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The role of affective touch in modulating emotion processing among preschool children

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ABSTRACT

Recognizing emotional expressions is a prerequisite for understanding others' feelings and intentions, a key component of social interactions that develops throughout childhood. In multisensory social environments, touch may be crucial for emotion processing, linking external sensory information with internal affective states. The current study investigated whether affective touch facilitates recognition of emotional expressions throughout childhood. Preschool children (N = 121 3- to 6-year-olds) were presented with different tactile stimulations followed by an emotion-matching task. Results revealed that affective touch fosters the recognition of negative emotions and increases the speed of association of positive emotions, highlighting the centrality of tactile experiences for socioemotional understanding. The current research opens new perspectives on how to support emotional recognition with potential consequences for the development of social functioning.

Introduction

The ability to accurately decode facial emotions is an essential component of the development of social functioning. Understanding others' emotion expressions allows children to infer others' internal thoughts and states, thereby adjusting their own responses accordingly in order to build effective social interactions. In fact, children's ability to recognize emotion facial expressions has been shown to be related to social adjustment and quality of peer relationships (Leppänen & Hietanen, 2001;

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Wang et al., 2019). Therefore, investigating and supporting emotion recognition from early childhood is of vital importance to promote the development of socioemotional skills (Trentacosta & Fine, 2010). Infants a few months old are able to discriminate between basic emotion expressions, suggesting that they can detect configurations of features that give affective meaning to facial expressions (Nelson & De Haan, 1997; Serrano et al., 1992). Notably, in ambiguous situations, infants can use a caregiver's facial expressions to guide their own behavior, approaching or withdrawing from a new stimulus according to the valence of the emotion displayed (Klinnert et al., 1986). By preschool age, most children show good ability to accurately label how another person is feeling by encoding cues from facial expressions. This contributes to children's socioemotional skills to correctly interpret emotional messages from others and adjust their own behavior accordingly, forming the basis for successful and effective interactions with significant others (i.e., peers, parents, and teachers; Parker et al., 2013). However, full proficiency in recognizing and understanding emotion facial expressions gradually develops with age, undergoing qualitative changes throughout childhood. It has been hypothesized that initially children divide facial expressions into two categories in terms of valence, corresponding to "feeling good" and "feeling bad," which are then gradually differentiated into discrete emotions (Widen, 2013). Traditionally, a set of six basic emotions has been considered, including happiness, sadness, fear, anger, surprise, and disgust (Ekman, 2003). Previous studies suggest that there are different developmental courses in discriminating facial expressions depending on the emotion. Specifically, there is extensive agreement that positive expressions, in particular happiness, are recognized earlier and more accurately than negative expressions (Gao & Maurer, 2010; Herba et al., 2006; Rodger et al., 2015; Widen & Russell, 2003). Less consistent results have been reported about the specific order in which negative expressions can be correctly recognized. Some evidence suggests that the ability to distinguish sadness, fear, anger, and then disgust gradually emerges in this order (Durand et al., 2007), whereas other findings point to an earlier sensitivity to disgust and fear compared with anger and sadness (Gao & Maurer, 2010). It has been suggested that across development children adopt different strategies that enhance the efficiency of facial emotion processing, with younger children typically using a piecemeal strategy focusing on distinctive facial features and older children using a configural strategy based on the relations among facial features (Aylward et al., 2005). The gradual acquisition of full competence in facial expression processing can be explained by the interactive specialization development of the underlying neural networks (Bigelow et al., 2021). Emotional face processing involves a network of brain areas, including the fusiform gyrus, which shows selective activation in response to facial stimuli (Kanwisher et al., 1997) that is enhanced by emotional expressions (Critchley et al., 2000), the prefrontal cortex (Winston et al., 2003), the insula (Carr et al., 2003), and the amygdala, which is preferentially activated by fearful facial expressions (Morris et al., 1996; Whalen et al., 2001) and happy faces (van den Bulk et al., 2014). These brain areas continue to develop throughout childhood and adolescence, undergoing anatomic and functional changes and fine-tuning their ability to decode emotion facial expressions (Aylward et al., 2005).

It is worth mentioning that children's ability to recognize others' emotions is not limited to faces. In everyday life, children interpret facial expressions in light of multiple pieces of available information, such as facial movements, vocal expressions, body poses, and context (Parker et al., 2013). Most of the research examining children's emotion recognition has been conducted focusing on visual processing of facial expressions without including other sensory modalities. Socioemotional cues from different senses may co-occur and shape emotion processing. In particular, tactile stimulation has been shown to be a meaningful component of social connection and communication of emotions from the earliest stages of development (Walker & McGlone, 2013). Beyond the sensory-discriminative dimension of touch, which conveys information about the physical properties of the external object touching the skin, tactile stimulation also provides information about the internal state of the organism (e.g., what the experience of being touched feels like) and can be used to communicate important socioemotional significance (McGlone et al., 2014). This second dimension of touch has been referred to as affective touch and is mediated by the activation of C-tactile afferents, a class of low-threshold unmyelinated fibers present mainly on the hairy skin of mammals (Vallbo et al., 1999). Although recent evidence demonstrated sparse innervation of C-tactile afferents also on glabrous skin, C-tactile innervation density on hairy skin is thought to be about seven times higher, reflecting the fact that different body parts serve very different tactile functions; whereas the glabrous skin of the hand is involved in tactile exploration, object identification, and complex motor tasks, the hairy skin is more involved in the reception of touch (Watkins et al., 2021). The C-tactile afferents constitute a distinct anatomical and functional tactile system that optimally responds to gentle, slow, caress-like touch delivered at a velocity of 1 to 10 cm/s and at normal human skin temperature (Ackerley et al., 2014). Notably, activation of C-tactile afferents has been found to strongly and consistently correlate with subjective sensation of pleasantness (Löken et al., 2009). Thus, C-tactile afferents seem to be tuned to specific features of skin-to-skin contact, providing a neurobiological foundation for the processing of socially relevant and emotional aspects of tactile interaction (Morrison et al., 2010). At the neural level, C-tactile afferents project to the posterior insula, which is crucially involved in interoceptive processing (e.g., sensing, integrating, and interpreting signals originating from inside the body) and supports an early convergence of sensory and affective signals to produce subjective feeling and emotional response to a given sensory experience (Craig, 2002). Moreover, connectivity modeling analysis revealed a somatovisceral network of functional coactivation with the posterior insula, which includes primary and secondary somatosensory cortices, striatum, thalamus, frontal operculum, and medial prefrontal cortex (Morrison, 2016). This functional network supports the emotional appraisal of tactile interactions contributing to the formation of affective and motivational dispositions that may influence social perception and interpersonal behaviors. Notably, the overlap between the brain areas activated by affective touch and socioemotional brain networks point to the essential contribution of affective touch in social cognition and emotion processing (Olausson et al., 2010). Indeed, individuals are accurate in discriminating different categories of emotions, even when they communicate exclusively through touch (Hertenstein et al., 2006). Furthermore, touch can increase the salience of social signals from other sensory modalities, intensifying the emotional valence on the basis of the context. More specifically, affective touch has been demonstrated to modulate social appraisal of facial expressions, making smiling faces seem more friendly and making attractive and angry faces seem less friendly and attractive (Ellingsen et al., 2014).

From a developmental perspective, affective tactile experiences are at the core of interpersonal interactions from the very first stages of life and represent a foundation for self-regulation, socioemotional, and cognitive developmental trajectories (Farroni et al., 2022; Walker & McGlone, 2013). At birth, newborns already show sensitivity to affective touch, modulating their physiological state depending on the type of tactile stimulation they are receiving (Della Longa et al., 2022; Manzotti et al., 2019). There is also evidence that insular cortex is responsive to affective touch within the first weeks of life, indicating an early integration of tactile information with homeostatic processes that may modulate autonomic body regulation and affective states (Jönsson et al., 2018; Tuulari et al., 2019). Indeed, affective touch was reported to be effective in promoting infants' emotion regulation in distress situations. During maternal unavailability, such as interruption of reciprocal face-to-face interaction (i.e., still face procedure; Tronick et al., 1978), maternal touch can regulate infants' behavioral and physiological stress responses and facilitates the recovery of normal affective states (Feldman et al., 2010; Stack & Muir, 1992). Beyond infancy, tactile stimulation can be used by caregivers to comfort and regulate children's emotional responses as well as direct or maintain children's attention to some activities (Cekaite & Bergnehr, 2018). For example, parental touch has been proven to be effective in reducing children's attentional biases toward threatening stimuli (i.e., angry faces) and increasing trust in children with greater social anxiety (Brummelman et al., 2019). According to the interactive specialization model (Johnson, 2011), the interplay between neurobehavioral organization and sensory experiences during specific time windows of life (i.e., critical periods) has a critical impact in shaping developmental trajectories (Dehorter & Del Pino, 2020), suggesting that early tactile experiences have the potential to modulate cognitive and socioemotional abilities with cascading effects on social and behavioral adaptive functioning. In support of this perspective, the frequency of maternal touch during free play has been shown to be associated with preschool children's posterior superior temporal sulcus activity at rest, which seems to be involved in mentalizing and preference for social reward (Brauer et al., 2016). Furthermore, a longitudinal study investigating the long-term effects of skin-to-skin contact during the neonatal period suggests that maternal bodily contact after preterm birth enhances mother–child interpersonal synchrony across development, which in turn predicts amygdala and insula responsiveness to others' emotions (Ulmer Yaniv et al., 2021). These results indicate the crucial role of affective tactile interactions for tuning the human social brain, underpinning socioemotional development and social interactions. The aforementioned studies relate the frequency of affective touch interactions at early developmental ages to children's socioemotional abilities at later ages, yet the literature on the possible effects of affective touch in the short term on preschool emotion recognition abilities seems rather lacking.

The current study aimed to investigate the role of affective touch in modulating visual perception of facial expressions, facilitating the recognition and association of emotions among preschool-aged children. In the process of interpreting emotion facial expressions, inputs from different sensory modalities and contextual information feedback combine to influence one another. Previous research investigating the combination of visual and auditory signals showed evidence that multimodal presentations yield faster and more accurate emotion judgments (Klasen et al., 2012). Thus, in the current study we investigated whether interoceptive information provided by affective touch might foster more productive predictions about the affective states of others, contributing to the ability to decode emotional expressions. More specifically, we expected that children would report brush stroking (affective touch) as more pleasant than tapping with a brush handle (non-affective touch), and we hypothesized that exposure to affective touch, compared with non-affective touch, would promote socioemotional processing, helping children to discriminate and understand emotion facial expressions as measured by accuracy and speed in associating faces that display the same emotion (emotion-matching task). Moreover, to investigate whether affective touch has a different effect on positive versus negative emotional expressions, we considered the valence of the emotional face. Across different sensory modalities, one very basic feature of emotional stimuli is their valence, which refers to the fact that emotional stimuli can be classified as positive (pleasant) or negative (unpleasant) (Kauschke et al., 2019). Recent evidence supports that although each of the six basic emotions contains both negativity and positivity, some of them (including sadness, fear, anger, and disgust) are generally reported as negative emotions with some cultural differences, whereas happiness is rated as a positive emotion across Western and Eastern countries and surprise is considered a relatively positive emotion with careful consideration on different conceptualizations of type of surprise (An et al., 2017). Indeed, with respect to the valence, surprise is more ambiguous than the other basic emotions and should be interpreted as either positive or negative depending on specific contextual information (Neta & Kim, 2022). Given that valence is a crucial factor for the representation and categorization of human emotions, we decided to investigate whether affective touch may specifically increase the processing of positive emotional expressions (congruency effect) rather than increasing the emotional salience of facial expressions beyond their valence. We also aimed to explore possible age- and sex-related differences. Specifically, facial emotion processing emerges and rapidly improves during infancy, continuing to be fine-tuned throughout childhood. Thus, we considered the factor age as a continuous variable to take a developmental perspective in the investigation of accurate decoding of facial expressions as a key component of gradually developing socioemotional functioning. Finally, sex is another important factor that should be considered. Whereas some studies suggest that males and females perform at equivalent levels on emotion recognition tasks (Della Longa et al., 2022; Romani-Sponchiado et al., 2022), others reported a consistent female advantage (Lawrence et al., 2015; McClure, 2000; Wang et al., 2019). There is additional evidence in support of possible sex differences in affective touch perception, with females being more sensitive to affective aspects of touch and responding with higher scores of pleasantness (Russo et al., 2020). Previous studies with adults also indicate the sex asymmetries in the accuracy of communicating distinct emotions via touch; it seems that women can more accurately communicate sympathy and happiness by briefly touching the arm of a stranger, whereas men are more effective in communicating anger (Hertenstein & Keltner, 2011). However, developmental studies did not find significant sex differences in psychophysical ratings in response to affective touch (Croy et al., 2019). These discrepancies in previous findings suggest that further investigation is needed to better understand whether females and males follow a different development pathway in affective touch perception, in the acquisition of emotion recognition competences, and in the interplay between sensory and emotion processing.

Method

Participants

The study was conducted in kindergartens near Padova (Italy). A total of 121 preschool children (67 girls and 54 boys) were included in the study. All children were 3 to 6 years old, with a mean age of 4.72 years (*SD* = 0.89). Parents gave written consent for their children's participation after being informed about the procedure and the aims of the research project. The local ethical committee of psychological research at the University of Padova approved the study protocol.

Stimuli and procedure

At the beginning of the experimental session, each participant was presented with two types of tactile stimuli in order to verify that children were comfortable with being touched and to assess the subjective pleasantness. The tactile stimulations were applied in a proximal-to-distal direction on children's dorsal forearm with a cosmetic brush (5-cm width; see Fig. 1) by a trained experimenter who sat on the side of the children to have easy access to their exposed forearm. Each participant was exposed to two different types of tactile stimulation characterized as follows: (a) affective touch—gentle stroking with brush bristles at a velocity of approximately 3 cm/s; and (b) non-affective touch—gentle tapping with the brush handle at a rate of approximately one tap per second. Tactile stimulation was administered in a 9-cm-long skin area for a duration of 15 s for each condition. To keep the rate of stimulation constant, the experimenter provided a defined number of touches during this time interval, which varied according to the condition. Specifically, in the affective condition 5

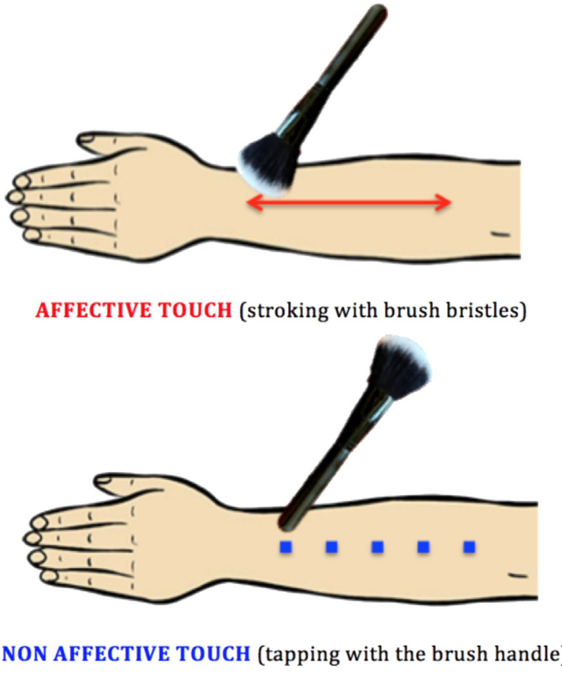


Fig. 1. Schematic representation of tactile stimulations. Affective touch comprises stroking the selected area of skin (9 cm) for 3 s, resulting in a stroking velocity of 3 cm/s. The total duration of stimulation is 15 s (5 strokes). Non-affective touch comprises rhythmic tapping on the selected area of skin (5 points, 2 cm apart) repeated three times in 15 s, resulting in a rate of approximately 1 tap per second. Note that the representation of the brush is an actual photograph of the cosmetic brush that we used in the experiment.

strokes of 3 s each were given (to keep the rate of tactile stimulation constant at 3 cm/s), whereas in the non-affective condition 1 tap per second was provided for a total of 15 taps. Of note, to cover the same skin surface area for both affective and non-affective touch, the stimulation points in the non-affective condition were about 2 cm apart (which means having 5 points on the selected area), and therefore 3 series of taps were performed for a total duration of 15 s (for a schematic representation of tactile stimulation, see Fig. 1). Different studies have used many variations of type and duration of tactile stimulation (see Cruciani et al., 2021, for a review). In the current study, we selected a medium duration of stimulation (15 s) in order to give all children enough time to tune to the stimulation without losing their attention. Note that previous studies with infants showed that similar durations of affective touch were effective in modulating physiological and visual behavioral responses (Fairhurst et al., 2014; Della Longa et al., 2021a,b).

The two types of touch were selected in the attempt to match the extent of sensory input by equating the contact area and the stimulation rate while differentiating affective value by varying both source of touch (soft brush bristles vs, wooden brush handle) and spatiotemporal dynamics of the tactile interaction (stroking vs. tapping). Based on the neurophysiological characteristics of the C-tactile system, soft and gentle dynamic stroking represents an optimal tactile stimulation for activating the C-tactile afferents, whereas tapping with a hard material is supposed to result in very scarce or no activation of C-tactile afferents. Notably, a neuroimaging study found a main effect of type of touch, indicating greater activation in the posterior insula, which is a primary neural target of C-tactile afferents, during stroking compared with tapping (Kress et al., 2011), and newborn infants seem to already be able to discriminate and modulate their physiological state in response to stroking versus tapping tactile stimulation (Della Longa et al., 2021a,b). To assess whether, at the subjective level, stroking with brush bristles (affective touch condition) was perceived as more pleasant and affective compared with tapping with the brush handle (non-affective touch condition), children were asked to rate the pleasantness of tactile stimulations on a visual analogue scale (e.g., Löken et al., 2011). The scale was designed to be easily understood by children who could freely move a slider bar presented on a touchscreen from *not pleasant at all* (−10) to *very pleasant* (+10). More specifically, because young children might not be able to translate a subjective sensory experience into a linear format (Shields et al., 2003), we used emoticons to exemplify the degree of pleasantness and explained to the children that one extremity of the scale meant ‘‘I don't like the touch at all" (sad face), whereas the opposite extremity meant ‘‘I like the touch very much" (happy face) and that they could freely move and stop the pointer in any position, meaning ‘‘I like the touch so-so." A 5-point Likert scale with emoticons has been previously used with children to evaluate tactile stimulation (see Cascio et al., 2016; Croy et al., 2019), However, in the current study, we used a child-friendly touchscreen, allowing children to stop the pointer also in intermediate positions between one face and another. Thus, the total possible scores ranged from −10 to +10 on a 20-cm linear bar (see scale representation in Fig. 2, top left). After that, we ran a brief emotion recognition task to ensure children's comprehension of emotional categories and to evaluate their ability to associate a specific emotional context with the appropriate facial expression. Specifically, six sentences, one for each of the basic emotions (happiness, surprise, fear, sadness, anger, and disgust; Ekman, 2003), were read to the children, asking them to choose which of three faces with different facial expressions was feeling that specific emotion.

Before the experimental task, children were provided with instructions and a short practice (4 trials) about how to associate geometric elements that share a common feature (same shape) but are not identical (different color). More specifically, by clicking on the touchscreen, children were asked to match a target geometric element presented at the top to one of two geometric elements presented on the bottom. This practice was included to ensure that children understood the response format and to become acquainted with the rules of the experimental task. The emotion-matching task consisted of associating the emotion of a target face with one of the two choices presented below. The task was adapted from Herba et al. (2006), using faces from the validated Dartmouth Database of Children's Faces (Dalrymple et al., 2013). A total of 24 trials were presented, grouped in blocks of 6 trials. Before each block, children were presented with tactile stimulation lasting 15 s that could be either affective or non-affective. To control for possible long-lasting effects of touch, we counterbalanced the order of the tactile stimulation, starting with the affective condition (two blocks) followed by the non-affective condition (two blocks) or vice versa. To rule out the possibility of effects related to specific

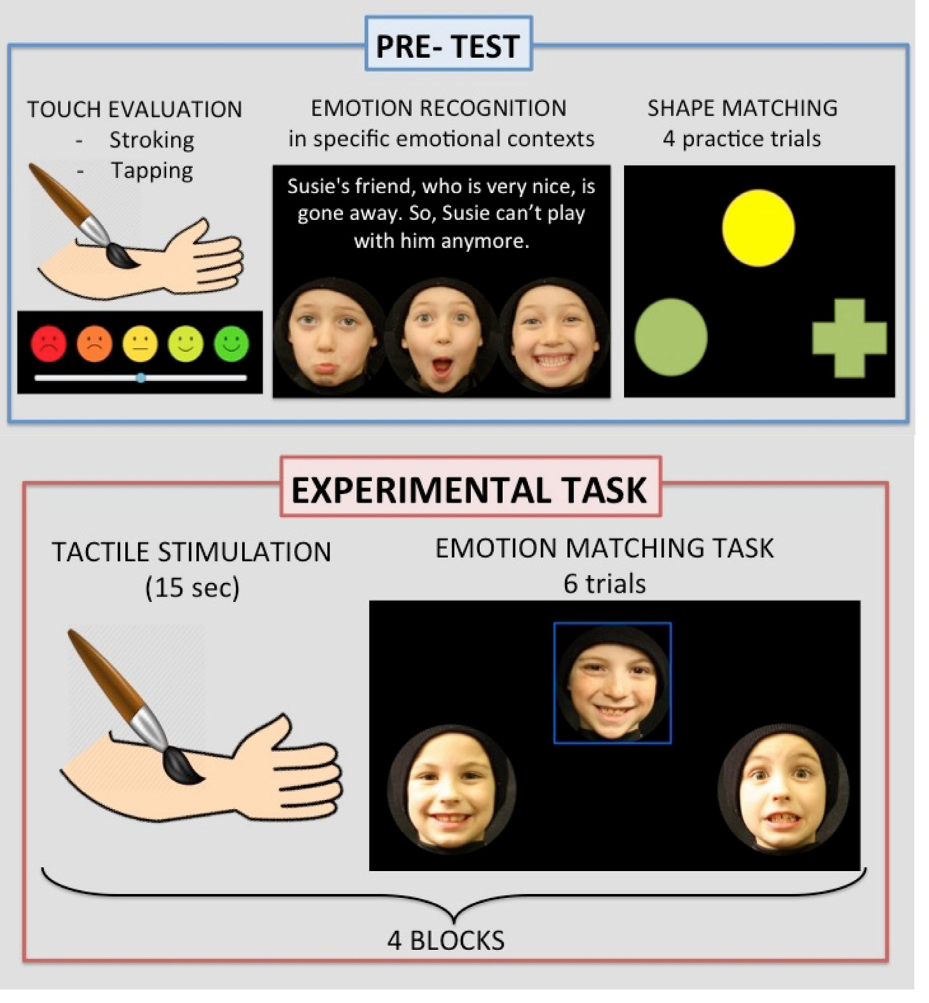


Fig. 2. Schematic representation of the experimental paradigm. In the pretest, participants were presented with a touch evaluation, emotion recognition of facial expression based on a naturalistic emotional context, and a shape matching practice. During the experimental task, participants were presented with four blocks. Each block started with a tactile stimulation lasting 15 s (either affective or non-affective touch), followed by 6 trials in which children were asked to match the target emotional face (upper face) with one of the two choices below.

combinations of faces, we counterbalanced the sets of stimuli between tactile conditions, meaning that each set of specific facial expressions was presented in association either with affective touch for some of the participants or with non-affective touch for other participants. The order of trials within each set of stimuli presented in an experimental block was randomly selected for each child. Overall, each of the six basic emotions appeared as a target stimulus twice for each child. Specifically, each emotion expression was displayed by both a model of a White girl and a model of a White boy to control for possible sex bias due to the congruence (or incongruence) between participants' sex and the model's sex (Fig. 2).

Data preprocessing and statistical analyses

As preliminary analyses, we considered the percentage of correct answers in selecting the most appropriate facial expression given a specific emotional context and the children's subjective pleasantness scores for both affective and non-affective touch. Then, we analyzed data from the emotion-matching task considering two dependent variables: accuracy and response time (RT). Before running the analyses, data from the emotion-matching task were filtered, excluding trials in which RTs were either shorter than 600 ms, meaning that the children anticipated the response before looking at all the stimuli presented, or longer than 30,000 ms, indicating that the child got distracted or made a break. A total of 42 trials among 2904 (24 trials for each of 121 participants) were excluded, corresponding to 1.5% of the observations. When analyzing RT, we included only the trials in which children provided a correct response (i.e., accuracy = 1).

All statistical analyses were performed using R, a software environment for statistical computing and graphics (R Project, n.d.). We used a model comparison approach specifying several predictors of interest for each dependent variable, and their statistical evidence was evaluated using the information criterion. Each set of models was compared through the Akaike information criterion (AIC; Akaike, 1992) and AIC weights (Wagenmakers & Farrell, 2004). More specifically, we selected the model that produced the lowest AIC value (Hooper et al., 2008) and quantified the strengths of evidence supporting this selection using its AIC weight, which can be interpreted as the probability of that model being the most plausible given the data and the set of candidate models (Wagenmakers & Farrell, 2004). Then we tested the effects predicted by the best model. Generalized mixed-effect models were employed to account for the repeated-measure design of the experiment (i.e., trials nested within participants; Hooper et al., 2008). Specifically we used the *glmer* function from the "lme4" package (Bates et al., 2015), and *p* values were also calculated using the "lmerTest" package (Kuznetsova et al., 2017). We also reported the conditional R^2 (associated with fixed effects plus random effects), which was calculated using the r^2 function from the "performance" package. For each dependent variable the distribution was specified. In particular, for subjective pleasantness, we specified a Poisson distribution to account for the discrete number of possible outcomes of the dependent variable (from −10 to +10); for accuracy, we specified a binomial distribution to account for the binary nature of the dependent variable (1 = correct, 0 = incorrect); finally, for RT, we specified a gamma distribution to account for the positively skewed nature of the dependent variable. For subjective pleasantness, we considered a set of models as follows:

- Model 0 (null model): specified the hypothesis of no difference due to the independent variables and only accounted for individual variability;
- Model 1: specified the hypothesis of a touch condition effect;
- Model 2: specified the hypothesis of additive touch condition and age effects;
- Model 3: specified the hypothesis of a two-way interaction effect between touch condition and age;
- Model 4: specified the hypothesis of a two-way interaction effect between touch condition and age, with additive sex effect;
- Model 5: specified the hypothesis of a two-way interaction effect between touch condition and age and a two-way interaction effect between touch condition and sex.

For the emotion-matching task, we separately investigated whether each dependent variable (accuracy or RT) was influenced by the fixed effects of touch condition (two-level categorical factor: affective vs. non-affective touch), valence of the emotion expression (two-level categorical factor: positive [including happiness and surprise] vs. negative [including sadness, fear, anger, and disgust]), interaction between touch condition and valence of emotion, age (continuous numeric variable), sex (two-level categorical factor: female vs. male), interaction between touch condition and age, and interaction between touch condition and sex. All models accounted for the random effect of participants (i.e., interpersonal variability). We considered the eight models as follows:

- Model 0 (null model): specified the hypothesis of no difference due to the independent variables and only accounted for individual variability;
- Model 1: specified the hypothesis of a touch condition effect;
- Model 2: specified the hypothesis of additive touch condition and valence of emotion effect;
- Model 3: specified the hypothesis of a two-way interaction effect between touch condition and valence of emotion;
- Model 4: specified the hypothesis of a two-way interaction effect between touch condition and valence of emotion, with additive age effect;
- Model 5: specified the hypothesis of a two-way interaction effect between touch condition and valence of emotion, with additive age and sex effects;
- Model 6: specified the hypothesis of a two-way interaction effect between touch condition and valence of emotion and a two-way interaction effect between touch condition and age, with additive sex effect;
- Model 7: specified the hypothesis of three two-way interaction effects between touch condition and valence of emotion, age, and sex, respectively.

For further information about analyses on specific emotions, see the online supplementary material.

Results

Preliminary analyses: Emotion recognition and touch evaluation

To measure whether preschool children are able to recognize the most appropriate facial expression given a specific emotional context, we calculated the percentage of correct answers to six scenarios (one for each basic emotion). Results revealed that children performed on average better than chance (63%, *SD* = 24), with some emotion-related differences (see Table 1). For each emotional context, we provided three alternative facial expressions; thus, the chance level was set at 33.3%.

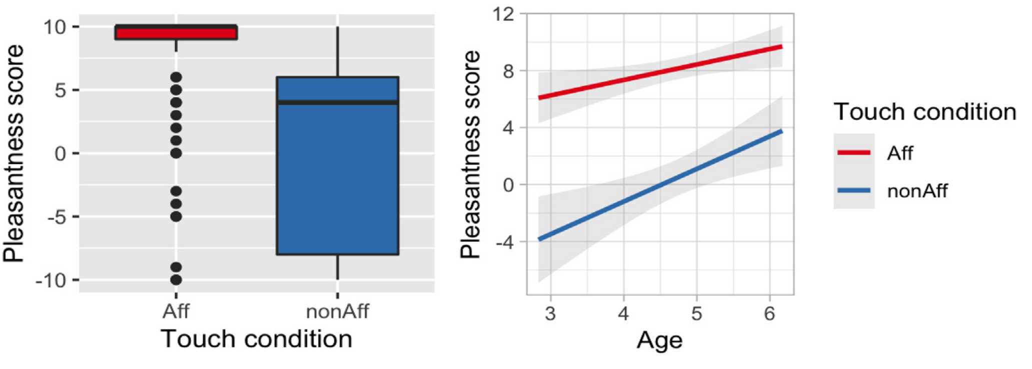
To analyze children's subjective pleasantness to tactile stimulation, we compared a set of six nested mixed-effect models as described in the "Statistical analyses" section above. According to the likelihood ratio test, the best-fitting model was Model 3 (AIC = 1910.9, ΔAIC = 14.16, R^2 = .698, χ^2 = 16.15, $p < .001$; for details on model comparison, see Table S1 in the supplementary material). A main effect of touch condition emerged ($B = -1.34$, $SE = 0.20$, $Z = -6.70$, $p < .001$), indicating higher pleasantness scores for the affective touch condition. A significant interaction effect between touch condition and age ($B = 0.16$, $SE = 0.04$, $Z = 4.02$, $p < .001$) suggested that whereas all children reported high scores of pleasantness for affective touch, younger children reported non-affective touch as more unpleasant compared with older children (Fig. 3).

Emotion-matching task: Accuracy

To analyze children's accuracy in matching faces expressing the same emotion, we compared a set of six nested mixed-effect models as described in the "Statistical analyses" section. According to the likelihood ratio test, the best-fitting model was Model 5 (AIC = 2977.6, ΔAIC = 2.87, χ^2 = 4.87, R^2 = .119, $p = .027$; for details on model comparison, see Table S2 in supplementary material). A main effect of touch condition emerged ($B = -0.39$, $SE = 0.11$, $Z = -3.49$, $p < .001$), indicating higher accuracy

Table 1
Descriptives of children's performance in recognizing the most appropriate facial expression given a specific emotional context

	Happiness	Sadness	Anger	Fear	Surprise	Disgust
Correct answers	96	89	87	63	62	61
Errors	25	32	34	58	59	60
Percentage of accuracy	76%	73%	72%	52%	51%	51%



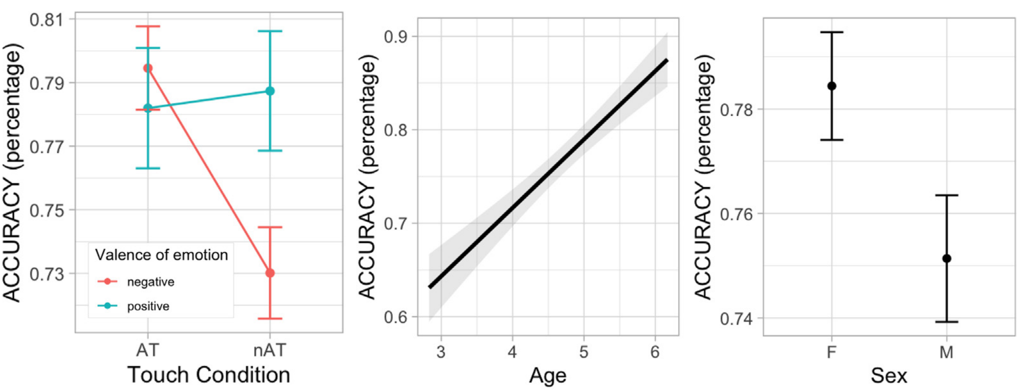
a b

Fig. 3. (A) Boxplot of pleasantness scores illustrating the main effect of touch. Central lines in the boxplots represent the median, upper and lower limits of the boxes represent the interquartile range, and the whiskers extend to the upper and lower extreme scores. Scores that are distant from other observations (outside 1.5 times the interquartile range) are represented as single data points. (B) Interaction effect between touch condition and age, indicating that pleasantness scores for non-affective (nonAff) touch increased more across early childhood compared with pleasantness scores for affective (Aff) touch.

for the affective touch condition. The significant interaction effect between touch condition and valence of emotion (B = 0.43, SE = 0.20, Z = 2.19, p < .028) suggested that children perform the worst in recognizing negative emotion expressions in the non-affective touch condition. Finally, main effects of age (B = 0.45, SE = 0.07, Z = 6.06, p < .001) and sex (B = −0.29, SE = 0.13, Z = −2.23, p = .026) also emerged, indicating that older children performed better than younger children and girls reported higher scores of accuracy compared with boys (Fig. 4).

Emotion-matching task: RTs

To analyze children's speed in matching emotion expressions, we compared a set of models including the same factors used to analyze accuracy scores. According to the likelihood ratio test, the



a b c

Fig. 4. Plots of the effects predicting accuracy. Dots represent the mean values, and bars represent the standard errors. (A) Interaction effect between touch condition and valence of emotion, indicating that accuracy of negative emotions increased in the affective touch (AT) condition compared with non-affective touch (nAT) condition. (B) Main effect of age, indicating that accuracy gradually increased with increasing age. (C) Main effect of sex, suggesting that female participants were more accurate than male participants. F, female; M, male.

best-fitting model was Model 6 (AIC = 9703.1, ΔAIC = 2.49, χ^2 = 4.494, R^2 = .008, p < .034; for details on model comparison see Table S3 in supplementary material). A main effect of valence of emotion emerged (B = 0.018, SE = 0.005, Z = 3.78, p < .001), indicating that children were faster in associating facial expression with positive valence compared with negative valence. The significant interaction effect between touch condition and valence of emotion (B = −0.018, SE = 0.006, Z = −2.85, p = .004) suggested that children were particularly fast in recognizing positive emotion expressions in the affective touch condition. Finally, a main effect of age (B = 0.024, SE = 0.006, Z = 4.12, p < .001) and an interaction effect between age and touch condition (B = −0.007, SE = 0.003, Z = −2.12, p = .034) emerged, indicating that overall older children were faster than younger children in the emotion n recognition task, in particular for the affective touch condition (Fig. 5).

Discussion

The current study shows evidence in support of the importance of affective touch to the way preschool children recognize and make sense of emotion facial expressions. Although the neurophysiological characteristics and positive hedonic valence of affective touch have been widely described as well as its central involvement in social affiliation since infancy (see Löken et al., 2009; Morrison et al., 2010; Walker & McGlone, 2013), less is known about the potential role of affective touch in promoting socioemotional and cognitive processing across early childhood. For the first time, we present evidence that tactile information modulates children's perceptual processing of facial expressions, facilitating recognition and comparison of emotions, which represents a vital prerequisite for the understanding of others' feelings and intentions to regulate their own behavior accordingly.

More specifically, we found that children clearly differentiate affective and non-affective touch at the level of perceived hedonic value, reporting higher scores of pleasantness for caress-like touch (affective touch) compared with rhythmic tapping (non-affective touch). An interaction effect between touch condition and age emerged, indicating that younger children reported lower scores of pleasantness, especially for the non-affective touch condition. These results could be explained by the fact that younger children tend to provide extreme values to the tactile stimulations, dichotomously distinguishing between positive and negative ratings (i.e., "I really like it" vs. "I don't like it so much"),

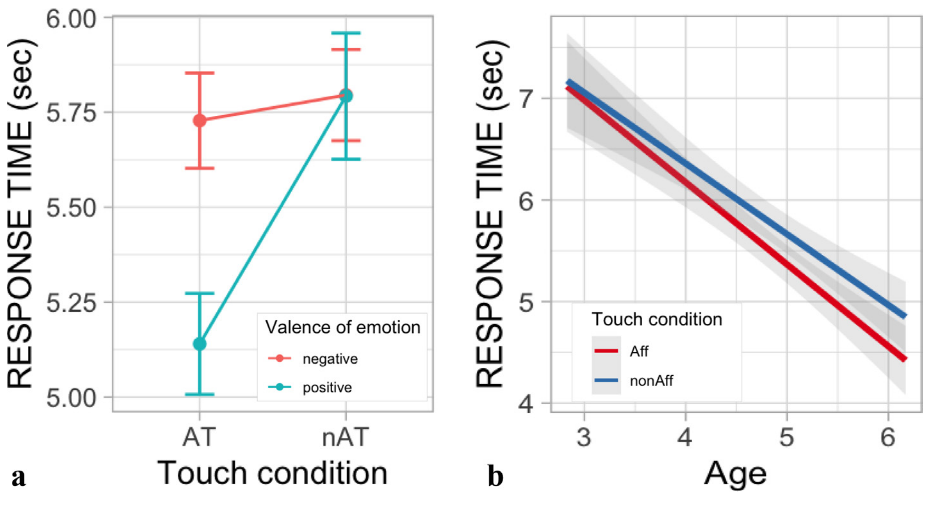


Fig. 5. Plots of the effects predicting response time. Dots represent the mean values, and bars represent the standard errors. (A) Interaction effect between touch condition and valence of emotion, indicating that positive emotions were associated faster in the affective touch (AT) condition compared with the non-affective touch (nAT) condition. (B) Interaction effect between age and touch condition, suggesting that with increasing age children become faster in providing responses, particularly in the affective touch (Aff) condition.

whereas older children were more prone to attribute intermediate values also, indicating a neutral valence of the tapping stimulation. Notably, in looking at the inter-individual variability, scores of pleasantness in the affective touch condition showed less variability, suggesting that affective touch was consistently reported as highly pleasant by nearly all participants, whereas individual scores were much more variable for the non-affective touch condition, suggesting that this specific type of tactile stimulation was perceived more variably among participants. Overall, our preliminary findings indicate that the tactile stimulations presented in the task were differently evaluated by preschool-age children in terms of pleasantness. This result is in line with previous studies showing a consistent relation between tactile stimulation targeting the C-tactile system and subjective scores of pleasantness (Löken et al., 2009), suggesting that humans prefer affective touch over non-affective touch from early childhood to adulthood (Croy et al., 2019).

Coming to the main results of the current study, we analyzed children's ability to associate different face identities expressing the same emotion, which indicates accurate decoding of emotional expressions, by considering both the accuracy and the speed of association in the emotion-matching task. Analyses of accuracy scores revealed that children are more accurate in recognizing emotional expressions in the affective touch condition, and this advantage is particularly evident for negative emotions, which are typically scarcely discriminated during early childhood. In fact, in the non-affective touch condition, children poorly recognized negative emotion expressions compared with positive emotion expressions, showing a pattern of performance similar to previous studies that did not include tactile stimulations and consistently reported happiness as the first emotion to be accurately recognized (Gao & Maurer, 2010; Herba et al., 2006; Rodger et al., 2015; Widen & Russell, 2003). However, in the affective touch condition this gap was filled, with children showing accurate recognition of both positive and negative expressions. More specifically, we observed a particular increase in accuracy scores in the affective touch condition compared with the non-affective touch condition for the emotions of anger, disgust, and fear (see supplementary material). For the first time, our results indicate that providing tactile stimulation that is thought to be optimal for activating the C-tactile system can modulate children's accuracy in recognizing and matching emotional facial expressions, increasing the discrimination of negative expressions to the level of positive expressions. Considering the speed of association, we found that children were particularly fast in matching positive emotion expressions in the affective touch condition. Whereas in the non-affective touch condition we observed similar RTs for both positive and negative expressions, in the affective touch condition children were significantly faster in matching positive emotional expressions. This advantage in terms of RT during the affective touch condition compared with the non-affective touch condition was particularly evident for facial expressions of surprise (see supplementary material). Taken together, these findings support previous empirical evidence for existing asymmetries in the way children process positive versus negative facial expressions (Kauschke et al., 2019) and indicate that affective touch is more than a positive cue that enhances the salience of congruent positive facial expressions given that it modulates the processing of both positive and negative facial expression in diverse manners. An alternative possibility is that affective touch enhances processing of more ambiguous emotions. According to previous evidence suggesting that young children distinguish facial expressions into two broad categories ("feeling good" and "feeling bad") before being able to accurately discriminate specific emotions (Widen, 2013), happiness and sadness may represent the most prototypical facial expressions on the continuum from positive to negative feelings. For these two emotions, children showed high accuracy and speed of processing irrespective of the tactile condition, whereas other emotions benefitted the most from the affective touch condition. More specifically, anger, fear, and disgust were associated with higher accuracy in the affective condition compared with the non-affective condition, whereas surprise expressions benefitted in terms of speed of association. The prominent effect of different types of touch in modulating the speed of association for the emotion of surprise deserves particular attention. Indeed, this emotion has been defined as ambiguously valenced because it could assume either a positive or negative valence depending on contextual factors (Neta & Kim, 2022). We can speculate that tactile stimulation offers a sensory framework that may modulate emotion evaluation, particularly in case of more ambiguous emotions. In this sense, expressions of surprise may assume a different valence according to the sensory information provided through tactile sensation and thus may be more affected by the type of touch. Further investigation is needed to better understand whether affective touch may have a role in promoting the processing of specific emotion categories more than others and what neurophysiological mechanisms may differentiate such differences in terms of accuracy and speed of processing.

These results are unlikely to be related to specific pairs of faces used in the task given that we made sure to counterbalance the sets of stimuli between tactile conditions, meaning that each set of specific facial expressions was presented in association either with affective touch for some of the participants or with non-affective touch for other participants. Thus, the effects that we observed are arguably due to tactile information, which were shown to be effective in modulating emotion facial expression processing. In particular, the current results point to a specific role of affective touch rather than a more general effect of tactile stimulation per se. Indeed, children showed a modulation of responses when they were provided with affective touch targeting the C-tactile system, but not when they perceived a neutral non-affective touch. It is possible to speculate that affective touch provides sensory information that carries emotional and social relevance and activates brain networks that enable our interactions with others by increasing sensitivity to their emotions and thoughts (Brauer et al., 2016). In this sense, affective touch may represent an important socioaffective sensory cue, which can tune children to better recognize and associate emotion facial expressions. In fact, emotions are characterized by a complex pattern of expressive, behavioral, physiological, and subjective feeling responses. Activation of one component might automatically activate other components, facilitating the processing of emotional information (Wood et al., 2016). Thus, affective touch may induce an affective state in oneself that provides an essential basis for inferring the emotions underlying the facial expressions expressed by others. In an embodied perspective, body representations and internal feelings are crucially involved when making emotional judgments as we vicariously activate somatosensory representations and internal body states to simulate and eventually understand how others feel (Niedenthal, 2007; Schirmer & Adolphs, 2017). Tactile information has a privileged role in evoking bodily sensations due to its interoceptive quality, which may foster the mutual influence between body responses and cognitive processing, both contributing to the understanding of others' emotions. Indeed, in contrast to other sensory modalities, the perception of touch requires direct physical contact eliciting fairly immediate bodily responses that carry simple affective qualities, which are likely to increase the emotional significance of other contextual information, such as facial expressions (Schirmer & Adolphs, 2017). Although this interpretation in terms of emotional attunement is intriguing, we cannot exclude that affective touch may have a more general effect on cognitive and executive skills. Indeed, an alternative explanation is that affective touch leads to a positive affective state and this specific state facilitates flexibility and reasoning skills. Future research should better clarify this possibility by testing the potential role of affective touch in modulating performance in cognitive and problem-solving tasks that do not involve emotional processing.

As expected, for both measures of accuracy and RT, an effect of age emerged, indicating that emotion recognition abilities are still developing across preschool age. Notably, when considering RT, an interaction effect between age and touch condition emerged, suggesting that with increasing age children's response times tend to decrease more for the affective touch condition compared with the non-affective touch condition. In line with studies indicating a female advantage in emotion related tasks (Lawrence et al., 2015; McClure, 2000; Wang et al., 2019), our results suggest that overall females are more accurate than males in matching emotion facial expressions, whereas no differences emerged in terms of speed of association. It is worth mentioning that no sex differences in perceived tactile pleasantness and no interaction effects between sex and tactile condition in the emotion-matching task emerged, suggesting that female and male preschool-aged participants showed a similar sensitivity to affective touch and that the female advantage in emotion processing is unlikely to be related to or modulated by affective touch perception. A meta-analysis on sex differences in the pleasantness perceived during affective touch showed evidence in support of a sex asymmetry, with adult females showing higher pleasantness ratings compared with adult males (Russo et al., 2020), whereas no sex differences emerged in the developmental population (Croy et al., 2019). The inconsistency of results and the limited number of studies conducted in children suggest the need for future research to take a developmental perspective in the investigation of sex differences across different sensory domains of emotional and socioaffective processing.

The current findings have important educational and clinical applications, paving the way for an innovative and multidimensional approach to typical and atypical development of socioemotional skills, which should aim to integrate sensory, cognitive, and affective aspects of emotion processing. A number of neurodevelopmental disorders (NDDs), such as autism spectrum disorder (Shanok et al., 2019), attention deficit/hyperactivity disorder (Maire et al., 2019), and developmental language disorder (Operto et al., 2020), entail concurrent poor ability to recognize emotion facial expressions, which may be related to socioemotional difficulties (Löytömäki et al., 2020; Yeung, 2022). Even in the absence of diagnosed NDDs, for multiple and diverse reasons, children may present socioemotional vulnerabilities that expose them to the risk for the emergence of social and behavioral problems in later development. For example, it has been shown that children born preterm have difficulties in decoding emotions of individuals in a naturalistic social interaction, particularly showing poor ability in processing nonverbal emotional cues from faces and bodies (Della Longa et al., 2022; Williamson & Jakobson, 2014). At the individual level, the ability to identify emotions was related to the number of autistic traits in preterm children (Williamson & Jakobson, 2014), suggesting that emotion processing is a key component of social and behavioral functioning. Notably, parenting also has a crucial effect on children's emotion processing; exposure to early adversity and abnormal affect behaviors from parents has been shown to interfere with children's ability to learn affective cues (Kujawa et al., 2014; Paine et al., 2023). On the contrary, warm parenting is positively associated with children's ability to recognize emotions showing a favorable influence on adopted children's mental health (Paine et al., 2023). This might be related to the fact that warm parents engage more in face-to-face interactions with their children. In addition, the frequency of maternal affective touch in ecological play situations positively predicts attention to faces (Reece et al., 2016) and increased connectivity in brain regions relevant for emotional and social processing (Brauer et al., 2016), suggesting that affective touch has the makings of a successful tool for promoting emotion recognition and socioaffective functioning throughout development. Results of the current study offer further support to a promising role of affective touch in emotion-focused interventions. Indeed, children with particular vulnerability in emotional and social processing may particularly benefit from multidimensional interventions that include tactile stimulations as an additional channel that activates socioemotional brain circuits, promotes physiological regulation, and converges information into a holistic understanding of another's feelings (Schirmer & Adolphs, 2017). In support of this approach, it has been shown that massage and social touch reduce autistic children's anxiety, improve sensory responses, self-regulatory abilities, and social communication, and facilitate the formation of social bounds with their parents (Lee et al., 2011; Silva et al., 2015; Walaszek et al., 2017).

Limits and future perspectives

The current study has some limitations that need to be addressed. From a methodological perspective, the use of a forced-choice procedure using a particular grouping of facial expressions may affect children's responses; previous evidence indicated how response alternatives affect children's ability to distinguish and recognize among facial expressions (Gao & Maurer, 2010). However, in our study all children were presented with the same trials but in a counterbalanced order, meaning that a specific set of trials was presented in both the affective and non-affective conditions across participants, excluding the possibility that our results regarding the contribution of tactile stimulations were affected by the specific combination of facial expressions presented. It is important to note that although the experimental sessions took place in a child-friendly and familiar environment (children's own school), the testing conditions (e.g., static images of faces, request to associate emotion facial expressions, tactile stimulation delivered with a brush) may lack ecological validity. Indeed, in everyday life facial expressions are dynamic and accompanied by other cues that co-occur to define a specific emotional context (e.g., voice, body posture), and tactile interactions may assume different significance according to the socioemotional context. To limit possible top-down influences of being touched by a stranger, for all participant stimulation we used an object (brush) instead of direct physical contact. Beyond limitation of experimental procedure, our results point to the importance of multisensory integration underling the need to better explore children's emotion recognition capacities in a complex ecological environment to assess their ability to combine and use signals from different sensory channels to make sense of the emotional context and understand others' feelings. Importantly, in everyday life children interact with a multitude of people who can be peers or not, familiar or unfamiliar. When processing others' emotions, they need to account for, and might be influenced by, other contextual factors, for instance, who the person expressing specific emotions is. Relatedly, one could wonder whether the effect of affective touch on emotion processing could be influenced by being familiar with facial stimuli expressing emotions. To address our research questions, we used faces of unfamiliar children around the same age as our participants, but future research should consider expanding on familiar and unfamiliar adults' faces to explore other contextual factors that might interact and modulate the effects found in the current study. Finally, our behavioral findings should be extended, including neural and physiological measures to better understand the underlying mechanisms that support the beneficial effect of touch in emotion processing. At the neural level, affective touch, mediated by CT afferents, has been shown to activate a network of brain areas that are involved both in the processing of socioaffective value of sensory stimulation and in more broad processes of emotional understanding (Gordon et al., 2013); thus, it is possible to speculate that tactile experience may predispose the organism to encode co-occurrent socially relevant information, such as emotional facial expressions. At the physiological level, affective touch has been reported to elicit parasympathetic activity (i.e., increased vagal tone) and release of oxytocin, which may reduce stress-related responses and promote emotional and self-regulatory processes (Uvnäs Moberg & Petersson, 2022).

Conclusions

The current findings suggest the centrality of sensory experiences, and in particular affective touch, for socioemotional understanding with potential consequences in the way children establish and maintain significant social interactions. We suggested that affective touch activates interoceptive and socioemotional brain circuits, which may provide valid support in facilitating the processing of emotion facial expressions. These results pave the way for defining new interventions with children who have difficulties in decoding emotions from faces with possible consequences for social and behavioral functioning.

Author contributions

L.D.L., L.C., and T.F. discussed the project. L.D.L. designed the method and prepared the materials. L.D.L. and L.C. collected the data. L.D.L. analyzed the data. L.D.L., L.C., and T.F. discussed the results. L.D.L. prepared the manuscript. All authors reviewed the manuscript and approved the final version of the manuscript.

Data availability

Data will be made available on request.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jecp.2023.105726.

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