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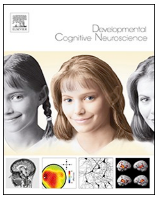

Tune to touch: Affective touch enhances learning of face identity in 4-month-old infants

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ABSTRACT

Touch provides more than sensory input for discrimination of what is on the skin. From early in development it has a rewarding and motivational value, which may reflect an evolutionary mechanism that promotes learning and affiliative bonding. In the present study we investigated whether affective touch helps infants tune to social signals, such as faces. Four-month-old infants were habituated to an individual face with averted gaze, which typically does not engage infants to the same extent as direct gaze does. As in a previous study, in the absence of touch, infants did not learn the identity of this face. Critically, 4-month-old infants did learn to discriminate this face when parents provided gentle stroking, but they did not when they experienced a non-social tactile stimulation. A preliminary follow-up eye-tracking study (Supplementary material) revealed no significant difference in the visual scanning of faces between touch and no-touch conditions, suggesting that affective touch may not affect the distribution of visual attention, but that it may promote more efficient learning of facial information.

1. Introduction

The human body is completely surrounded by the skin. As our largest organ, the skin is also the first to provide us with a direct means of contact with the outside physical and social world. Beyond its role in haptic perception, touch has been shown to engage affective and motivational processes, especially during social interactions (Morrison et al., 2010). This dual purpose of touch has been associated with several types of tactile stimulations that activate different type of peripheral afferents, processed in the brain via two dissociable neural pathways (McGlone et al., 2014). In particular, *social or affective touch* has been described as a type of light and gentle touch that has been linked to a class of slow-conducting, unmyelinated fibers (the CT afferents), present only in the hairy skin of mammals (Gordon et al., 2013; Löken et al., 2009; McGlone et al., 2007; Olausson et al., 2010). The C-tactile system is tuned to slow, dynamic properties of light touch that are prominent in affective skin-to-skin contact between individuals. It has been suggested that this system has a crucial role in the integration of physiological, cognitive, and affective aspects of socially relevant tactile information, providing a foundation for affiliative behaviour (Morrison et al., 2010).

In addition, animal work suggests tactile stimulation during the postnatal period is important for emotional development and stress reactivity (Meaney et al., 1996). Classic work with infant monkeys shows that comfort through tactile contact provided by an inanimate surrogate mother plays an important role in the infant's response to fear-inducing stimuli (Harlow and Zimmermann, 1959). When a fear-inducing stimulus was presented, infant macaque monkeys showed a distinct preference for, and displayed affective behaviours towards, a cloth mother surrogate compared to a hardware-cloth cylinder (wire mother), even when both provided nursing (Harlow and Zimmermann, 1959). Studies conducted with rodents provide evidence that the frequency of maternal care behaviours, such as licking and grooming, early in life, play an important role in modifying stress reactivity (Caldji et al., 1998; Kaffman and Meaney, 2007; Liu et al., 1997; Meaney, 2001). During a period of separation from the mother, loss of active tactile stimulation inhibits secretion of growth hormone and DNA synthesis, and stimulates a neuroendocrine stress response (Kuhn and Schanberg, 1998; Levine, 2001). Interestingly, these alterations could be reversed by stroking the pups with a brush, but not by other tactile manipulations such as pinching, vestibular stimulation or limb movements (Pauk et al., 1986). Moreover, naturally occurring variation in maternal care contributes to the development of individual differences in rats' behavioural and neuroendocrinal responses to stress during adulthood (Zhang et al., 2005).

Touch is a primary mode of communication between human parents

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and infants (Stack, 2001; Field, 2010). Parents often embrace and caress their infants and use touch to communicate reassurance, affection, and to direct attention (Cascio, 2010; Stack and Muir, 1992). Consistent with animal studies, research has focused on the impact of maternal touch on human infants' emotion regulation. During a still face paradigm (Tronick et al., 1978), in which mothers interrupted reciprocal social interaction and posed with a neutral facial expression, infants spent less time gazing and smiling at their mothers, exhibited increased negative affect and showed evidence of enhanced hypothalamic–pituitary–adrenal (HPA) axis reactivity (Adamson and Frick, 2003; Provenzi et al., 2016). When adults continued to touch infants during the still face period, infants showed a decrease in the stress response (crying) as well as an increase in social attention (eye contact) and positive affect (smiles and vocalizations; Stack and Muir, 1990, 1992).

The effects that, touch manipulation have on how long infants look at their caregiver's face in the above studies, suggest that touch might also play a communicative role, in addition to regulation of arousal levels (Hertenstein, 2002). It has been hypothesized that the functional role of affective touch has broadened during evolution, from being mainly related to nurturing in mammals, to having an additional socio-emotional role, promoting social interactions and communication in humans (Olausson et al., 2010). Roggman and Woodson (1989) compared segments of play sessions when mothers touched or refrained from touching their four-month-old babies and showed that maternal touch increases attention to the mother's face. A contingent social stimulation that included touch during parent-infant interactions was a more effective reinforcer for infants' eye-contact behaviour than contingent social stimulus that did not include touch (Pelaez-Nogueras et al., 1996).

During early infancy, learning to use information provided by faces and the ability to recognize familiar faces are skills of fundamental importance for social and cognitive development; attending to faces early in life plays a crucial role in shaping the brain' circuits involved in the social brain (Johnson, 2005). Thus, in the present study, we aimed to investigate whether affective touch helps infants to tune to others' social signals, in particular by enhancing face processing and subsequent discrimination. To test this hypothesis, we built on an existing paradigm that showed that four-month-old infants recognized a face identity when this face had direct gaze, but not when it had averted gaze (Farroni et al., 2007). Previous studies demonstrated that particular ostensive cues, such as direct gaze and infant directed speech, enhance social information processing. For example, infants followed the adult's gaze toward an object more frequently when gaze shifts were preceded by ostensive cues (Sensu and Cribra, 2008). In the present study, we hypothesized that affective touch may also act as an ostensive cue and promote better processing of concurrent social information. Specifically, we predicted that, when accompanied by affective touch as compared to in the absence of touch, infants will show learning of a face with averted gaze. In addition, we compared the touch provided by parent with a rhythmic tapping by a paintbrush in order to investigate whether affective touch has a particular social affective-motivational value rather than being a general attentional cue. To maximize the social influence of affective touch we use parents' stroking, as it is a familiar tactile stimulus for infants.

In a follow-up eye-tracking experiment (see SOM) we measured infants' attention distribution to the face with the aim of seeing whether the potential beneficial effects of affective touch are mediated by changes in facial scanning and in particular whether touch increased attention to the eyes, known to improve face recognition (Gliga and Csibra, 2007).

2. Methods

2.1. Participants

The study was conducted at the Paediatric Unit of the Hospital of Monfalcone (GO – Italy), where all infants were born. Forty-eight infants (21 female and 27 male) aged between 119 and 146 days (mean age 132 days) at time of test, took part in the study, with 16 infants in each condition. Ten additional infants participated but were excluded due to fussiness (n = 5), or a strong side bias (i.e. they oriented more than 85% of the time to the same side, n = 5). All infants were Caucasian and all of them met the screening criteria for normal delivery: birth weight > 2500 g, gestational age > 37 weeks and Apgar score ≥ 8 at 5 min after birth. No abnormalities were present at birth. Testing took place when babies were awake and alert. Parents were informed about the procedure and we obtained informed consent for their child's participation. The local Ethical Committee of Psychology Research (University of Padua) approved the study protocol.

2.2. Stimuli

Infants were presented with colourful photographs of female faces with averted gaze. In both parts of the study two faces were displayed side by side (Fig. 1). During the *habituation phase* the infants viewed two pictures of the same face, one on the right and one on the left of the centre of the screen, whereas during the *test phase* two different identity

Fig. 1. Example of the stimuli used in the experiment: a. Habituation period; b. Preference test.

faces, the familiar face and a novel one, were presented. Two face identities were used, both of them were images of Caucasian females faces with brown hair and dark eyes and a neutral expression. The stimuli presented were the same used in the previous study of Farroni et al. (2007). Which face identity was used during the habituation and the direction of the gaze (left or right) were counterbalanced across infants. The two identical faces subtended a visual angle of 18.4° and 21.4° each. In all of the stimuli, the pupil was 1 cm in diameter and the pairs of faces were 13.3 cm apart.

2.3. Procedure

Infants sat in an infant car seat 50 cm from a computer monitor. The screen was inclined to be parallel to the infants' face in order to allow for a better view. Infant eye level was aligned with the centre of the screen and infants' gaze was recorded using a video camera mounted above the monitor and centred on the infant's face. An experimenter monitored infant's gaze so that when she oriented to the screen, the habituation phase started. The lighting in the room was set to a low intensity to optimize the luminance. Determining the optimal amount of exposure to the stimuli for each individual infant is of fundamental importance because in early infancy there is a high individual variability in the looking time required to encode the familiarized stimulus (Houston-Price and Nakai, 2004). We therefore used an infant-controlled habituation to determine the optimal habituation time for each infant. An experimenter situated behind a curtain and looking towards the baby though a hole positioned at the level of the top of the screen, coded on line the infant's looking direction by holding down the buttons of two joysticks (one for the left looks and one for right looks). The button was released when the infant looked away from the screen. These presses were inputted to a software that calculated online when the infant reached a habituation criterion, i.e. when, from the fourth look on, the sum of any three consecutive looks (left or right) was 50% or less than the total of the first three looks. Once the infant had been habituated, the first test trial was shown, after a short attention getting stimulus, a cartoon accompanied with a sound (1 s). The test phase differed from the habituation phase in that different stimuli were presented on the right (e.g. the habituation stimulus) and one to the left side of the screen (e.g. the novel stimulus), their position being counterbalanced in the second test trial. The trial order was randomized between participants. Looking direction was coded on-line, in the same manner as for the habituation period. The images remained on the screen until the baby had looked at the stimuli for at least 20 s of cumulative looking time and at least 2 s towards each side. After reaching these criteria, the images disappeared from the screen when the baby looked away from the monitor for more than 2 consecutive seconds. Two expert experimenters conducted online coding. Although the experimenters were not blind to the touch condition, they were not aware of the position of the novel/familiar face presented to the baby, as they directly faced the baby while the baby was looking at the screen.

The tactile stimulation was administered only during the habituation period. There were three different between-subjects conditions: *No touch, Affective touch* and *Brush touch.* In the *No touch* condition infants were presented the habituation stimuli without any tactile stimulation (replicating Farroni et al., 2007). During the *Affective touch* condition the parents (all mothers) were asked to gentle stroke the baby's forehead while he or she was looking at the screen. To enhance the ecological validity, we did not use a standardized tactile stimulation, rather we asked parents to touch lightly and slowly their baby's forehead in the most natural way. During the *Brush touch* condition an experimenter rhythmically touched the infant's forehead with a soft paintbrush, at a slow pace kept consistent across infants. As we intended to isolate the affective-motivational valence of significant interpersonal touch, the two tactile conditions were both dynamic gentle tactile stimulations but they differed in many parameters that typically differentiate social versus non-social touch (temperature, texture, stroking vs. tapping). The parent and the experimenter who performed the touch were seated behind the infant therefore it was not possible for the infant to see their face or the source of the touch (hand or brush) during the habituation. Each infant was randomly assigned to one of these three conditions. The between-subject design was chosen to avoid infant fatigue and possible long-lasting effects of the touch condition on learning mechanisms.

2.4. Data analysis

Looking behaviour toward the stimuli were recorded as dependent measures for each infant and the total cumulative looking times to the left and right of the screen were calculated across the conditions. Given that the looking behaviour was coded on-line using two joysticks, a second experimenter performed an off-line coding of a subgroup (26 subjects, 54.2% of the total sample), using the software MANGOLD interact14. The Pearson Correlation between on line and off line coding was found to be high ($r = 0.86$, $p < 0.001$). Given this high correlation and given that on-line coding allowed the experimenter to adjust to changes in infant's position, which was not possible when recording the child's face on the camera, we decided to use the online coding for analysis. Note that the final results remain the same when considering the subset of off line coded data [one sample *t*-test: Touch condition $t(5) = 3.842$, $p = 0.012$; No touch condition $t(8) = -0.883$, $p = 0.403$; Brush condition $t(10) = 0.569$, $p = 0.582$].

3. Results

3.1. Habituation time

Habituation looking times were calculated as the cumulative time that the babies spent looking to both faces presented during the habituation period (Fig. 2). Infants looked at the screen for an average of 82.03 ($SD = 37.12$), in the Affective Touch condition, 70.37 ($SD = 41.33$) in the No touch condition, and 57.90 ($SD = 30.93$) in the Brush touch condition (Fig. 2). Data was normality distributed in all three conditions (Kolmogorov-Smirnov, all $p > 0.05$), and one-way ANOVA yielded no significant difference in the time to reach the habituation between groups ($F(2,45) = 1.73$; $p = 0.189$, $\eta^2 = 0.071$).

3.2. Test trials

We first calculated the total amount of time spent looking at the stimuli in the test trials (familiar + novel). Infants looked at the screen for an average of 52.85 s ($SD = 15.70$), in the Affective Touch condition, 47.38 s ($SD = 17.91$) in the No touch condition and 48.40 s (SD

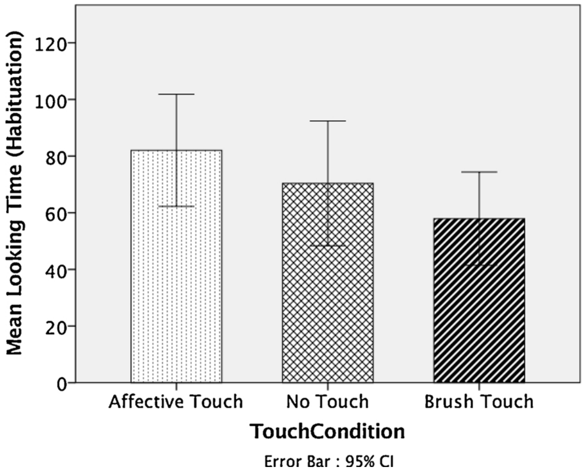

Fig. 2. Mean looking time (seconds) at the screen during habituation, across the three touch conditions.

Table 1
Mean total looking time to the familiarized stimulus and the new stimulus during test.

Touch Condition	Stimuli	Mean	SD	Percentage Looking at Novel face (SD)
Affective touch N = 16	Familiar	21.52 s	10.34	59.94 (12.60)
	Novel	31.34 s	10.63	
No touch N = 16	Familiar	23.95 s	10.40	49.67 (8.45)
	Novel	23.43 s	9.42	
Paintbrush touch N = 16	Familiar	23.30 s	9.43	49.28 (14.65)
	Novel	25.09 s	18.60	

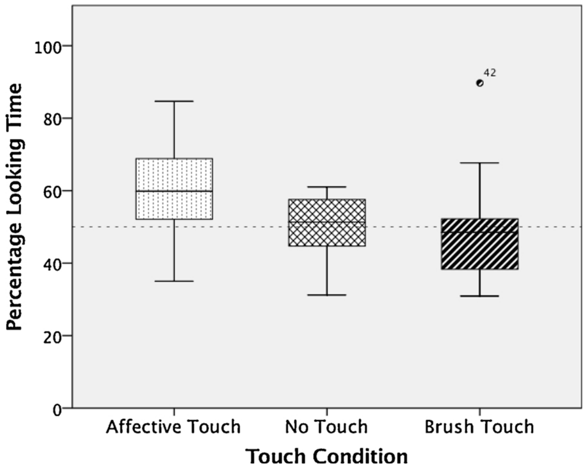

Fig. 3. Percentage looking time to the novel face in the three touch conditions. Central lines in the box plots represent the median, upper and lower limits of the boxes represent the interquartile range and the whiskers extend to the upper and lower extreme scores. One outlier (+2.76 DS) is represented for the Brush condition. The dashed line indicates chance level.

18.40) in the Brush touch condition. The Kolmogorov-Smirnov test revealed that in our sample data were not normally distributed, so we carried out our analysis using non-parametric statistics. A Kruskal-Wallis test yielded no significant difference among conditions, $H(2) = 3.456$, $p = 0.178$.

We then calculated the percentage of time spent looking at the novel face over the time spent looking at both faces (a novelty preference score, Table 1 and Fig. 3). After verifying the normality of the distribution in the three conditions (Kolmogorov-Smirnov, all $p > 0.05$) and the equality of variances (Levene test, $F(2,45) = 0.63$, $p = 0.537$), we performed three one sample *t*-tests in order to test whether the time spent looking at the novel face differed from the chance level (50%). Only in the Affective touch condition infants looked at the novel face more than the chance level ($t(15) = 3.157$, $p = 0.007$, $d = 0.789$), whereas the time spent looking at the novel face was not different from chance in the No touch ($t(15) = -0.155$, $p = 0.879$, $d = 0.004$) and Brush touch conditions ($t(15) = -0.198$, $p = 0.846$, $d = 0.049$).

A Kruskal-Wallis test comparing the three touch conditions yielded a significant effect of touch, $H(2) = 8.342$, $p = 0.015$. Mann-Whitney tests were used to follow up on this main effect. A Bonferroni correction was applied and so all effects are reported at a 0.025 level of significance. Infants looked longer towards the novel face when they experienced affective touch than when they were touched with a brush ($U = 65$, $p = 0.017$, $r = 0.429$) or when no tactile stimulation was experienced ($U = 60$, $p = 0{,}010$, $r = 0.452$).

4. Discussion

In the present study, we investigated whether affective touch helps infants process and discriminate a new face, for faces that did not engage them with direct gaze, thus replicating and extending the findings of Farroni et al. (2007). As in this previous study, without any tactile stimulation, four-month-old infants habituated to a face with averted gaze looked equally to the familiarized face and to a novel face in a post-habituation test. The absence of a preference suggested that infants did not discriminate the habituated face. Critically, infants whose parents gently stroked them during the habituation period, looked longer at the new face in the paired choice test, showing evidence of having discriminated this face, despite that fact that her eyes were averted. These findings support our hypothesis that touch may act as an ostensive cue, enhancing the salience of social information. Ecological parent-infant observational studies have shown that the development of social attentional skills is supported through reinforcement from the environment, as caregivers use multimodal strategies to guide infants in the detection of relevant social information. This selectively reinforces mutual attention though co-occurring behavioural modification in parent and infant, when engaging in interaction (Nomikou et al., 2013). In particular, touch has been shown to be an effective reinforcer for infants' social engagement (Pelaez-Nogueras et al., 1996).

We found support for our hypothesis that affective touch is processed differently from general tactile stimulation: when infants were rhythmically touched with a paintbrush, they did not show a novelty preference during the subsequent paired choice test. This null effect in not due to a different extent of tactile stimulation as we attempted to match contact area and stimulation rate as closely as possible between the affective touch and the brush touch condition. Given that simply being touched does not improve face learning we propose that the social relevance of stroking has a specific role in facilitating social information processing. We cannot identify which particular dimension of touch critically differentiated affective and non affective touch, since these stimulations differed in texture (softer for the human hand), velocity (stroking vs. tapping) and temperature (warmer for the human hand), which concurrently define a unique mode of social interaction through touch. A previous fMRI study with adults demonstrated that the neural response to different types of touch (stoking vs. tapping) was modulated by the nature of tactile stimulation (direct interpersonal touch vs. tactile stimulation applied through a velvet stick). Primary and secondary somatosensory areas as well as the posterior insula responded stronger when participants were stroked with a hand rather than a velvet stick, suggesting that direct interpersonal contact is processed differently from similar soft touch applied through inanimate objects (Kress et al., 2011).

The learning effects induced by touch raise the questions of what the mediating mechanisms may be. Different studies in adults have demonstrated that the way in which faces are scanned has an important role in face learning (Mäntylä and Holm, 2006). In particular, the accuracy in a face recognition task was higher when participants were allowed to move their eyes freely over the faces during learning than when they were required to fixate on the centre of the faces, suggesting that eye gaze movements to specific facial features may be necessary for successful recognition (Henderson et al., 2005). Moreover, it was shown that individuals with good face memory directed their gaze toward the eyes more frequently and for a longer time than individuals with poor face memory (Sekiguchi, 2011). In our study, the total looking times to reach the habituation did not differ between conditions. In a follow-up eye-tracking study we also failed to find any differences in how long infants spent looking at the face or at the eyes, in an Affective touch vs. a No touch condition (see SOM). These studies suggest that the better face discrimination in the Affective touch condition is not due to a longer exposure to key facial features but rather to a qualitative difference in social information processing.

Previous evidence, including work with animal models, suggested that affective touch modulates general arousal and stress levels (e.g. Stack and Muir, 1992). It remains a question for future research to determine whether the effects of affective touch are specific to social information processing, such as faces, rather than facilitating learning of information, more generally. Based on the current evidence we can nonetheless conclude that affective touch is an important modulator of facial information processing early in life, as it appears to improve facial identity discrimination, suggesting that it has a unique affective-motivational value, which may help promote engagement in social interactions.

Conflict of Interest

None.

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.dcn.2017.11.002.

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