion perception processes, at least regarding vocalizations. Whether this finding is a supramodal property of emotion perception processes, or rather specific to vocalizations, will be addressed in future studies comparing directly multiple modalities.

On the whole, our results indicate that age-related effects in the recognition of nonverbal vocalizations may be caused by factors other than general cognitive decline and top-down regulatory mechanisms. The deterioration of neural structures involved in emotion processing is a plausible underlying mechanism, which has been put forward for other modalities, such as facial expressions and speech prosody (e.g., Cacioppo et al., 2011; Ruffman et al., 2008). Examining brain mechanisms is outside the scope of this study, but there is evidence of decline in brain structures including the prefrontal cortex (Raz et al., 2005), superior temporal sulcus (Sowell et al., 2003), amygdala (Walhovd et al., 2005), and insula (Good et al., 2001), and these structures are involved in the processing of emotion vocalizations (Scott et al., 2010). Because ageing is a complex process, accompanied by a multitude of changes, other factors may play a role as well, such as differences in hormones (e.g., Chahal & Drake, 2007) and neurotransmitters (e.g., Bäckman, Nyberg, Lindenberger, Li, & Farde, 2006; Ruffman et al., 2008).

We found age-related differences in the patterns of acoustic cues that predicted responses, with younger and older participants weighing some cues differently. Importantly, these differences do

[4] The pilot study included younger participants only, and so we cannot ensure that the match between positive and negative emotions regarding arousal generalizes to the older participants group, particularly considering evidence that arousal effects elicited by negative emotions may change with age (e.g., Cacioppo et al., 2011). However, this does not seem to have affected comparability across valence to an important extent, as intensity ratings of specific emotions in the main study were similar for positive and negative emotions, both in older (55 and 54.9 on average, respectively) and younger (70.4 and 67.9) participants.

not seem to stem from a decreased efficiency of older participants in picking up on acoustic cues to guide their responses, because ratings varied as a function of acoustic features just as much in younger and older participants. Instead, they may reflect changes in the inference rules used to perceive emotional vocalizations. Future studies using larger stimulus sets varying widely in terms of acoustic features, or using techniques to selectively remove/alter specific cues (e.g., noise-vocoding; spectral rotations), will allow for a systematic analysis of age-related effects in how acoustic features are relied upon. It will also be interesting to collect valence and arousal ratings in addition to categorical ones, and explore the possibility that younger participants base their inferences relatively more on well-defined configurations of cues for each emotion category, whereas older ones may rely more on configurations of cues signaling broader affective dimensions.

Considerations and Future Directions

The present study raises several questions. First, we used an "extreme age group" design (Isaacowitz & Stanley, 2011), comparing two samples of individuals differing widely in age. However, some previous research using finer gradations in age indicated that modulations in emotion recognition may be found in middle-age, around the early 40s (e.g., Calder et al., 2003; Isaacowitz et al., 2007; Lima & Castro, 2011a, 2011b; Mill et al., 2009; Paulmann et al., 2008). Thus, future studies will need to look at how vocalizations changes across the whole adult life span, for instance, by using continuous age samples in correlational designs or by implementing longitudinal designs. Second, although we ensured that participants had acceptable hearing thresholds (30 dB HL) for frequencies between 500 Hz and 4,000 Hz, and it has been shown that declines in emotion recognition are not reducible to thresholds elevations (e.g., Mitchell, 2007; Mitchell et al., 2011; Orbelo et al., 2005), a more fine-grained inspection of suprathreshold hearing abilities could have been enlightening. Lambrecht et al. (2012) observed that average hearing loss does not predict age-related decrements in speech prosody, but analyses on separate frequency bands revealed that variability in hearing at 4,000 Hz and 250 Hz does. Hence, we cannot exclude the possibility that individual differences in hearing abilities, or subtle difficulties not captured by our screening test, predict variability in the processing of emotional vocalizations. Third, the speakers who produced the vocalizations varied widely in age (27 to 43 years old), but they were more close to the younger age band than to the older one. It is possible that younger participants' advantage is related to own-age effects: Their greater recent interactions with people of the same age as the speakers may explain their improved emotion recognition competence (Phillips & Slessor, 2011). This potential confound should be addressed, even though available empirical evidence for facial expressions indicates that age-related decrements in emotion recognition are found both when the actors are younger and when they are older (Ebner & Johnson, 2009; Riediger et al., 2011). Fourth, because our task involved performing many judgments ($N = 640$), it can be argued that fatigue could have played a role for older participants' results. This is an unlikely possibility, however, because participants could take breaks as they wished, and increased fatigue would predict a more erratic performance overall, not systematic lower ratings for the intended scales and systematic higher ratings on specific nonintended scales.

Concerning the fact that age-related effects in the present study did not differ across valences, an interesting question is whether this can be modulated by task conditions and instructions (Reed & Carstensen, 2012). Recently, Ritchey, Bessette-Symons, Hayes, and Cabeza (2011) observed that whether or not valence modulates age-related effects in neural responses to emotional pictures depends on task conditions: When participants were instructed to focus on the perceptual features of the pictures (e.g., color; shallow condition), no valence-related modulations were found; when participants were instructed to carefully analyze the stimuli for meaning and interpretation (deep semantic elaboration condition), the ventrolateral and medial prefrontal cortices, which are linked to self-referential and emotion regulation processes, were more activated by positive versus negative pictures in older adults. These results suggest that valence-related modulations are not automatic—they are contingent upon controlled mechanisms. In a previous study, we found that valence may modulate age-related effects for emotion recognition in music, with decrements being significant for negative (fear and sadness) but not for positive (happiness and peacefulness) emotions (Lima & Castro, 2011a), and this may be related to the fact that music readily engages controlled self-referential and regulatory mechanisms (Trost, Ethofer, Zentner, & Vuilleumier, 2012). Manipulating the degree of semantic elaboration and the specific task conditions will be valuable for future studies on ageing and nonverbal expressions. Other interesting questions will be to determine whether age-related effects occur at automatic or at controlled stages of processing, and whether they can be modulated by contextual information, for instance using vocalizations embedded in multimodal stimuli.

Conclusions

The present study shows that the processing of nonverbal emotion vocalizations is modulated by the perceiver's age. Age-related decrements were uncovered for positive and negative emotion categories in ratings and accuracy. We tested for the first time a wide range of positive and negative emotions, and observed that age-related effects were not modulated by valence—no evidence was found for a preference for positive information in older adults. Additionally, age-related differences were explained neither by decline in domain-general cognitive abilities nor by differences in current affect, emotion regulation, and personality traits. Moreover, the observed decrements were echoed in differences in the specific patterns of acoustic cues that drove responses, suggesting that ageing is associated with changes in the inference rules used to process vocalizations. To conclude, our results highlight the importance of incorporating distinct positive emotions into the study of emotion recognition. Counteracting the strong bias toward negative emotion categories in emotion research will be key to advances in the understanding of the mechanisms underlying age-related differences in emotion recognition. Additionally, looking at modalities other than facial expressions will be crucial to have a full scientific understanding of how we handle the multitude of nonverbal cues that characterize social interactions.

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(*Appendices follow*)

Appendix A

Illustrative Scenarios Provided for Each Emotion

Emotions	Scenario
Achievement	You are a football fan and your team wins the most important game of the championship
Amusement	Someone tells you a joke that you find really funny
Pleasure	You are eating your favorite dessert, which you had not eaten for a long time
Relief	You think you lost your wallet but find it again
Anger	Someone is being deliberately very rude to you and you loose all your patience
Disgust	You put your hand in vomit
Fear	Someone suddenly taps on your shoulder in a dark alleyway
Sadness	You find out that someone close to you has died

Appendix B

Acoustic Characteristics of Nonverbal Vocalizations for Each Emotion Category

Stimulus type	Acoustic cue											
	Duration (ms)	Int_M (dB)	Int_{SD} (dB)	Amp Onsets	$F0_M$ (Hz)	$F0_{SD}$ (Hz)	$F0_{MIN}$ (Hz)	$F0_{MAX}$ (Hz)	$F0_{RANGE}$ (Hz)	$Spectral_{COG}$ (Hz)	$Spectral_{SD}$ (Hz)	H/N_{RATIO} (dB)
Achievement	1018	81.5	8.9	1.5	483.3	128.8	222.2	658.9	436.7	855.8	541.9	21.4
Amusement	1000	72.1	10.3	3.8	391.3	134.1	218.6	652.7	434.1	1043.4	1239.9	6.8
Pleasure	1114	80.6	6.5	2	182.2	56	113	322.9	209.9	247.9	249.9	21.6
Relief	916	72.3	9.1	1.3	502.2	124.6	315.7	707.4	391.7	837	1252.4	6.1
Anger	1048	78	9.3	2.3	264.7	112.2	105.1	454.1	349	1099	699.4	9
Disgust	920	71.6	9.5	3.1	332.1	147.1	162.6	604.1	441.5	1136.7	1215.4	8.6
Fear	914	71.9	12.6	1.8	434.7	59.4	333.6	556.4	222.8	1004.6	953.3	10.9
Sadness	1083	68.4	9.5	4.4	373.7	105.3	233.4	595.3	361.9	797.1	1116.6	8

Note. Int = intensity; Amp = amplitude; COG = center of gravity; H/N = harmonics-to-noise.

(*Appendices continue*)

Appendix C

Distribution of Categorization Rates for Each Emotion Category (Percentage, Rows) in Younger And Older Participants

	Distribution of responses (percentage)								
Group/Emotion	Achievement	Amusement	Pleasure	Relief	Anger	Disgust	Fear	Sadness	Ambivalent
Younger									
Achievement	**65.3 (5.3)**	4.2	0.2	5.6	0	0	0	0	24.7
Amusement	2.6	**76 (2.8)**	0.2	0.5	0	0	0.2	6.5	14
Pleasure	0.2	0.5	**92.1 (1.7)**	0	0.2	0.2	0	0	6.7
Relief	0.7	0	1.4	**86.7 (2.8)**	0.2	0	1.9	0	9.1
Anger	0.9	0.2	0	0	**74.9 (3.4)**	5.8	2.6	0.2	15.3
Disgust	0.2	0	0	0	2.6	**91.2 (1.5)**	0.5	0.2	5.3
Fear	0.9	0.2	0.2	1.4	0.2	1.2	**77.2 (2.8)**	5.3	13.3
Sadness	0	0.2	0	0	0	0	7.2	**80.9 (2.9)**	11.6
Older									
Achievement	**41.2 (5.4)**	2.1	7	16.5	0.2	0	0	0	33
Amusement	7.2	**42.3 (5.3)**	3.3	11.9	0.2	0.4	1.2	4.9	28.6
Pleasure	2.1	0.5	**60.9 (4.7)**	4.4	1.4	4	0.5	1.2	25.1
Relief	4.2	0.2	3.5	**64.2 (4.7)**	0.5	1.4	5.6	0	20.5
Anger	7.2	0.5	1.2	3.7	**39.5 (4.5)**	15.6	3	0.2	29.1
Disgust	1.6	0.2	1.6	0.9	2.6	**74 (4.2)**	3	0.7	15.3
Fear	4.9	0.2	3.5	5.6	1.2	2.8	**49.5 (4.5)**	6.5	25.8
Sadness	0.2	0.9	1.4	0.9	0.7	2.3	12.8	**61.4 (5.1)**	19.3

Note. Diagonal cells in bold indicate correct categorizations. Standard errors are given in parentheses. Ambivalent responses correspond to situations in which the highest rating was assigned to more than one emotion with identical magnitude (e.g., giving 6 for sadness and also for fear, and lower ratings for the other categories).

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