Emotional Prosody Recognition Enhances and Progressively Complexifies From Childhood to Adolescence

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Abstract

Background: Emotional prosody is the result of the dynamic variation of acoustical non-verbal aspects of language that allow people to convey and recognize emotions. Understanding how this recognition develops during childhood to adolescence is the goal of the present paper. We also aim to test the maturation of the ability to perceive mixed emotions in voice.

Methods: We tested 133 children and adolescents, aged between 6 and 17 years old, exposed to 4 kinds of emotional (anger, fear, happiness, and sadness) and neutral linguistic meaningless stimuli. Participants were asked to judge the type and degree of perceived emotion on continuous scales.

Results: By means of a general linear mixed model analysis, as predicted, a significant interaction between age and emotion was found. The ability to recognize emotions significantly increased with age for all emotional and neutral vocalizations. Girls recognized anger better than boys, who instead confused fear with neutral prosody more than girls did. Across all ages, only marginally significant differences were found between anger, happiness, and neutral versus sadness, which was more difficult to recognize. Finally, as age increased, participants were significantly more likely to attribute mixed emotions to emotional prosody, showing the progressive complexification of the emotional content representation that young adults perceived in emotional prosody.

Conclusions: The ability to identify basic emotions from linguistically meaningless stimuli develops from childhood to adolescence. Interestingly, this maturation was not only evidenced in the accuracy of emotion detection, but also in a complexification of emotion attribution in prosody.

Introduction

The ability to decode others' emotions during social exchanges is not only crucial for developing social abilities, but is necessary for establishing fundamental affiliations in infancy and intimate relationships during development and in life (1, 2).

Basic characteristics of emotion knowledge develop early in life and increase throughout childhood and adolescence, improving our emotion understanding and our ability to manage and adaptively utilize emotions in crucial periods of development (3, 4).

A disturbed recognition of emotions is often associated with atypical developmental trajectories, such as autism spectrum disorder (5, 6), down syndrome (7, 8), attention deficit hyperactivity disorder (9, 10), and with a broad range of child psychopathologies (11, 12). Also, children's negative early social experiences influence their perception of emotion-specific information and, in case of abuse or neglect, their interpretation and understanding of emotional signals varies from control pairs, becoming more variable and less accurate respectively (13–15).

In atypical development, children with a sensory disability have consistent delays in acquiring emotion recognition and emotion understanding abilities, and a specific sensory impairment – such as a hearing impairment – is linked to a delayed acquisition of a broad range of necessary abilities for recognizing emotions in vocal cues during social interactions (16).

On the other hand, children with a high level of emotion recognition ability are more able to regulate their feelings and more successful at interacting with their peers (16, 17).

Emotion recognition, especially in childhood and adolescence, is profoundly linked with emotion regulation, which leads to better school performance and to improved relationships with teachers in school (18). Higher levels of emotion knowledge lead to better social skills in childhood and adolescence (19) and, later in life, it is a strong predictor of effective social behavior as well as early school and later academic success (20–22).

However, this maturation can not only manifest in an increased ability to recognize and experience emotions, but it also in an improved capacity to perceive and experience mixed emotions. While children up 5-6 years of age tend to perceive and experience single, often polarized emotions (e.g., good and bad) (23), as they grow up there is a tendency for emotional experiences to become more complex, mixed or even contradictory (24). In a developmental continuity perspective, this ability to understand mixed-emotions is rooted in early childhood. Actually, a more secure attachment between mothers and infants predicts a better ability to decode mixed emotion at 6 years (25).

Two sensory abilities, the visual and auditory, play a crucial role in early emotion recognition from faces and voices, respectively. Emotion has also been shown to enhance the sensory processing of faces and voices, raising information saliency, and potentially increasing the inferences that may be made from this information during social interactions (26).

From a developmental perspective, these two categories of emotional information, visual and auditory, are related and both support early multimodal recognition of emotions, as in adults (27). In the newborn period, facial recognition of an intimate partner is likely rooted in a prior experience with the mother's voice, the latter being a highly salient and detectable signal even during the pregnancy (28, 29). During infant and child development, senses operate together to convey and to process emotional information, and the role of redundancy in cross-modal expression and perception of emotions is crucial for their emotional development (30–32).

At 6 months of age, following prior exposure to voices infants could transfer amodal information from emotional voices to faces (33). During childhood development, this ability to extract amodal emotion information seems to increase with age and depends on the specific emotion presented (34). Finally, the role of early visual experience is determinant for recognizing emotional prosody, as suggested by a recent study examining prosody accuracy rates in students with congenital or adventitious blindness (35).

However, while facial recognition of non-verbal cues has been broadly investigated in a developmental perspective (36–38), the origins and development of vocal emotion recognition during childhood has been under-investigated (39).

The development of emotion recognition in nonlinguistic vocalizations

The majority of studies investigating children's and adolescents' ability to recognize emotions have used vocal nonlinguistic utterances as experimental stimuli.

Sauter and colleagues (40), used vocal non speech sounds such as laughs, sighs, and grunts, asking children to associate vocalizations with facial expressions in pictures in a four-way forced choice task. As for linguistic stimuli, children as young as 5 years could reliably infer emotions from non-verbal vocal cues. However, this recognition did not improve significantly with age, probably due to an early ability to associate laughs, sighs, and grunts to the correct facial expression. This was not the case for linguistic stimuli (emotionally inflected speech), which were better recognized as age increased. Similarly, Chronaki et al., (3) asked 4- to 11-year-olds to recognize emotions from non-word vocal stimuli ('ah' interjection) and reported an improvement in emotion recognition with age, with a continuing development in late childhood.

Finally, Grosbras et al., (41) used vocal bursts expressing four basic emotions and asked children and adolescents to detect the correct emotion in a forced choice task. The ability to recognize emotions in nonlinguistic utterances increased with age and was driven by anger and fear recognition. Interestingly, between 14 and 15 years of age adolescents reached adult performances in emotion recognition, and across ages, girls obtained better scores than boys for several emotions.

Emotional prosody recognition in linguistic vocalizations

Emotional prosody can be defined as the ensemble of segmental and supra-segmental variations (referring to melodic aspects) of our speech production during an emotion episode (42). Emotional prosody categories have been described as correlating with a range of acoustic features which are essentially musical: rhythm, pitch, tone, amplitude, accent, pause, duration (43), and their unfolding.

Morningstar and colleagues, in their systematic review (44), report that the ability to detect emotions in language begins very early (26) and it improves with age over childhood (3, 40, 45–47). However, one of the limitations of the existing studies on the maturation of vocal prosody perception was the use of complex semantic and linguistic stimuli, and the results being confounded by the development of language abilities.

As for adults, we believe that a better paradigm to investigate the ontogenetic human ability to extract emotion information from vocal prosody is by using meaningless speech stimuli (pseudo-words building up pseudo-sentences respecting linguistic rules such as syllabic and word organization) avoiding then the interaction between linguistic semantic and emotional prosody information (48–53). The stimuli we propose in the present study are linguistic, but meaningless, and do not convey a semantic content but keep prosodic information.

Emotional prosody recognition is thus conceived as an interface between language and affect (42). The vocal communication of emotions is thought to follow a model of dyadic processes, which are determinant for accurate encoding (or production) and decoding (or recognition) of vocal affects during social exchanges (54–56). In these processes, prosodic features of vocal production play a fundamental role in decoding partners' emotions (57) and is a key index for assessing children, adolescents, and adults' affective abilities.

Aims and hypothesis

The primary objective of the present study was to test if children's ability to recognize emotions from meaningless vocal stimuli increased with age. Secondly, we tested the evolution of the tendency, for the correct responses, of attributing mixed emotions to emotional prosody, during childhood and adolescence. For the latter, we tested on continuous scales the progressive complexification of the emotional content representation that children and young adults perceived in vocal affective prosody. As the ability to feel mixed emotions increased with the age, we posited that similar trajectories would also manifest in the recognition of mixed emotions in vocal prosody.

Methods

Participants and procedure. 133 participants (58 males) aged between 6 and 17 years old (M = 11.32; SD = 5.6) were recruited from La Salle primary school in Thonon-les-Bains, France.

All experimental protocols were approved by the University of Geneva Ethics committee, and all methods were carried out in accordance with relevant guidelines and regulations. Finally, informed consent was obtained from all the subjects's legal guardians.

Participants were tested on individual laptops, the stimuli were presented through headphones, and the responses were made through ratings on continuous scales with a cursor. The testing phase was preceded by initial training where participants listened to bilaterally presented stimuli through a homemade Authorware program. Answers were considered correct when the target emotion was rated higher than other emotions on visual analog scales (58). In addition, participants had the option of responding "I don't know" and could listen to the emotional stimuli several times, up to three times maximum.

Stimuli. Participants were asked to judge four basic vocal emotions (joy, fear, anger, and sadness) and neutral stimuli expressed by adult voices. Judgments were made on six different visual analogic continuous scales (joy, fear, sadness, anger, neutral, and surprise).

Stimuli composed of pseudo-words constituting pseudo-sentences from the GEMEP (Geneva Multimodal Emotion Portrayals) corpus (49) and the Munich database (59) were used.

The 30 vocal stimuli (mean duration 2044ms, from 1205 to 5236ms) were pseudo-randomly (avoiding more than three consecutive stimuli of the same category) assigned to two different lists. The pseudo-randomization process was carried out with respect to the duration, the mean acoustic energy, and the standard deviation of the mean energy of each sound sample.

The use of meaningless utterances allows us to avoid the potential impact of the perception of meaningful lexical-semantic information upon perceiving vocally expressed emotions (see Appendix 1 for some examples of the adopted stimuli). We used the pseudo-utterances of these corpora, which were based on European languages (for syllabic and word organization) in order to avoid a confounding semantic effect.

Analysis and statistics

We performed General or Generalized linear mixed models using R (version 4.0.0) and RStudio (version 1.2.5042). Models included three fixed factors: Emotion presented (five modalities: anger, happy, neutral, fear, and sadness), Scales (six modalities: anger, happy, neutral, fear, sadness, and surprise), Age (as a continuous variable), and two random factors (user ID and corpus version: GEMEP and Munich corpora). We systematically tested the more complex model (e.g. for the full model: main effects and the interactions with Age, Emotion presented, and Scales) with the more pertinent simpler model (e.g. main effects plus double interactions), then the chi-square test either did or did not reveal a significant increase in explained variance for the more complex model (e.g. with the adding of the triple interaction). For the analysis on correct responses, we discretized the response as correct (1) or incorrect (0) according to the scores on the continuous scales for each trial. The response was discretized as correct if the participant's score on the target scale was the highest (e.g. highest value for the fear scale for a fearful vocalization); then we used Generalized linear mixed models with a binomial family. To test the significant increase or decrease of emotion recognition with Age, we tested to what extent the slope of the percentage of correct responses with Age was different from 0. For the complexification hypothesis we used the sum of the values judged on non-target scales using only the correct trials (those with the highest values on the target scale). Then we predicted an increase of the sum on the non-target scales, as an indicator of more complex emotion attribution, with Age. For contrast analysis, we used the emmeans R package. We corrected the p values using Bonferroni multiple correction when the tests were not independent (e.g. for non-target emotion, corrected p-value = 0.5/6 = .0083). The datasets generated during the current study are available from the corresponding author upon request.

Results

Age and Sex effect. The general effect of Age was not significant (χ^2 (1) = 1.01, p = .310), but, as predicted, the interaction between Age, Emotion, and Scales revealed that children's ability to correctly recognize the target emotion increased with age (χ^2 (1) = 224.56, p < .001, see Fig. 1).

In particular, the percentage of correct responses significantly increased with Age for Anger (χ^2 (1) = 13.22, p < .001), Happiness (χ^2 (1) = 22.75, p < .001), Neutral (χ^2 (1) = 22.30, p < .001), and Fear (χ^2 (1) = 19.96, p < .001). The test of the slope against zero for Sadness (χ^2 (1) = 5.05, p = .025) did not reach the corrected p value (p= .008).

The percentage of responses for the five presented emotions are reported in Appendix 1, Table 1.

All other tested comparisons are reported in Appendix 1, Table 2.

As age increases, Fear was less confused with Happiness, Neutral, and Sadness (i.e., for Happiness, χ^2 (1) = 8.21, p = .004), and Neutral was less confused with Sadness (χ^2 (1) = 8.25, p = .004). The confounder, Surprise, tended to remain stable across ages and across target emotions.

The effect of Sex was marginally significant across ages and emotions (p = .069), with a significantly better performance of girls versus boys to recognize Anger (χ^2 (1) = 3.88, p = .049). Moreover, boys rated Fear as Neutral, significantly more than girls did (χ^2 (1) = 4.75, p = .029). For a graphical representation of the evolution of correct responses, see Appendix Figure A1.

Emotion effect. The percentage of correct responses homogeneously increased with Age across Emotions ($p < 2.2 \times 10^{-16}$, for details see Table 1). This increase with age, calculated with the slope contrasts, was not significantly different across emotions, except for the contrasts between Anger, Happiness, and Neutral versus Sadness slopes that were marginally significant (Anger/Sadness: χ^2 (1) = 2.88, p = .089; Happiness/Sadness: χ^2 (1) = 3.32, p = .068; Neutral/Sadness: χ^2 (1) = 3.64, p = .056). When comparing the means of the corrected responses without the Age groups, Anger was the emotion recognized in prosody with the highest accuracy, followed by Neutral and Fear. Happiness and Sadness were around the same level, being less well recognized than the others (see Appendix Figure A1 and Appendix Table A1 for the mean values, as well as Appendix Table A2 for systematic contrasts).

Mixed Emotion Recognition. Even in the presence of a correct detection of the target emotion, participants added other emotions as being present in the vocal prosody extracts. These additional emotion attributions significantly increased with age (χ^2 (1) = 26.18, p < .001). Results reported in Figure 2 show that mixed emotion recognition increased non-linearly between age groups. For example, children aged between 6 and 7 years old did not differ from the 8-9 year-olds (corrected p value is .013; t(1) = - 2.38, p = .018), and 8-9 year old children did not differ from the 10-11's (t(1) = 0.6, p = .550). However, the 10-11's and 12-13's showed higher mixed emotion recognition levels than the 6-7's (t(1) = 2.92, p = .004; and t(1) = 3.35, p = .001 respectively), and the same thing happened for the 14-17 year old children when compared to the 8-9's (t(1) = 2.73, p = .006).

Discussion

The main aim of the present study was to understand how the recognition of emotional prosody develops from childhood to adolescence.

First, we demonstrated that a participants' ability to correctly recognize the target emotion in prosody increased with age, from childhood to adolescence. This was true for all tested emotions except for sadness, which was stable across ages. Moreover, the ability to recognize these emotions, across all ages, did not differ across emotions, except again for sadness which was less well recognized than anger, happiness, and neutral stimuli. Secondly, girls tended to recognize anger better than boys, and boys confused fear and neutral stimuli significantly more than girls did.

Finally, as age increased, participants were significantly more likely to attribute mixed emotions to emotional prosody, showing the progressive complexification of the emotion representation that young adults perceive in emotional prosody.

Age, sex and emotion effect

To our knowledge, until now no studies have focused on the development of emotional prosody recognition from meaningless linguistic vocalizations from childhood to adolescence. This is surprising given that in the whole preverbal period infants exclusively rely on perceived acoustic vocal aspects of their caregiver's verbal utterances to infer their partner's emotions and intentions. And this inference process, largely based on the musicality of vocal interactions and not on semantic word meaning, happens in early and crucial phases of infants' social and emotional development (60). Young infants are sensitive to prosodic variations in adults' voices, such as those associated with infant-directed speech (61–63), which is related to their cognitive and emotional development (64). In fact, in the first months of life infants develop the necessary abilities to decode other's emotions from their utterance's prosody: not only are they oriented to human voices and emotions from birth (65), but they are also sensitive to prosodic characteristics of speech (66–69). During infancy, emotional prosody elicits increased brain responses compared to neutral vocalizations in voice-sensitive regions in typical development (26), which is not the case for infants at risk for autism spectrum disorder (70). Infants from 3 to 7 months old showed early specialization for emotions in adult nonspeech vocalizations (65), especially for negative emotions, and from 5 months they can regulate their behaviors according to different vocal affects that adults display (71, 72), in unfamiliar languages too. Taken together, these results show that significant, and affective vital, prosodic emotions are decoded very early by young infants, even earlier than in speech, and that young infants can detect the sound of emotions before and beyond language acquisition, affectively tuning to them (73, 74).

In his review on the development of face and voice processing during infancy and childhood, Grossman examines the event-related potential correlates of emotion processing in the voice during infancy (26), then he discusses his data in light of adult studies and concludes that infants and children allocate more attentional resources to angry than to happy or neutral voices. This last observation may partially explain why in the present study it is more difficult for children and young adults to correctly identify sadness than anger. Our findings on sadness perception are consistent with previous results reporting that young children had difficulty recognizing sadness in voices (3, 75), except for one study where sadness was expressed by cry vocalizations (41). However, apart from sadness, all other basic emotions were identified with equal accuracy. This aspect, on the contrary, is not in line with previous research reporting, for example, that across age groups happiness was the easiest emotion to recognize (41). This may be due to the fact that in our study the stimuli were based on a linguistic structure and that they were longer and more complex than vocal bursts (41) or non-speech sounds, such as laughs, sighs, and grunts (40).

Regarding the sex hypothesis, the present study confirms previously reported results: girls, across ages, are slightly favored in encoding the nonverbal elements of emotion expression in voices and faces (76–78). There is also a potential increase in the size of this advantage from childhood to early adulthood (79). In particular, we found a specific ability for girls in recognizing negative emotions, such as anger. This is in line with Grosbras et al. (41) who also found sex differences between adolescent boys and girls in the identification of basic emotions in vocal bursts, in particular for fear. Also, in the present study, fear is less confused by girls and this result is in line with studies on the development of facial emotion recognition (80). Taken together, the present results are consistent with most of the literature in confirming that girls show better and more accurate detection of negative emotions, such as anger and fear. This could be explained, at least in part, by the theory proposing that women must produce stronger self-protective reactions than men to cope with aggressive behaviors, such as anger and fear-related behaviors, during evolution.

Whether the emotion recognition of anger and fear also show specific different neural correlates during emotion processing is still unknown (81, 82).

Mixed Emotion Recognition increases from childhood to adolescence

One of the indexes for evaluating emotion maturation is the increased ability to experience and to recognize mixed emotions in others. During childhood there is an evident tendency to feel and to attribute a single emotion, this tendency gradually complexifies during development (83). Children between 3 and 6 years of age demonstrate an initial capacity to both experience and understand mixed emotions (84). This ability gradually develops, together with the ability to experience complex and possibly contradictory mixed emotions, as for example in the context of sarcasm or irony in complex social interactions. It is also possible that the differences between younger and older children in recognizing mixed emotions are mediated by developmental differences in empathy, the ability to experience others' emotions. To our knowledge, this complexification perspective, positing that there is a continuity in the emotional development of children, has never been tested for prosody. In the present study we demonstrated that this complexification of the emotional construct is also evidenced in vocal emotion recognition and that it matures gradually during adolescence. Specifically, the reported results suggest it takes at least 2-3 years for emotion recognition from prosody to become more complex and show a significant increase in mixed emotion detection values. Again, in line with the view of a continuity in emotion development from childhood, adolescents gradually improve, at least up to 12-14 years old, their ability to decode mixed emotions in prosody. Further studies are needed to determine whether the developmental increase in the understanding and experiencing of mixed and contradictory emotions also develops during the lifespan.

Conclusions

To conclude, our study demonstrates for the first time that the ability to identify basic emotions from linguistically meaningless stimuli, thus not related to their semantic content, develops from childhood to adolescence. Interestingly, this maturation was not only evidenced in the accuracy of emotion detection, but also in a complexification of emotion attribution in prosody. Understanding emotions from emotional prosody is crucial during interactions, and complexifying our understanding of other's emotions allows for a more flexible adaptation to others' intentions and to plural social demands.

However, few studies are conducted on the neural mechanisms that might contribute to this maturation process. Potentially, the brain areas involved in adult vocal perception may show age-related changes, especially from childhood to adolescence, underpinning their capacity to recognize emotions from linguistically meaningless stimuli.

Future research should investigate the neural correlates of age-related improvement in emotional prosody recognition and the emergence of complexification in emotion recognition during adolescence.

Declarations

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Tables

Tables 1 and 2 are not available with this version.

Figures

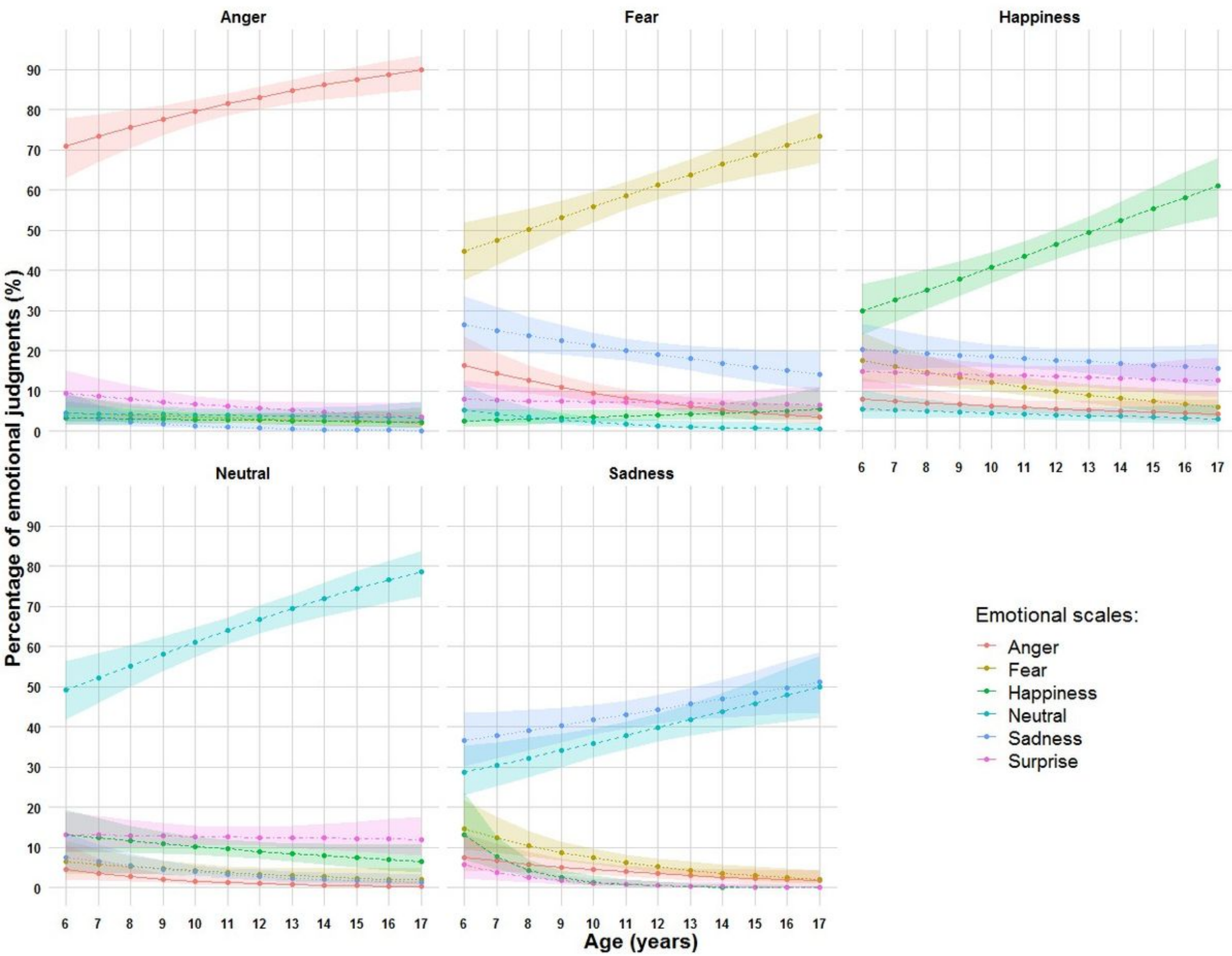

Figure 1

Percentages of emotion judgments as a function of age. Shaded areas represent 95% confidence intervals. The percentage of correct responses homogeneously increased with age.

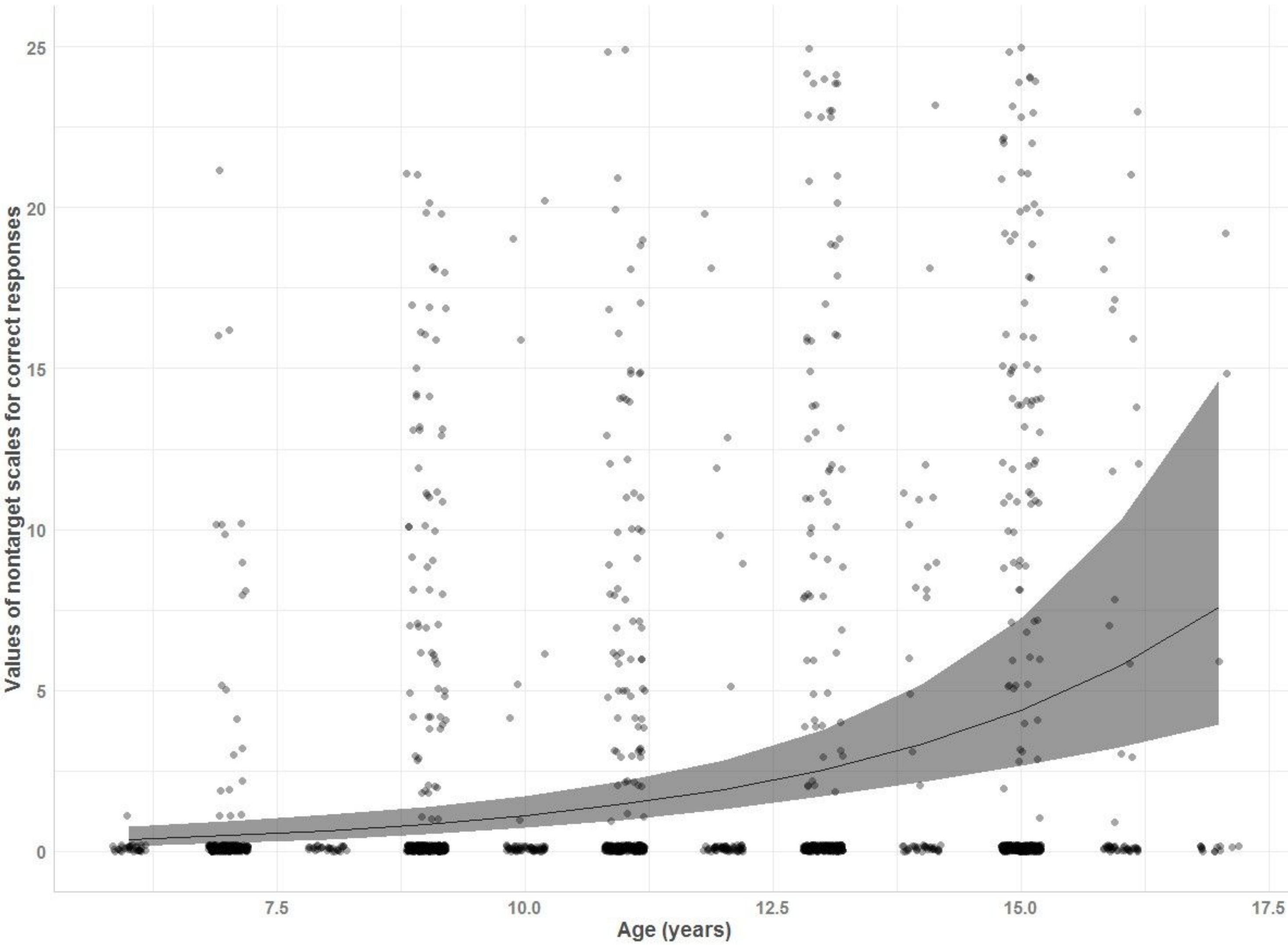

Figure 2

Index of Mixed Emotion Detection which significantly, but gradually, increases with age. Shaded areas represent 95% confidence intervals.

Supplementary Files

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- Appendix1Tables29Dec2021.docx