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Touch and look: The role of affective touch in promoting infants' attention towards complex visual scenes

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Abstract

In a complex social environment, stimuli from different sensory modalities need to be integrated to decode communicative meanings. From very early in life, infants have to combine a multitude of sensory features with social and affective attributes. Of all senses, touch constitutes a privileged channel to carry affective-motivational meanings and foster social connection. In the present study, we investigate whether sharing sensory stimulation that varies for its affective value differentially affects infants' attention towards visual stimuli. 6 to 11-month-old infants ($N = 42$) were familiarized with two characters respectively matched with tactile (affective or non-affective) and auditory stimulation; then repeatedly exposed to scenes where the two characters moved towards target objects. Our results showed a main effect of stimulation (sound vs. touch) on looking times during familiarization, with longer looking times when sound is provided. During scenes presentation, a main effect of the type of touch (affective vs. non affective) emerged, with longer looking times in infants that previously experienced affective touch, suggesting that this sensory experience may critically engage the self and modulate infant attention. Overall, these findings suggest that while sound acts as attention getter, affective touch supports sustained attention towards complex visual scenes beyond the stimulation period itself.

1 | INTRODUCTION

In neonates, touch is a cornerstone of interpersonal interactions and sensory-cognitive development crucially shaping functional aspects of the developing brain (Brauer et al., 2016). Touch not only provides a way for exploring the environment to get discriminative information, but also carries affective motivational meanings that are conveyed within social interactions. More specifically, affective touch—defined as gentle caress-like stroking—provides information from inside and outside ones' body (Fotopoulou & Tsakiris, 2017), fosters social functioning (Della Longa et al., 2019) and contributes to body awareness acquisition and the self-other distinction (Filippetti et al., 2013), with cascading effects on the development of social cognition (Della Longa et al., 2020). Affective touch represents a distinct dimension from sensory-discriminative touch, mediated by the activation of C-tactile afferents (McGlone et al., 2014). This class of low-threshold, unmyelinated afferents are present only in the hairy skin of mammals and selectively respond to dynamic gentle touch delivered between 1 and 10 cm/s within skin-like temperature (Ackerley et al., 2014). The activation of C-tactile afferents is related to subjective experiences of pleasantness (Löken et al., 2009), suggesting their involvement in the emotional and motivational facets of tactile stimulation that boost physical contact and proximity between individuals (Morrison et al., 2010). Importantly, C-tactile afferents project to the posterior insula (Björnsdotter et al., 2010), which supports the integration of sensory with affective information and contributes to an interoceptive representation of the body (Craig, 2003). Furthermore, functional coactivation of an extended network of brain regions known to be involved in social perception has been found (Morrison, 2016), suggesting that affective touch plays a central role in the formation of emotional and motivational dispositions that influence social behavior. Notably, developmental studies highlighted that the insular region is responsive to affective touch from very early in life (Jönsson et al., 2018; Tuulari et al., 2019) suggesting that affective touch might represent a crucial component of early experiences of affective sharing and social bounding.

Sensory experiences have been shown to modulate self-other representation and connection, which may be particularly powerful in the case of shared affective touch. Indeed, passively receiving a common and synchronous sensory stimulation increases a sense of affiliation and similarity between interacting individuals (Rabinowitch & Knafo-Noam, 2015; Wheatley et al., 2012). For instance, children who participated in short, synchronous rhythmic tactile interaction perceived themselves as more similar and close to their interaction partner than children who engaged in asynchronous interaction or no interaction at all, highlighting that shared synchronous tactile experience influence social attitude in childhood (Rabinowitch & Knafo-Noam, 2015). Furthermore, sharing a synchronous visual-tactile experience can even reshape self-other boundaries, as demonstrated by the well-established paradigm of the enfacement illusion. This illusion consists in the subjective experience of looking at one's own face while in fact looking at another person's face and it rises when brushing the participants' cheek while they are watching a stranger's face being brushed in a synchronous fashion (Porciello et al., 2018). Importantly, the modulation of self-other boundary extends beyond facial perception to a more conceptual merging between self and other, which affects social cognition processes (Paladino et al., 2010). Interestingly, affective touch seems to enhance the enfacement illusion (Panagiotopoulou et al., 2017). Congruently, infants showed a visual preference for another infant's face being stroked synchronously respectively with their own face (Filippetti et al., 2013, 2016) and such preference seems to be modulated by the activation of C-tactile afferents (Della Longa et al., 2020), indicating that the integration of multisensory and affective information lays the foundation for the development of a sense of bodily self and a connection with the others. An early predisposition for the integration of multisensory stimuli is evident at birth. In fact, newborns manifest an early ability to detect synchrony between visual and tactile stimuli, especially when this is related to their body (Filippetti et al., 2013). Similarly, the ability to detect synchrony between visual and tactile stimuli, especially when the visual cues are related to their bodies is evident early in infancy. For instance, 5-month-old infants stroked with a brush at a slow velocity exhibited a preference for a synchronous video, indicating that certain types of touch, such as slow stroking, facilitated their detection of body-related visuo-tactile synchrony (Della Longa et al., 2019). Affective touch has also been shown to assist in the modulation of 6- to 8-month-old infants' evasive behaviors toward people and object exploration (Tanaka et al., 2021). Relatedly, it has been suggested that the early recognition of mutual experiences and self-other correspondence in action and perception gives rise to interpreting others as having similar psychological states and emotions, which represents a starting point for social cognition and intersubjectivity (Meltzoff, 2007).

In addition to the affective and communicative dimensions of the interaction, it is important to consider the low-level sensory aspects that are crucial from the earliest stages of life and closely relate to the multisensory integration of sensorimotor contingencies. Multisensory processes include the ability to combine information from the different sensory channels in order to create accurate representation of the external stimuli, which can modulate attention towards the surrounding environment and guide behavior (Wallace, 2004). During the neonatal period, integration of lower-level physical stimulus features (such as duration, rhythm and intensity) across senses, is a first critical step for interpreting stimuli and making sense of multiple streams of information without perceiving the environment as confusing and distracting (Murray et al., 2016). Indeed, the ability to perceive sensory contingencies and detect their co-occurrence is crucial for infants to explore and learn from the external world (Köster et al., 2020). Multisensory experiences endured during the first stages of life, when the nervous system is still developing, have a broad impact on later development across multiple domains from sensory processing to higher cognitive and socio-emotional functioning (Nelson, 2000). In fact, the experience of touch, sounds, voices, smells and visual stimuli in daily contexts not only carries information about the surrounding environment per se, but is often matched with social and emotional meanings. Crucially, the social environment is by nature complex in structure and, to guide infants in the detection of relevant information, caregivers often adopt multimodal strategies, which support the development of social attentional skills (Nomikou et al., 2013). For example, the visual information infants typically receive during social exchanges (e.g., eye contact, smiling faces) is often complemented by auditory and tactile cues, which can orient and support infants' attention towards specific targets facilitating the processing of relevant information. Indeed, it has been shown that simple auditory stimuli contribute to establishing an intermediate level of arousal that enhances 6.5-month-old infants' orienting to a visual target (Kleberg et al., 2019). Interestingly, neural evidence highlights that auditory information accompanying visual stimuli not only activates auditory regions but also facilitates activation in the occipital visual regions at 3 months already, suggesting that the neural effect of multisensory information is not merely additive. Whilst some characteristics that are dictated by temporal dynamics (i.e., rhythm) can be shared by stimuli originating from multiple sensory channels, distinct sensory features might also provide specific contributions to infants development. For example, the significance of rhythmic auditory stimulation has been studied for the development of attention and language learning (Gervain, 2018; Langus et al., 2017), while tactile information satisfies the human need for social proximity and has thus been hypothesized to foster self-other connection.

In the present study, we ask whether sharing sensory stimulation coming from different channels (sound, touch) differentially affects infants' attention towards visual stimuli. We are also interested in exploring whether the affective valence of touch modulates infants' attention and ability to learn about other's preferences. More specifically, we investigated whether sharing an affective tactile experience with a character, may have a peculiar effect in connecting the self with the visual scene modulating infants attitude to follow the character movements on the screen. To achieve this goal, we compared tactile with acoustic stimulation, which is typically used in developmental studies to orient infants' attention towards the screen. Moreover, we manipulated the valence of the tactile stimulation, comparing affective and neutral tactile stimulations. We hypothesized that the effect of affective touch in modulating infants' visual behavior goes beyond a pure attention getting effect, that immediately captures infants' attention, and instead supports more complex information processing.

2 | MATERIALS AND METHODS

2.1 | Participants

Forty-two infants (24 female, 18 male) took part in the study. At the time of the test infants were aged between 5.5 and 12 months (mean = 279.7 days, SD = 43 days). The selection of this age range is supported by previous literature showing that the effect of affective touch on social stimuli processing is observable as early as 5 months of age (Della Longa et al., 2019), consistent with evidence for social specialization around 6 months of age (Johnson, 2011; Pascalis et al., 2002). The definition of 12 months as the high threshold is motivated, on the one hand, by the value of exploring the phenomenon of interest from a developmental perspective and, on the other hand, by the need for feasibility of the task itself given its online nature. Thirty-one additional infants were tested, but not included in the final sample due to stimulation being mistakenly provided by the caregiver ($N = 12$), age ($N = 9$), technical problems ($N = 5$), fussiness ($N = 2$), strong side bias (e.g., looked >90% of the time to the same side of the screen, $N = 2$), low looking (e.g., looked away from the screen >90% of the time in at least one phase of the experiment; $N = 1$). Data were collected between October 2020 and May 2021. The conduction of an online experiment during that period was necessary to directly measure the phenomenon of interest despite the period of closures due to COVID-19. On the other hand, the technical limitations and the lower control on the experimental setting led to higher rates of participant exclusion from analyses.

Inclusion criteria consisted in gestational age between 37 and 41 weeks, absence of complications during delivery and normal weight at birth (>2500 g). Parents were informed about the procedure and informed consent for their infant's participation was obtained at the beginning of the experimental session, before any assessment or data collection. All procedures involving human subjects in this study were approved by the local Ethical Committee of Psychology Research of the University of Padova (protocol n. 3758). The study was conducted according to guidelines laid down in the Declaration of Helsinki.

Recruitment took place through two main channels. Families were either contacted from the birth records of the Pediatric Unit of Monfalcone Hospital (Gorizia, Italy) where infants were born or from the Babylab database of the University of Padova.

2.2 | Stimuli and procedure

The study took place online, using Labvanced (Finger et al., 2017), when infants were awake and alert. Parents accessed the experimental session from the comfort of their houses, using a computer with an Internet connection, a webcam and Google Chrome. They were asked to sit in front of the computer, with infants sitting on their lap and the webcam framing infants' faces. The whole session was video recorded to allow offline coding of infants' looking behavior. After the informed consent was given, parents were provided with detailed audiovisual instructions on when and how to perform tactile stimulation to their infants during the task.

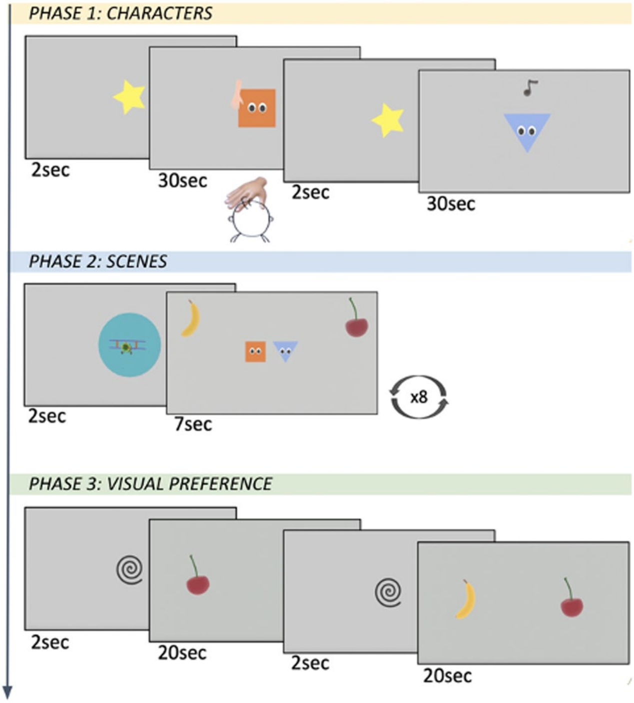

FIGURE 1 Experimental paradigm.

The experimental task consisted of three phases (see Figure 1). In the first phase infants were sequentially presented with two animated characters, a square and a triangle. Each character was presented for 30 s and the two were interspersed with a brief attention getter to ensure that the infant was looking at the center of the screen when the character appeared. One character was matched to auditory stimulation, while the other was matched to tactile stimulation. For auditory stimulation, all infants saw a moving musical note above the character while hearing a rhythmic sound. For tactile stimulation, the infant saw the character being touched by a moving hand while being touched similarly by the parent. The movement of the musical note and of the hand was matched to create a consistent rhythm across simulations. Moreover, the type of touch was manipulated as a between-subjects condition. One group of infants ($N = 21$) was exposed to a gentle caress-like stroking (affective touch), while another group of infants ($N = 21$) was presented with a gentle tapping (non-affective touch). Both tactile stimulations were provided to infants' forehead and matched for dynamic and rhythmic properties, while differing for socio-affective value (affective vs. non-affective touch). Therefore, type of stimulation is a within-subject factor (sound stimulation vs. touch stimulation) and type of touch is a between-subject factor (affective vs. non-affective touch). The order of presentation of touch and sound was counterbalanced between participants. In this first phase we ask whether infants' attention towards a character might be modulated by sharing different rhythmic sensory experiences with the same character and more specifically whether affective touch carries a specific socio-affective value that may modulate infant's subsequent attention to the actions performed by that character.

The second phase consisted of a visual presentation of scenes where the two previously seen characters moved towards two fruits (banana and cherry). Scenes were 7-s-long and were presented repeatedly for 8 times. The fruits were alternatively located in the four corners of the screen across trials, while the combination of which character reached each specific fruit remained constant across scenes in the attempt to create an association between character and fruit. This association (square vs. triangle—banana vs. cherry) was counterbalanced between participants. In this phase we explore whether infants' modulate their visual attention towards actions performed by characters with whom they have previously shared different rhythmic sensory experiences.

The third phase consisted of a paired visual preference test, with the two fruits being presented side by side for 40 s (two trials of 20 s each with exchanged position). In this last phase, we ask whether a possible preference for characters associated with different sensory experiences could be generalized to the objects that were targets of the action.

2.3 | Data analysis

Infants' looking behavior was coded offline by two independent coders using the Datavyu software, a video coding and data visualization tool for collecting behavioral data from video (Datavyu Team, 2014). Offline coding of a randomly selected subgroup of participants (10 participants, 24% of the total sample) was performed by both coders. Inter-rater reliability was found to be excellent (Hallgren, 2012). Inter-class correlation was calculated separately for the three phases: characters (ICC = 0.95), scenes (ICC = 0.88) and test (ICC = 0.93).

For the first and second phases, the percentage of looking time towards each character was calculated over the total time of stimulus presentation in order to quantify infants' visual attention towards each stimulus. For the third phase, the percentage of looking times towards each stimulus was calculated over the total looking time. This allowed us to measure a preference for a stimulus compared to the other. Descriptive statistics of these measures are reported in Table 1.

All statistical analyses were performed using *R*, a software environment for statistical computing and graphics (R Core Team, 2013). Specifically, we adopted a mixed-model approach using the “lmer” function from the “lme4” package (Bates et al., 2015). We also used “r.squaredGLMM” function from the MuMIn package (Barton, 2009) to compute marginal and conditional *R*-squared, respectively associated with fixed effects and fixed plus random effects and the “lmerTest” package (Kuznetsova et al., 2017) to compute the *p*-values. For each phase, we conducted model comparison and selected the model that best predicted our data based on the Akaike Information Criterion (AIC). The model producing the lowest AIC value was considered the most plausible (Hooper et al., 2008). Importantly, mixed models allowed us to account for fixed effects related to experimental manipulations as well as random effects, which are associated with individual units randomly drawn from population (Baayen et al., 2008; Gelman & Hill, 2006).

3 | RESULTS

We conducted separate analyses for the three experimental phases. Five nested mixed-effect models were tested for each phase. In each tested model, the dependent variable was the percentage of looking

TABLE 1 Percentage of looking times for each experimental phase (means and standard deviations). Note that tactile and auditory stimulation were only provided during the first phase. Sound and touch columns in phases two and three refer to looking times towards the character and object associated with each stimulation in phase one.

		Phase 1		Phase 2		Phase 3	
Target associated with stimulation in phase 1		**Sound**	**Touch**	**Sound**	**Touch**	**Sound**	**Touch**
Group	Affective	71.7 (22.3)	57.5 (23.6)	35.6 (8.3)	36.6 (9.2)	24.1 (11.9)	24.1 (9.7)
	Non-affective	66.3 (19.8)	48.2 (18.9)	31.6 (7.6)	30.4 (10.9)	20.7 (8.8)	23.6 (11.5)

TABLE 2 Model comparison for predicting looking time during phase 1 (characters). Note that lower AIC indicates better fitting models.

Tested models	Variables	AIC	Marginal R^2	χ^2	p
Model 0	Random effect of participants	767.19			
Model 1	+ Stimulation	754.43	0.127	14.754	<.001
Model 2	+ Group	754.44	0.151	1.993	.158
Model 3	+ Interaction stimulation *x* group	756.19	0.151	0.250	.617
Model 4	+ Age	754.45	0.194	3.739	.053

Abbreviation: AIC, Akaike Information Criterion.

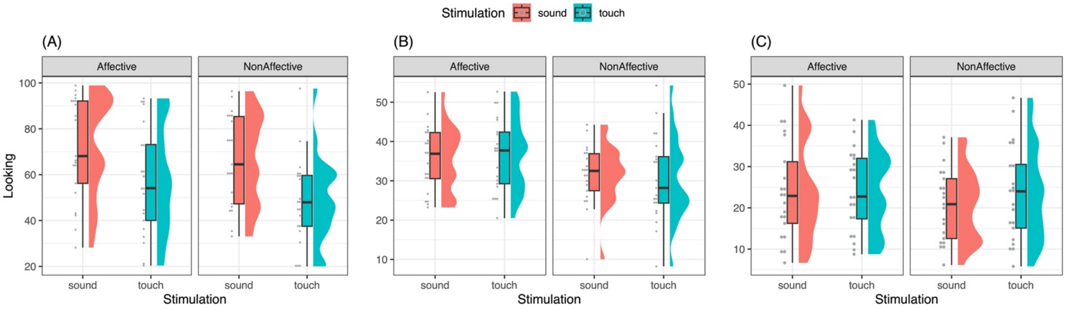

FIGURE 2 Percentages of looking times during (a) character presentation (phase 1), (b) scenes presentation (Phase 2), (c) visual preference test (Phase 3).

time. The null model (Model 0) only included the random effect of participants, subsequently we added the type of Stimulation (2 levels: sound, touch; Model 1), the Group (2 levels: affective, non-affective; Model 2), the interaction Stimulation *x* Group (Model 3), participant's Age (Model 4).

For phase 1, the likelihood ratio test showed that Model 1 was the best at predicting the collected data (Table 2, Figure 2a). The model explained 12.7% of the variance ($p < .001$). The main effect of Stimulation emerged ($t = -4.15$, SE = 3.89, $p < .001$), indicating that infants looked longer to the character when this was presented with sound, compared to touch (Figure 3a).

For phase 2, the likelihood ratio test showed that the Model 2 was the best at predicting the collected data (Table 3, Figure 2b). The model explained 7.4% of the variance ($p = .029$). The main effect of Group emerged ($t = -2.20$, SE = 2.31, $p = .034$), indicating that infants exposed to affective touch in the previous phase looked longer to scenes presentation overall, compared to infants that previously experienced non-affective touch (Figure 3b). Contrary to our hypothesis, no effect of stimulation was found in phase 2, meaning that infants did not exhibit differential attention between the two characters based on whether they shared touch or sound experiences with them.

For phase 3, the likelihood ratio test showed that the null model was the best at predicting the collected data (Table 4, Figure 2c) suggesting that infants did not manifest any visual preference for the two fruits.

4 | DISCUSSION

In our study we explored whether sharing an affective tactile experience with a character modulates infants' disposition to follow the character's actions. To control for the level of alertness and exclude a mere effect of attentional getting, we matched tactile with auditory stimulation. Moreover, we investigated the specific involvement of C-tactile afferents, by comparing affective (stroking) and

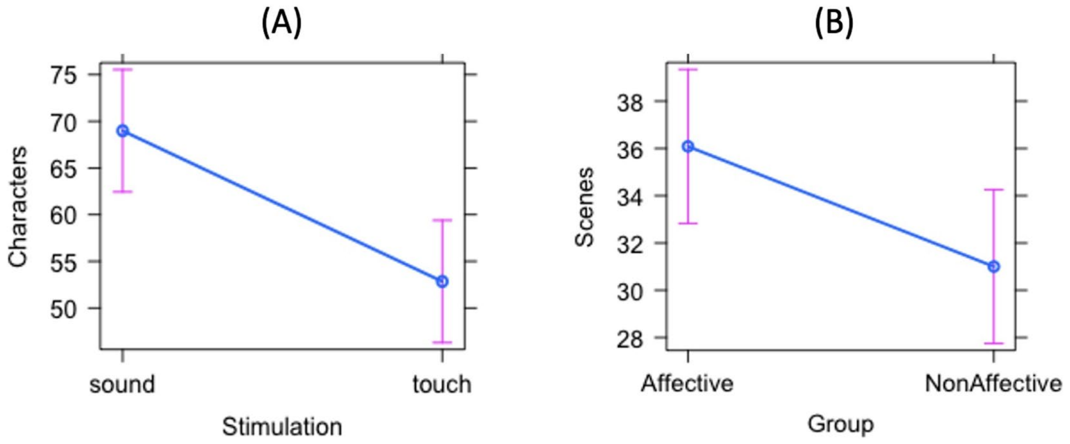

FIGURE 3 Main effect of (a) stimulation during phase 1 and of (b) group during phase 2 on looking times.

TABLE 3 Model comparison for predicting looking time during phase 2 (scenes). Note that lower AIC indicates better fitting models.

Tested models	Variables	AIC	Marginal R^2	χ^2	p
Model 0	Random effect of participants	609.60			
Model 1	+ Stimulation	611.60	0.000	0.002	.967
Model 2	+ Group	608.82	0.074	4.782	.029
Model 3	+ Interaction stimulation *x* group	610.33	0.077	0.490	.484
Model 4	+ Age	610.71	0.098	1.619	.203

Abbreviation: AIC, Akaike Information Criterion.

TABLE 4 Model comparison for predicting looking time during phase 3 (visual preference test). Note that lower AIC indicates better fitting models.

Tested models	Variables	AIC	Marginal R^2	χ^2	p
Model 0	Random effect of participants	630.14			
Model 1	+ Stimulation	631.43	0.005	0.710	.399
Model 2	+ Group	632.91	0.013	0.521	.470
Model 3	+ Interaction stimulation *x* group	634.26	0.017	0.655	.418
Model 4	+ Age	635.37	0.031	0.892	.345

Abbreviation: AIC, Akaike Information Criterion.

non-affective (tapping) touch. Tactile simulations perceived by infants on their own forehead were matched with corresponding visual information on the character on the screen.

While we predicted increased attention towards the character with whom affective touch was shared, our results showed that infants looked longer to characters when these were presented with sound rather than touch. This is however in line with previous studies showing that auditory information is an effective way to capture immediate visual attention (Muir & Field, 1979). An alternative hypothesis might be that touch acts like a distraction from the visual scene, with infants' attention being more likely to be driven away from the screen and towards their own body while they are touched. In fact, touch is an inherently bidirectional sensory modality, as when being touched we not only feel the other, but also the self (Boehme & Olausson, 2022). Although this alternative hypothesis could explain the reduced looking time to the screen during tactile stimulation compared to sound stimulation, of greater significance is the fact that the specific type of tactile interaction seems effective in modulating subsequent engagement with the surrounding environment, promoting infants' visual attention. In fact, in a second phase when neither auditory nor tactile stimulation was provided, infants who previously experienced affective touch looked longer to visual scenes they were presented with rather than the specific character with whom affective touch was shared. These results indicate that tactile stimulation does not act as a mere attentional getter, rather it predisposes infants to explore the surrounding environment and facilitates sustained attention towards complex visual scenes, even when the stimulation has been interrupted. Infants who experienced affective touch in Phase 1 presented higher looking times in Phase 2, compared to infants who experienced non-affective touch. The effect seems therefore to be specific for affective touch, suggesting a possible involvement of the C-tactile system. In line, when exploring the data from infants in the affective group only we descriptively observe that total looking times of infants who experience touch first are higher, compared to those who heard auditory stimulation first (see Supporting Information S1). We therefore suggest that affective touch operates on the scale of the entire learning episode, rather than on the specific event where the infants shared affective touch moments with the characters. The experience of affective touch might help infants to be more connected and involved in the situation, thus willing to look longer at the following visual scenes irrespectively of the specific character with whom they shared the sensory stimulation. Indeed, infants looked in a similar way to the movements of both characters previously associated respectively with touch and with sound. This indicates that they did not create a specific association between the character and the sensory experience. Consequently, in the final part, infants did not show a preference for any of the two objects presented representing the target of each character's action in the previous scenes. The absence of a preference in the last phase might alternatively indicate that infants were not able to associate the target of the character's action to the character itself.

Since attention is a multidimensional construct, we suggest that sensory stimulation provided through auditory and affective-tactile channels might contribute differently to various attentional dimensions. More specifically, sound might foster alerting processes, increasing attention on-the-moment when sound itself is presented. Affective touch, on the other hand, seems to support sustained attention processes. This takes on particular relevance when considering the complexity of stimuli that are presented without sound or touch. Indeed, affective touch appears to be effective in sustaining infants' attention towards complex scenes where multiple characters are moving, while sound and non-affective touch did not. Consistent with our results, Tanaka et al. (2021) also showed that the quantity of affective touch experienced in caregiving interaction modulated infants' attitude to explore their physical and social environment, suggesting that affective touch might predispose the organism to encode information for a more extended time window. This is also in line with previous behavioral and physiological evidence highlighting an increased visual attention to stimuli previously presented in the context of affective touch, possible supported by an increased parasympathetic activity (i.e., attenuation of heart rate) during affective touch stimulation (Della Longa et al., 2020). Relatedly, a speculation might be made in terms of which physiological mechanisms possibly underlie the diverse effect of rhythmic stimulation provided through different sensory channels. In fact, sound might elicit a sympathetic activation, as suggested by studies showing increased arousal (i.e., pupil dilation) in response to simple sounds (Kleberg et al., 2019), while tactile stimulation, and in particular affective touch, may involve a parasympathetic response. Indeed, multiple studies found that affective touch elicits an increase of vagal tone, suggesting that a socially-salient tactile information has a role in facilitating an orienting response in both adults (Ditzen et al., 2007; Pawling et al., 2017) and infants (Fairhurst et al., 2014). At the neural level, as suggested by Begus & Bonawitz., (2020), theta activity offers insights into infants' learning processes beyond behavioral measures, and parallels between adult and infant theta modulation hint at its potential role in early attention and learning. Interestingly, variations in frontal theta-band oscillations during infants' object exploration have been shown to predict subsequent recognition (Begus at el., 2015) and have been shown to be modulated by affective touch (von Mohr et al., 2018). In order to better understand the mechanisms underlying the effect of touch in promoting visual attention from early infancy, future studies should include additional measures (i.e., Heart Rate Variability, Theta-band activity) and increase the statistical power by enhancing the sample size.

4.1 | Conclusions

In conclusion, our study found that 6- to 12-month-old infants' attentive system is differentially impacted by sensory information coming from diverse sensory channels. In fact, while sound has an attention capture role, affective touch promotes sustained attention and predisposes the organism to explore a complex visual environment beyond the time of stimulation itself. We speculated that affective touch has a vital role in engaging the sense of self as part of a multisensory experience, crucially modulating the processing of co-occurrent information from other senses. The present study opens new research questions on the role of multisensory information and affective touch for infants' attention and learning.

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CONFLICT OF INTEREST STATEMENT

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. We are grateful to the infants who took part in this study and their parents for their fundamental contribution. We would like to thank the medical and nursing staff of the Pediatric Unit of the Hospital of Monfalcone for their collaboration. We are particularly grateful to Giorgia Benvenuti and Giorgia Semenzin for their help with offline video coding. The authors declare no conflicts of interest with regard to the funding source for this study.

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SUPPORTING INFORMATION

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