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Emotion recognition development: Preliminary evidence for an effect of school pedagogical practices

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ABSTRACT

While emotion recognition is shaped through social interactions from a child's early years through at least late adolescence, no emphasis has thus far been given to the effects of daily experiences at school. We posited that enriched, more diverse, and less competitive social interactions fostered by some pedagogical practices may contribute to emotion recognition processes in children. Here, we investigated differences in emotion recognition among schoolchildren experiencing the Montessori versus traditional practices. Children performed two tasks; one measuring the impact of social context on fear-surprise perception, and one measuring their bias toward happiness or anger. Results suggest that children experiencing traditional practices show a higher sensitivity to fear-recognition, while children attending Montessori schools show a higher integration of social cues and perceive expressions of happiness for longer durations. Such preliminary findings call for replication and further research to determine which pedagogical features from the Montessori method may explain these effects.

1. Introduction

Research concerning the role of emotions in school-related social behavior, well-being, and academic performance, as well as the role of school interventions on the development of social and emotional competencies has substantially grown in the last two decades (see e.g., Nathanson, Rivers, Flynn, & Brackett, 2016; Pekrun & Linnenbrink-Garcia, 2014). Emotion recognition abilities, broadly defined here as the way individuals perceive, identify, categorize, or interpret others' emotional expressions, are typically considered to be a key process involved in socio-emotional competencies (e.g., Ohl, Fox, & Mitchell, 2013). Culture and early life experiences have been shown to influence such emotion recognition abilities (e.g., Gendron, Roberson, van der Vyver, & Barrett, 2014; Yik, Widen, & Russell, 2013), and evidence indicates that targeted school-based interventions also have the potential to improve them (Garner & Waajid, 2008; Nathanson et al., 2016, for example), thereby benefiting scholastic outcomes, personal well-being, as well as long-term positive and cooperative social interactions (Immordino-Yang, Darling-Hammond, & Krone, 2019). For instance, MacCann et al. (2020) recently showed that emotional intelligence can predict academic performance. To the best of our knowledge, no study to date has examined the extent to which unsupervised socio-emotional learning induced by school pedagogical practices contributes to schoolchildren's emotion recognition abilities. Given some divergent characteristics of the Montessori versus traditional pedagogical principles, we aimed at obtaining preliminary evidence that emotion recognition performances differ in children attending Montessori versus traditional schools.

1.1. Emotion recognition development

The ability to adequately identify and categorize emotions emerges early in life (see Widen & Russell, 2013), with a protracted maturation through adolescence (e.g., Thomas, De Bellis, Graham, & LaBar, 2007) and life-long modifications (Ruffman, Henry, Livingstone, & Phillips, 2008). While happiness is the first emotion that infants easily recognize (Herba & Phillips, 2004; Palama, Malsert, & Gentaz, 2018), the ability to recognize fear, surprise, and disgust improves from 3 to 10 years of age (Coenen, Aarnoudse, Huitema, Braams, & Veenstra, 2013; Widen & Russell, 2003, 2013), suggesting that some emotions require more cognitive development and/or more complex socio-emotional experiences to be learned. Emotion recognition not only requires us to track

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emotional cues from the face, voice, and body, but to also integrate contextual information for the attribution of an emotion to be made (e.g., Mumenthaler & Sander, 2012; 2019).

1.2. Contextual social cues

It takes more than perceiving an isolated facial, vocal, or postural expression to recognize an emotion: There is growing evidence indicating that the very process of emotion recognition is integrating contextual information (such as co-occurring body cues or social information) in order to identify an emotion (Aviezer, Ensenberg, & Hassin, 2017; Mumenthaler & Sander, 2019). Evidence suggests that some contextual effects in emotion recognition may even automatically take place in adults (e.g., Aviezer, Bentin, Dudareva, & Hassin, 2011; Leitzke & Pollak, 2016; Mumenthaler & Sander, 2015). The contextual effects are particularly observed when the to-be-recognized expressions are ambiguous such as when they are perceived as expressing both fear and surprise (see Mumenthaler & Sander, 2015; 2019). Studies in children even suggest that children rely more on social cues than facial cues to efficiently recognize an emotion, and that they look longer at co-occurring contextual cues to identify emotions such as fear, surprise, or disgust than adults (Durand, Gallay, Seigneuric, Robichon, & Baudouin, 2007; Widen & Russell, 2010). The efficiency of such processing increases with age (e.g., Theurel et al., 2016) and is modulated by targeted training in children aged 3–12 years (for a review, see Theurel & Gentaz, 2015).

1.3. Positivity/Negativity Bias

Studies propose a process of probabilistic learning across development that improves emotion recognition: Associations experienced over time cumulate to guide selective attention (Plate, Fulvio, Shutts, Green, & Pollak, 2018). While babies and infants look longer at happy faces than angry ones (Farroni, Menon, Rigato, & Johnson, 2007; Grossmann, Striano, & Friederici, 2007), adults seem to exhibit the opposite pattern, even cross-culturally (Marinetti, Mesquita, Yik, Cragwall, & Gallagher, 2012). This is sometimes interpreted as a “threat advantage”, an effect where dangerous cues (e.g., angry faces) are more salient and thus processed longer than safer cues (e.g., happy faces). Interestingly, a recent study reported developmental changes (8–23 years of age) in the brain networks subserving salience detection and cognitive control of emotion recognition, fearful and angry faces being subject to more considerable functional reorganization (Zhang, Padmanabhan, Gross, & Menon, 2019). The developmental shift in emotional valence perception (Kauschke, Bahn, Vesker, & Schwarzer, 2019) parallels the calibration of threat perception across development, with a potential cascading effect from early childhood to late adolescence. In fact, the miscalibration of threatening signals can lead to an overcautious attentional bias toward negative emotional stimuli, as is the case with social anxiety (Maoz et al., 2016) or depression (Gollan et al., 2016), which typically emerges during adolescence (Siegel & Dickstein, 2012). In addition, studies on early experiences, such as exposure to family violence or acute adversity, align with this idea. Indeed, they report a link between early-life adversity, an attentional bias toward negative stimuli (e.g., Dannlowski et al., 2013) or threat, and a higher level of anxiety at an older age (Briggs-Gowan et al., 2015). Importantly, the capacity to assign valence to a stimulus can be biased toward positive or negative emotional stimuli (positive/negative bias) and has a direct impact on the person's interpretation and handling of a situation (Moser, Hajcak, Huppert, Foa, & Simons, 2008). In fact, a bias toward positive stimuli (positivity bias) is related to an increase in positive emotion and better regulation of negative emotions, as well as predicts an individual's resilience to stress (Thoern, Grueschow, Ehlert, Ruff, & Kleim, 2016; Van Bockstaele et al., 2018).

1.4. Effective school practices

If early social experiences modulate an individual's emotion recognition abilities, one can then hypothesize that social interactions experienced at school also contribute to the development of emotion recognition competencies. Children from 4 to 12 years of age spend at least 6 h a day in school environments, which are essentially social settings. It is therefore crucial to understand the impact that school pedagogical practices can have not only on children's academic outcomes but also on their socio-emotional competencies, such as emotion recognition abilities, that can, in turn, also predict academic performance (MacCann et al., 2020).

So far, the few studies that have linked education with emotion recognition skills have focused on the education level. These studies reported that students with a higher education level perform better on emotion recognition tasks (Mill, Allik, Realo, & Valk, 2009; Trauffer, Widen, & Russell, 2013; Wolfgang & Cohen, 1988) and show differential brain activation in emotion-related neural substrates (e.g., the amygdala; Demenescu et al., 2014). It could be that growing up in dense social contexts, such as those inherent to educational environments where social interactions are intense and diverse, offer unsupervised learning of emotion recognition (Huelle, Sack, Broer, Komlewa, & Anders, 2014). If true, schoolchildren experiencing enriched social environments and fostered peer-to-peer interactions throughout their daily school practices would show different emotion recognition capacities than schoolchildren of the same age experiencing less diverse social practices. As a “case study”, we compared two school pedagogical practices: the Montessori method and traditional practices. Both can be of high quality, but vary in how unsupervised learning and social interactions take place both quantitatively (e.g., amount of time allocated for social interactions), and qualitatively (e.g., with respect to the form and diversity of the social interactions within the environment).

The so-called traditional schools have quite homogeneous pedagogical practices as described by the local policies about school curricula. Schoolchildren typically (i) interact out-class with peers, mainly during recess (twice per day, for 20–30 min), and are otherwise asked to work individually at their desk for most of their time; (ii) are in class environments with peers of a similar age lead by one teacher at a time; (iii) receive formal assessments with grades and receive punishments for their behavior (e.g., class exclusion, extra hours after school). Within a typical competitive class climate (Hayek, Toma, Guidotti, Oberle, & Butera, 2017; Hayek, Toma, Oberle, & Butera, 2015), children may undermine their emotion recognition capacities, or even bias them. In adults, competitive climates have been shown to bias intra- and inter-group emotion recognition (Lazerus, Ingbretsen, Stolier, Freeman, & Cikara, 2016). Furthermore, school-related anxiety is also often reported in students experiencing traditional pedagogical practices (Briggs-Gowan et al., 2015; Steinmayr, Crede, McElvany, & Wirthwein, 2015). In adults, anxiety increases threat sensitivity (i.e., more fear or anger perceived; Meyer & Gawlowska, 2017; Notebaert et al., 2018; Proudfit, Inzlicht, & Mennin, 2013).

On the other hand, the Montessori practices, when implemented with high fidelity, provide schoolchildren (i) with in-class peer interactions by keeping the teacher-to-children ratio low so they communicate during on-going work all day long, or share learning moments in small groups; (ii) with multi-grade classrooms (i.e., 3–6 years old, 6–9 years old, 9–12 years old stay together); (iii) with no grades or punishments (Denervaud, Knebel, Hagmann, & Gentaz, 2019; Lillard, 2011, 2019, 2012; Marshall, 2017; Montessori, 1936; Rathunde, 2001). Montessori-schooled children experience a higher percentage of social interactions with peers, as well as more individualized exchanges with their teacher (Baines & Snortum, 1973; Hojnoski et al., 2008). They may learn more from their peers, not only at a cognitive level, but also at a social-emotional one, potentially increasing their emotion recognition capacity. However, there is scarce and indirect evidence

suggesting socio-emotional advantages for schoolchildren experiencing Montessori practices compared with their peers exposed to traditional practices. More precisely, Montessori students were reported to be better at self-regulation, to have more positive social interactions, better conflict-monitoring skills, and a higher well-being at school (Alves et al., 2015; Denervaud et al., 2019; Ervin, Wash, & Mecca, 2010; Flynn, 1991; Lillard & Else-Quest, 2006; Lillard et al., 2017a; Rathunde & Csikszentmihalyi, 2005). This form of self-monitoring and resilient behavior is related to a bias toward positive information in adults (Thoern et al., 2016; Van Bockstaele et al., 2018).

Taken together, these elements suggest that school pedagogical practices have an impact on the development of socio-emotional processes such as emotion recognition.

1.5. Hypotheses

The aim of this study was to investigate how the differences in social interactions and environments experienced over the last 6 years would impact 8–12 years old's emotion recognition abilities. In particular, we were interested in investigating (i) the processing of social emotional cues displayed in context; and (ii) the bias toward positive emotion. Accordingly, we measured these effects by adapting two tasks. First, we adapted an existing social appraisal task for 8- to 12-year-old schoolchildren to test the influence of social contextual cues on the categorization of an ambiguous facial expression (50% surprise-50% fear morphed face). It may be that children who learn more from peers on a daily basis could be particularly sensitive to children's expressions. Therefore, both child and adult faces were used as stimuli for the social context. Second, we used an offset reaction time task of dynamic emotional changes (morphing video clips) to test for the presence of any positivity bias. We hypothesized that, based on the indirect preliminary evidence previously cited, schoolchildren experiencing Montessori practices compared with traditional practices would (i) be more efficient at integrating social cues in the emotion recognition process; (ii) be more biased toward positive emotional faces; and (iii) show a lower fear recognition sensitivity.

2. Methods

2.1. Study sites and participants

2.1.1. Selection criteria for the schools

Montessori private schools (4 classes from 3 different schools) were selected following the criteria set by the International Montessori Association (https://montessori-ami.org), and ensured to have a high fidelity in the implementation of their curriculum (Lillard, 2012):

(i) self-directed activities, through the use of Montessori educational materials;
(ii) self-correction and no formal assessments;
(iii) children have the opportunity to work for 3 uninterrupted hours;
(iv) classes with at least 3 different age-levels.

The Swiss public schools were selected based on their rigorous application of the local policies for traditional pedagogical practices, which was observed and discussed with the school Directors. Traditional public schools (3 classes from 2 different schools) were selected in a specific area based on the city's official statistical data on mean salary to only include an upper-class population (as a way to control some family related variables when comparing this group with the group of children attending Montessori schools), and they were controlled for their application of the official local study plan:

(i) lecture-style, adult-driven interactions;
(ii) feedback in the form of grades and summative assessments;
(iii) children are given a break every hour, and mainly interact with their peers during these breaks;
(iv) one age-level per class.

The teachers' and students' participation was voluntary.

2.1.2. Participants

In total, a subset of 57 children were recruited in the framework of a larger study, which includes neuroimaging and other behavioral measures aimed at evaluating the school environment's impact on a series of psychological processes. The present study was conducted in accordance with the Declaration of Helsinki and with ethics approval from the department of Psychology from the University of Geneva. Written parental consent was obtained for each child and informed consent was provided by each adult participant. For this specific study, inclusion criteria were the age of the participants (8–12 years of age) and belonging to one of the two schooling systems for always or at least the last 6 years (according to parental report). The Montessori group was composed of 28 children (M_{age} = 10.07, SD = 1.35), 16 boys and 12 girls recruited from 3 different schools. The group of children attending traditional public schools was composed of 29 children (M_{age} = 10.64, SD = 1.02), 15 boys and 14 girls recruited from 3 different schools.

Group Variables. *Socio-Economic Status (SES).* Due to local policies in Switzerland, no public Montessori schools exist. In order to control for the fact that the Montessori schools included in this study were all private schools, the selected traditional public schools were located in specific areas to include a disproportionately upper-class population. Parents were also asked to complete a socio-economic questionnaire to assess their education level and professional level. More precisely, in the questionnaire, the parent(s) had to select which of the four options best described their education level (e.g., less than a high school diploma to university level) and professional level (e.g., unemployed to senior executive employee) (Genoud, 2011).

Fluid Intelligence. To account for the effect of intelligence in emotion recognition abilities (Schlegel et al., 2020), fluid intelligence was determined using the black and white short version of the Raven matrices (Raven, Raven, & Court, 2003). The child is presented with a pattern that is missing a piece and is asked to select a piece from several options to complete the given pattern. Children from both school systems showed a similar level of fluid intelligence.

2.2. Measures

Each participant completed two separate experimental tasks. Given the partially exploratory nature of this study and its sample size, we computed sensitivity analyses to determine a priori the critical F and t for the expected effects to ensure a statistical power of 80% (G*Power 3; Faul, Erdfelder, Lang, & Buchner, 2007).

2.2.1. Emotion categorization with social context

The social context task, adapted from Mumenthaler and Sander (2012), was programmed using Matlab with the Psychophysics Toolbox extensions (Brainard, 1997). During the task, the participants were asked to look at a fixation cross on one side of the screen while a social context was displayed on the other side. The social context consisted of a Caucasian front-facing adult or child (male or female) face from the Radboud database (Langner et al., 2010), with either an angry or neutral facial expression (referred to as the “contextual face”). A congruent non-verbal emotional prosody (Banse & Scherer, 1996) was simultaneously played bilaterally to foster the contextual emotion. For the so-called contextual faces of children, the pitch was adapted by an upward transposition (shift in tone) of the adult voice to mimic a child's prosody. After a 50 ms presentation of the fixation cross, it was replaced by a target face. All target faces were of front-facing static Caucasian children with either a neutral or a morphed emotional expression. The morphed expression was always a mixed facial expression composed of

50% surprise and 50% fear (see Fig. 1A). In order to create these faces, surprise and fear faces from the CAFE database (LoBue, Baker, & Thrasher, 2018) were morphed at 50% with FantaMorph-Abrosoft. The neutral faces served as a control condition, while the morphed faces were used for the experimental condition. The presentation side was counter balanced across the block, and the total presentation time of the target faces was 2 s. After the presentation of the stimuli, the child was asked to select the emotional label corresponding to the target face from 5 different options (fear, surprise, shame, sadness, or "something else"), which were presented in a randomized order between participants. No time limit was set for the response. At the beginning of the task, the child was instructed to "look at the fixation cross and rate the following target picture." Each child performed 2 familiarization trials, followed by 4 blocks of 32 trials, each of which was pseudo-randomized with a controlled number of stimuli for gender, age, and left or right gaze per block (see Fig. SI 1).

2.2.2. Positivity/Negativity Bias

Short morphing video-clips with either an adult or a baby face displaying a continuum of a 100% (pure) happy or anger expression that was gradually changing into a 100% of the other expression (from Korb et al., 2015) were used. Each 5-s clip consisted of 60 frames (see Fig. 1B). The child was asked to press the space bar as soon as s/he could no longer perceive the first emotion. Every child performed one familiarization trial of the baby and adult trials, followed by two blocks (randomly starting by adult or baby) of 24 video-clips of faces (see Fig. SI 2), with a balanced gender presentation.

2.3. Procedure

The experiments were conducted *in situ* at the end of the school year, where children performed the tasks in a random order on a laptop with headphones, in a separate quiet room.

3. Results

Statistical analyses were performed with R (R Core Team, 2014) and with the Jamovi open-source software (Version 0.9).

3.1. Group Variables

Participants with missing data for one of the two tasks (n = 9), outside of the target age (2 SD from the mean; n = 4) or with low SES (n = 1) or low fluid intelligence (n = 1) were excluded from the analysis. In total, data from 57 children were analyzed. Regarding the fluid intelligence measure, correct answers for the Raven matrices task (PM-47) were summed (maximum 36 points) and reported as a single score for each participant (missing data from one participant). The socio-economic status (SES) was rated from the parental questionnaires; answers were summed (maximum score is 8) and scores were averaged when both parents responded (missing data from one participant). All scores were normalized. Three independent-sample t-tests were conducted comparing the age, fluid intelligence, and SES scores of the Montessori versus the traditional schoolchildren. There were no significant differences in the scores (all p's > 0.05; see Table SI 1), suggesting a between-group homogeneity in these variables.

3.2. Emotion categorization with social context

The responses to the adapted social appraisal task were summed per conditions over all trials for each participant. Two repeated measures analyses of variance (ANOVA) were conducted on the means of each condition to examine the effects of the contextual face (child versus adult), the contextual emotion (anger versus neutral), and the type of schooling system (Montessori versus traditional) on emotion recognition (fear, surprise, shame, sadness, "something else") of the target face; one analysis was performed on the control condition (neutral target face), and the other, on the morphed fear-surprise target face (experimental condition) (see Fig. SI 3 for the mean number of responses per condition). For the experimental condition, we established the critical F accounting for an interaction between responses and context as 1.60 based on a sensitivity analysis with a power of at least 80% (Faul et al., 2007).

For the control condition, in which the target was a neutral face and the contextual faces could be either a neutral or an angry face, no significant between-group effect was observed (see Fig. SI 4, Table SI 2). For both the control and the experimental conditions, there was no significant difference observed between the adult and children faces (see Fig. SI 5).

For the experimental condition, where the target face was morphed to express 50% fear and 50% surprise, there was a significant interaction between the school pedagogical practices experienced by the children and the responses given, $F(4,220) = 2.93$, $p = 0.022$, $\eta p^2 = 0.05$[1]. The actual F-value was higher than the critical F computed, confirming the reliability of our measure (Faul et al., 2007). This was further confirmed by a reliable post-hoc power of 86.6% (Fig. 2). The results indicated that schoolchildren exposed to Montessori pedagogical practices perceived more "surprise" in the ambiguous faces than traditionally-schooled students did when the social context was neutral ($t(220) = 4.00$, $p_{Tukey} = 0.013$, $d = 0.31$). However, when the social context displayed an angry face, no significant difference was observed for the "surprise" responses between the two groups. In addition, for both angry and neutral contexts, schoolchildren exposed to traditional practices significantly reported more "fear" than "surprise" in the ambiguous faces ($t(295) = 3.77$, $p_{Tukey} = 0.026$, $d = 0.39$; $t(295) = 4.61$, $p_{Tukey} < 0.001$, $d = 0.37$, respectively), a pattern that was not observed in schoolchildren exposed to Montessori practices. Furthermore, independently of the context, schoolchildren exposed to Montessori pedagogical practices gave significantly less fear responses for the ambiguous faces than the schoolchildren exposed to traditional practices ($t(55) = -2.47$, $p = 0.017$, $d = 0.65$) (see Table SI 3 for details).

3.3. Positivity/Negativity Bias

We computed a score for the positivity bias using the offset reaction times (RT) of the pooled data from both the baby and adult conditions (i.e., starting with an anger expression *versus* starting with a happy expression). By computing the reaction time for each condition, we derived individual differences in positive emotion perception (*positivity bias [ms]* = RT_{happy} - RT_{angry}). An independent t-test was conducted to compare the positivity bias between the Montessori and traditional schoolchildren. We established a critical t of 1.67 based on a sensitivity analysis with a power of 80%. The results indicated a significant positivity bias in favor of the Montessori schoolchildren ($M = 80.4$ [ms], SD = 320 [ms]) compared to the traditional schoolchildren ($M = -83.3$ [ms], SD = 276 [ms]), $t(55) = 2.07$, $p = 0.043$. The actual t-value was higher than the critical t computed a priori ($2.07 > 1.67$), suggesting a reliable measured effect. As an additional measure of positive versus negative sensitivity, children with either a negative (< 0 [ms]) or a positive bias (> 0 [ms]) were classified into two groups, "positively" or "negatively" biased (Fig. 3). An independent Chi-square test was computed to compare the frequency of positively *versus* negatively biased schoolchildren in the Montessori and traditional systems. A significant interaction was found, X^2 (1, $N = 57$) = 9.27, $p = 0.002$.[2] The schoolchildren enrolled in the

[1] When including all data collected (i.e., adding the data from the children who did not participate in the Positivity/negativity Bias task, N = 62), the triple interaction was robustly present, $F(4,220) = 3.27$, $p = 0.012$, $\eta p^2 = 0.05$ (see Table SI 4).

[2] The results are significantly different even when introducing more data

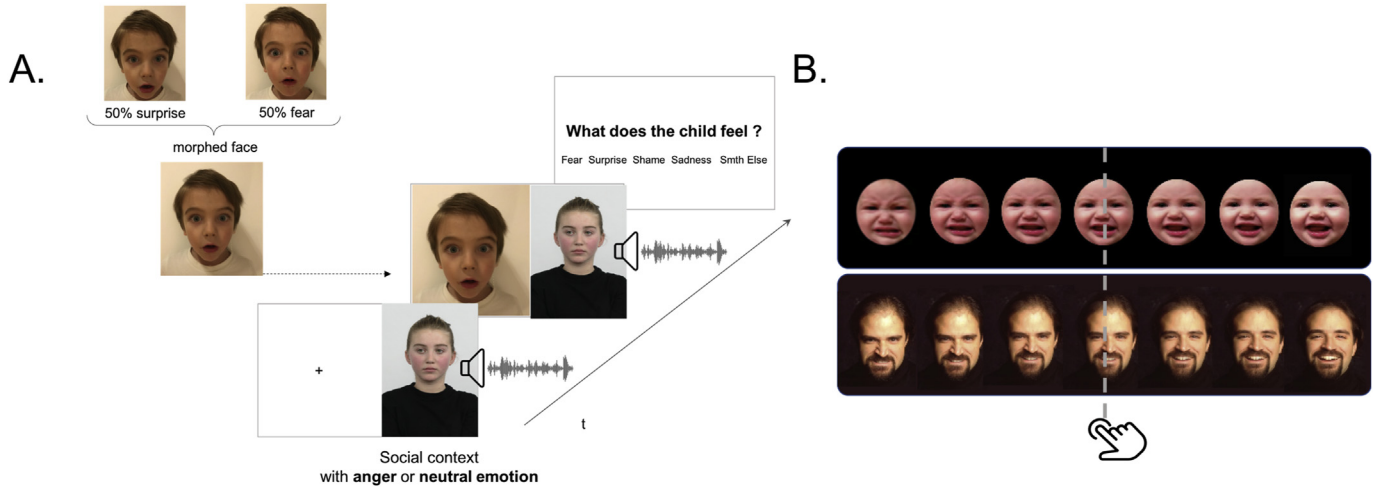

Fig. 1. A. Emotion Categorization with Social Context. In this task, schoolchildren were first presented with a social context in the form of an adult or child face expressing either anger or no emotion (neutral) concomitant with a congruent emotional prosody; then, a target face appeared in the form of a neutral child expression or an ambiguous (50% fear-50% surprise morphed) child expression. After the stimuli presentation, schoolchildren were asked to label the emotion of the target face (forced choice between fear, surprise, shame, sadness, or "something else"). **B. Positivity/Negativity Bias.** In this task, schoolchildren were asked to track a dynamic change in emotions from positive to negative or the opposite (morphing video clips) in baby or adult faces. They were asked to detect when the first emotion (happiness or anger) had stopped.

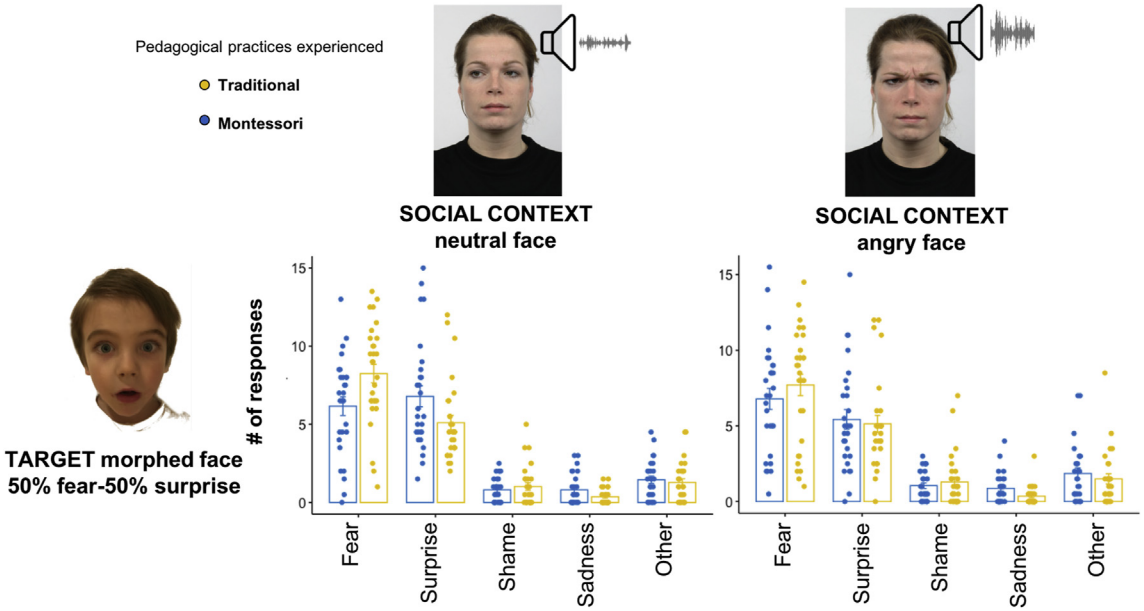

Fig. 2. Emotion Categorization with Social Context. Emotion recognition in the ambiguous condition (50% fear-50% surprise morphed face) with either a child or an adult in context, with an angry or neutral facial expression (from the Radboud database) combined with a congruent emotional prosody. The descriptive plot shows the results of the triple interaction (contextual face × responses given × school pedagogy). Error bars represent SE.

Montessori system were more likely to present a positivity bias (67.9%) than the traditional schoolchildren (27.6%) (Fig. SI 6).

4. Discussion

This study was a first attempt at investigating whether the social environment, as operationalized by school pedagogical practices, has the potential to modulate emotion recognition in children. We tested 57 children (8–12 years old) experiencing either Montessori or traditional practices for always or at least the past six years (as reported on the parental questionnaire). We first measured individual sensitivity to contextual social cues in fear perception. Second, we investigated the bias toward positive or negative emotional facial expressions.

Results from the social context task suggest that the contextual cues were integrated differently depending on the pedagogical practices the schoolchildren experienced. Emotion attribution for the ambiguous target face (morphed to contain 50% fear and 50% surprise) was found to be different in the angry *versus* neutral social contexts for schoolchildren experiencing Montessori practices: these children attributed less "surprise" when exposed to the angry versus neutral social context. No evidence was found for such an integration of social cues (i.e., differential recognition pattern according to the context) in children experiencing traditional practices. Interestingly, these children attributed more "fear" than "surprise" to the ambiguous faces when the context

(*footnote continued*)
(adding participants that had not participated in the emotion categorization with social context task); X^2 (1, N = 61) = 8.70, p = 0.003.

Fig. 3. Positivity/Negativity Bias. The capacity to assign valence to a stimulus can be biased toward positive *versus* negative emotional stimuli, and is measured through the positivity bias: the difference between the amount of time (RT) spent perceiving positive stimuli (here, happy faces) and the amount of time (RT) spent perceiving negative stimuli (here, angry faces).

displayed an angry face and a neutral face, suggesting a higher fear-recognition sensitivity in these children compared with those attending Montessori schools. Taken together, these results suggest that the integration of social cues in the process of emotion recognition is modulated by the early social environment. Although further research is needed to reach such a conclusion, it is possible that daily enriching social interactions, which are promoted in the Montessori method, may hasten the maturation of the contextual cue integration (training-effect, such as is found in unsupervised learning, see Huelle et al., 2014). Furthermore, the higher fear sensitivity and related threat calibration in schoolchildren exposed to traditional practices may tentatively reflect their experience of a more competitive environment (through grading for example, Hayek et al., 2017), or less peer interactions during learning. These effects may have an impact on the underlying flexibility in cognitive processes through daily cumulative social experiences, thereby potentially causing long-term effects on social behaviors (van Duijvenvoorde, Peters, Braams, & Crone, 2016) and undermining the integration of social contexts that could lead to suboptimal interpersonal relationships (Maoz et al., 2016). It would be interesting to test, in a future study, whether systematically introducing more peer-to-peer working interactions on a daily basis in traditional practices would engender an increase in social cue integration. In fact, when working together, schoolchildren need to coordinate their goals, overcome conflicts, develop their theory of mind mechanisms, and regulate their emotions (Ainsworth & Baumeister, 2013; Domberg, Koymen, & Tomasello, 2018). All these aspects may benefit socio-emotional skills. Finally, to confirm our preliminary findings, studying the response patterns of younger children (i.e., with less experience in each pedagogical method) and tracking their development, within a longitudinal and randomized framework, seems necessary.

In addition, results from the second experiment also suggest a different pattern of emotion processing for children who attended Montessori *versus* traditional schools. More specifically, in the task where children had to notice when the dynamical facial expression changed, schoolchildren attending the Montessori schools perceived happy expressions for a longer duration than they perceived angry expressions, an effect that we can refer to as a positivity bias. In contrast, anger expressions were perceived for a longer duration than happy expressions in schoolchildren exposed to traditional practices. These results suggest that the school pedagogical practices experienced by schoolchildren contribute to the emergence of such a positive/negative bias.

The pattern observed in Montessori-schooled children is consistent with previous studies reporting a relatively high positive affect at - and toward - school in children experiencing Montessori practices (Denervaud et al., 2019; Lillard & Else-Quest, 2006; Lillard et al., 2017b; Rathunde & Csikszentmihalyi, 2005). A bias toward positive stimuli, which has been shown in many paradigms (Pool, Brosch, Delplanque, & Sander, 2016), can be influenced by a current positive mood (e.g., Wadlinger & Isaacowitz, 2006), and impact emotion regulation that can lead to more positive social interactions (Thoern et al., 2016; Van Bockstaele et al., 2018). Conversely, the pattern observed in children attending traditional schools parallels adults' longer looking times at angry faces compared to happy faces (Marinetti et al., 2012), and suggests a precocious "threat advantage" bias (Marinetti et al., 2012; Martinez, Falvello, Aviezer, & Todorov, 2016). A too large bias toward negative stimuli may have deleterious implications on emotion regulation or affective disorders such as anxiety or depression (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & van IJzendoorn, 2007; Bone et al., 2019).

Future studies could test whether the school climate, and its direct impact on students' well-being (Steinmayr, Heyder, Naumburg, Michels, & Wirthwein, 2018), may be an underlying feature shaping attentional bias. More research is clearly needed to replicate these effects and understand their origins, using multiple tasks, larger populations, randomized designs, and manipulating variables that relate to school-induced mood and anxiety.

Consistent with the proposal that emotion recognition ability depends on education, our research provides preliminary evidence suggesting that this ability not only depends on the level of education (e.g., Trauffer et al., 2013) but also on the pedagogical practices. Crucially, some specific pedagogical features from the Montessori education may explain such differences, but cannot be inferred from our study. The measured effects are certainly not specific to the Montessori pedagogy, but rather to some variables found in this pedagogy (e.g., a focus on collaborative learning with peers, multi-grade classrooms). From a different perspective, recent results showing that the more a student talked in class, the better they performed in a reading literacy test are

inspiring in this respect (Sedova et al., 2019). An interesting approach would be to compare specific pedagogical practices by systematically as well as empirically testing them using designs manipulating specific variables such as the diversity of social interactions during learning hours (e.g., age and diversity of the children who interact and the social contexts in which the interactions take place), moods induced, feedback given, or active collaborative learning. Although new research should test whether these results can be replicated, and if they are directly caused by the school environment and/or by other factors, such as family-related variables (Castro, Halberstadt, Lozada, & Craig, 2015), our findings suggest that the early social environment influences emotion recognition mechanisms. With respect to theories of emotion, our results are particularly compatible with appraisal theory's account of emotion recognition (e.g., Sander, Grandjean, Kaiser, Wehrle, & Scherer, 2007) as well as with theories focusing on emotion attribution (see Widen and Russell, 2013). Both account for the contextual effects (see Aviezer, Ensenberg, & Hassi, 2017) and for the existence of environmental modulators of emotion recognition (see Trauffer et al., 2013) in children.

CRediT authorship contribution statement

Solange Denervaud: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Visualization, Writing - original draft. **Christian Mumenthaler:** Conceptualization, Formal analysis, Methodology, Software, Writing - review & editing. **Edouard Gentaz:** Funding acquisition, Writing - review & editing. **David Sander:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Writing - review & editing.

Declaration of competing interest

No potential conflict of interest was reported by the authors.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2020.101353.

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