Caregiver mirroring as a foundation for facial feedback mechanisms in emotion perception

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Abstract

The facial feedback hypothesis suggests that facial muscle activity contributes to emotion perception, but the developmental origins of this mechanism remain underspecified. This theoretical paper argues that caregiver mirroring - specifically caregivers' contingent imitation of infant facial expressions - plays a critical role in establishing the facial feedback mechanism. Drawing on previous empirical findings, we propose that repeated episodes of being mirrored provide infants with reliable sensorimotor contingencies linking facial action, proprioceptive feedback, and emotional states. We further consider situations that impede caregiver mirroring – such as infant dummy (pacifier) use and caregiver botulinum toxin (Botox) treatment – as naturalistic perturbations of these contingencies. This paper highlights how caregiver facial mirroring may scaffold infants' developing emotion processing, offering a socially embedded perspective on the early development of embodied emotional understanding.

Keywords: caregiver mirroring, mimicry, facial feedback, emotion processing

I. Introduction

The idea that facial muscle activity shapes emotional experience has a long history in psychological theory, dating back to Charles Darwin's (1872) and William James' (1884) observations on the expression of emotion. In its modern form, the facial feedback hypothesis proposes that afferent signals arising from facial muscle activity contribute to the perception and experience of emotion (Adelmann & Zajonc, 1989; Strack et al., 1988). After a period of controversy triggered by a large-scale replication failure (Wagenmakers et al., 2016), the facial feedback hypothesis has recently regained empirical traction through more methodologically refined investigations (Baker et al., 2025; Coles et al., 2022; Efthimiou, Perusquía-Hernández, et al., 2024; Noah et al., 2018), and remains an influential framework within embodied accounts of emotion and social cognition.

Despite this renewed empirical interest, a fundamental question remains largely unaddressed: how do facial feedback mechanisms develop? The existing literature treats the link between facial muscle activity and affective states largely as a given, with little consideration of how proprioceptive signals from facial movement come to carry emotional meaning in the first place. Here we argue that the answer lies, at least in part, in early social experience. Specifically, we propose that caregiver mirroring, the contingent imitation of infants' facial expressions during early face-to-face interaction, plays a critical role in establishing the sensorimotor foundations of the facial feedback mechanism. When caregivers reliably respond to an infant's facial expression with a topographically matched expression of their own, they create a predictable social contingency: the infant's facial action is met with a visually salient, affectively congruent response. Repeated across thousands of interaction episodes, we suggest that these contingencies provide infants with the learning opportunities through which facial movement becomes associated with proprioceptive feedback, affective states, and the visual representations of others' emotional facial expressions. We thus propose that caregiver mirroring underlies the development of the facial feedback mechanism.

This theoretical paper draws on converging evidence to develop and evaluate this proposal. We begin by reviewing the facial feedback hypothesis and its current empirical support in adults, before introducing the concept of caregiver mirroring and presenting our core theoretical argument. Here we draw on sensorimotor learning accounts (Heyes, 2001; Keysers & Perrett, 2004), the social biofeedback model (Gergely & Watson, 1996), and prior empirical findings linking maternal mirroring to infants' responses to others' facial expressions (de Klerk et al., 2019; Murray et al., 2016, 2018; Rayson et al., 2017; Richmond et al., 2026) to propose a developmental account of facial feedback mechanisms. We then consider the neurobiological mechanisms that may implement this learning, including the role of the motor system and predictive coding frameworks, before examining naturalistic, non-pathological perturbations of the mirroring relationship – including infant dummy (pacifier)[1] use, caregiver botulinum toxin (Botox) treatment, and technoference – as informative real-life disruptions of the proposed developmental mechanism. Finally, we discuss implications for clinical intervention and highlight priorities for future empirical work. Taken together, this paper offers a socially embedded account of how facial feedback mechanisms may develop, with implications not only for theories of embodied cognition but also for our understanding of the foundational role of early caregiver mirroring in shaping the developing mind.

II. The Facial Feedback Hypothesis: Theoretical and Empirical Background

The facial feedback hypothesis proposes that there is a bidirectional link between the way we express and feel emotion, such that producing a facial expression is not only a reflection of our feelings, but can itself influence how we feel (McIntosh, 1996). This idea is central to broader theories of "embodied cognition", which propose that emotion perception relies not only on visual analysis of another person's emotional expression, but also on activity in the observer's own

[1] The terms 'dummy' (British English) and 'pacifier' (American English) refer to the same object. For consistency, we use 'dummy' throughout the remainder of this manuscript.

sensorimotor system (Niedenthal, 2007; Wood, Rychlowska, et al., 2016). When it comes to the face[2], this view suggests that seeing a facial expression automatically elicits subtle facial mimicry in the observer, activating similar motor and affective states that are thought to facilitate understanding of others' emotions.

This account of sensorimotor involvement in emotion perception highlights the need to distinguish between two closely related but conceptually distinct processes: facial mimicry and facial feedback. Facial mimicry refers to the tendency to spontaneously and unconsciously activate facial muscles that correspond to an observed facial expression (Dimberg, 1982). Facial feedback refers to the proprioceptive signals generated by one's own facial muscle activity, and the way these signals contribute to emotional experience and emotion perception (Coles et al., 2019). However, because proprioceptive feedback is rarely measured directly, studies often use facial mimicry as an observable proxy of the facial muscle activity through which facial feedback is thought to contribute to emotion processing.

Indeed, research has demonstrated positive associations between facial mimicry and empathy (Drimalla et al., 2019; Holland et al., 2021; Sonnby–Borgström, 2002), and has shown that more precise facial imitation is associated with greater emotion recognition accuracy in both autistic and neurotypical participants (Drimalla et al., 2021). These findings are consistent with the idea that facial motor activity is not merely an expression of emotion but an active contributor to its processing.

This perspective is further supported by experimental research directly manipulating facial muscle activity. For instance, inducing a smile – such as by having participants hold a pen between their teeth – has been shown to speed up the perception of happy faces and bodies (Marmolejo-Ramos et al., 2020) and improve working memory for ambiguous happy expressions (Kuehne et al., 2021). Conversely, disturbing facial feedback, for example by applying a stiffening gel to the face,

[2] Embodied cognition theories extend beyond the face, encompassing bodily states and actions more broadly (e.g., posture, gesture, and whole-body movement) in perception, cognition, and emotion (e.g. Niedenthal et al., 2005). Here we focus specifically on the facial domain, given its particular relevance to the facial feedback hypothesis.

reduces accuracy when comparing emotional facial expressions (Wood, Lupyan, et al., 2016). Similarly, temporarily paralyzing facial muscles with Botox decreases the perceived intensity of subtle facial expressions and slows their recognition (Baumeister et al., 2016). Together, these and other findings suggest that facial muscle activity plays a causal role in how emotions are experienced and perceived.

Despite this body of evidence, the facial feedback hypothesis remains controversial. One important issue concerns the mechanisms underlying facial mimicry. Some have argued that, rather than arising from a direct perception–action coupling, observing an emotional expression first induces a similar affective state in the observer (i.e. emotional contagion), which then gives rise to the matching facial muscle activity (e.g. Hatfield et al., 1993). On this account, facial mimicry is a downstream consequence of shared affect rather than a perceptual-motor phenomenon in its own right. Unfortunately, there is no straightforward way to empirically distinguish between these accounts. Inclusion of non-facial emotional pictures as control stimuli, as suggested for example by Costa et al. (2025), is unlikely to provide conclusive answers. The reason is that similar facial responses to both stimulus types would not preclude the two responses being driven by different underlying mechanisms, for instance, contagion in response to non-facial emotional pictures and perception-action coupling in response to facial expressions. Conversely, if responses differ markedly by stimulus type, this would not necessarily indicate that different mechanisms are at play either: it could instead reflect the same mechanism (e.g. emotional contagion) operating with different strengths across stimulus types (e.g. facial expressions evoking stronger affective responses than non-facial emotional stimuli). One way to potentially distinguish between these accounts would to examine facial mimicry to emotional facial expressions across cultures that differ in early face-to-face contact (e.g. Keller et al., 2011). If mimicry is primarily driven by emotional contagion, it should be relatively similar across such cultures; if it depends on perceptual-motor couplings shaped by caregiver mirroring, mimicry should instead be reduced in cultures with less face-to-face infant care.

Another major issue is that observed facial feedback effects are often small and inconsistent across studies (Coles et al., 2019). A well-known example is the classic 1980's finding that holding a pen between the teeth (thereby activating smiling muscles) increased amusement ratings of cartoons, compared to holding a pen between the lips, which prevents smiling (Strack et al., 1988). Crucially, this effect failed to replicate in a large multi-laboratory study (Wagenmakers et al., 2016). However, this does not imply that the facial feedback hypothesis should be dismissed altogether. Indeed, it has since been suggested that the use of a webcam to monitor participants in the replication study may have inhibited spontaneous facial responding, thereby attenuating the effect (Noah et al., 2018). Consistent with this, a meta-analysis of the broader facial feedback literature found a small but significant effect of facial feedback on emotional experience, though with considerable variability across studies (Coles et al., 2019). Such mixed results may partly stem from limitations in commonly used experimental paradigms. Tasks that require participants to voluntarily pose expressions or maintain unnatural muscle positions can be effortful and difficult to sustain consistently. Moreover, studies with people who received Botox injections or have long-term paralysis introduce additional complications, as these scenarios allow time for compensatory strategies or neural adaptation, potentially masking the true effects of reduced facial feedback.

To address these limitations, Korb and colleagues recently introduced facial neuromuscular electrical stimulation (fNMES). This technique uses brief, low-intensity electrical pulses delivered through surface electrodes to activate specific facial muscles (Efthimiou, Perusquía-Hernández, et al., 2024). Electrodes placed on the cheeks, for example, can target the main smiling muscle, while those placed below the mouth corners can activate muscles associated with sadness. Using fNMES, recent experiments have shown that briefly inducing a smile makes participants more likely to perceive happiness in emotionally ambiguous faces (Baker et al., 2025; Efthimiou, Baker, et al., 2024). Such findings support the idea that spontaneous facial muscle activity contributes directly to emotion recognition, in line with theories of embodied cognition (Wood, Rychlowska, et al., 2016).

It is important to note that facial feedback is unlikely to be the sole mechanism underlying emotion recognition. For example, individuals with Moebius syndrome, a condition characterised by congenital facial paralysis, show largely intact emotion recognition abilities (Bate et al., 2013; Calder et al., 2000; Pereira & Vannuscorps, 2025; Rives Bogart & Matsumoto, 2010; Vannuscorps et al., 2020), suggesting that facial mimicry and the accompanying facial muscle feedback is not strictly necessary for emotion recognition. However, more recent studies paint a more nuanced picture: while basic recognition abilities may be preserved, individuals with Moebius syndrome often show residual deficits (Schiano Lomoriello et al., 2023), as well as differences in neural processing of emotional faces, especially more ambiguous ones (Japee et al., 2023; Quettier et al., 2023; Sessa et al., 2022). These findings suggest that although alternative mechanisms can compensate for the lack of facial feedback, embodied simulation normally contributes to efficient and fine-grained emotion processing. Nevertheless, most modern scholars view facial feedback as just one of several contributors to emotion recognition, alongside other factors such as visual expertise and context (Japee, 2024; Steward et al., 2025). Facial feedback mechanisms may therefore be best understood as modulatory rather than foundational, contributing most meaningfully under conditions of perceptual ambiguity or degraded sensory input (Niedenthal et al., 2010; Pereira & Vannuscorps, 2025), and operating alongside other perceptual, cognitive, and social processes supporting emotion recognition.

Crucially, the conditions under which facial feedback may be most influential – perceptual ambiguity and/or degraded sensory input – are precisely those that characterise much of early perceptual experience. Infants are still developing the perceptual and cognitive capacities needed to decode complex social and emotional cues (Sroufe, 1997), suggesting that supplementary signals such as facial proprioception may play a particularly important role during this period. This raises the question of how such mechanisms come to operate in the first place. However, thus far, the developmental origins of facial feedback remain largely unspecified in the literature. In the next section we set out our proposal that caregiver mirroring plays a key role in this process.

III. Caregiver mirroring and the development of facial feedback

A wealth of research has demonstrated that infants are highly sensitive to the contingency between their own actions and their caregivers' responses. From the earliest weeks of life, infants detect and respond to the temporal regularities in caregiver behaviour (Censullo et al., 1985; Devouche & Gratier, 2019), and react with distress when these contingencies are disrupted (for example demonstrated by the still face procedure, in which a caregiver's shift to an unresponsive, neutral expression reliably elicits negative affect in the infant; Tronick et al., 1978). One particularly pervasive form of contingent responsiveness is imitation: caregivers spontaneously and frequently copy their infants' facial expressions and vocalisations during natural interactions (Jones, 2009; Moran et al., 1987). This contingent imitation or mirroring has been proposed to play an important role in early socio-cognitive development, contributing to the emergence of emotional self-awareness (Gergely & Watson, 1996) and the sense of self (Prinz, 2017). Here we propose that caregivers' pervasive imitation of infant facial expressions may have an additional developmental consequence. Specifically, we argue that repeated episodes of facial mirroring provide infants with reliable sensorimotor contingencies through which facial muscle activity becomes linked to affective states, thereby scaffolding the facial feedback mechanisms that later support emotion processing.

Expanding on existing sensorimotor learning accounts (Heyes, 2001; Keysers & Perrett, 2004) and Gergely and Watson's social biofeedback theory of parental affect-mirroring (1996, 1999), our account proposes that when infants experience caregiver mirroring of their emotional facial expressions, there is correlated activation of several key representations: their own affective state, the motor representation of their own facial expression, its proprioceptive consequences, and the visual representation of the caregiver's matching expression (see Figure 1). Over repeated mirroring episodes, these co-activated representations are thought to become linked in such a way that when one of these representations is activated, i.e. when the infant observes someone else performing a similar emotional facial expression, the previously associated motor, proprioceptive, and affective representations are activated as well. The caregiver's mirroring response also provides a form of social reinforcement, in that the infant's facial action is reliably met with an affectively congruent response from another person – strengthening the correspondence between facial configurations and emotional states (Gergely & Watson, 1996, 1999). Over time, and across many such episodes, we propose that infants gradually build an internal model in which specific facial configurations are tied to particular felt states and to the emotional expressions of others, laying the groundwork for the embodied recognition of emotion[3].

Preliminary evidence for this account comes from studies that have demonstrated a relationship between caregiver imitation and infant's mimicry of others' facial actions. For example, de Klerk et al. (2019) found that mothers' tendency to imitate their 4-month-old's facial expressions was positively associated with the infants' facial mimicry. This is consistent with the idea that caregiver mirroring supports the development of perceptual-motor couplings that may support an early form of embodied simulation and are a precursor to later affective sharing and emotion recognition.

While direct longitudinal evidence linking caregiver mirroring and infant facial mimicry to later emotion recognition or other socio-emotional outcomes is currently lacking, a number of findings are consistent with the developmental account proposed here. One example is Murray et al.'s (2016) work on early caregiver-infant interaction, which found that specific forms of maternal responsiveness, including mirroring and marked responses, predicted subsequent increases in infants' social expressiveness over the first two months of life. This work suggests that caregiver mirroring does not merely reflect overall interaction quality, but may constitute a form of responsiveness that plays a unique role in shaping early socio-emotional development.

[3] Note that the social biofeedback framework (Gergely & Watson, 1996) does not require caregiver mirroring to be visual or facial specifically. Affectively contingent vocal responses could plausibly support related developmental outcomes. Here we focus on facial mirroring given the evidence linking it to the development of facial sensorimotor coupling (Rayson et al., 2017; Richmond et al., 2026; Murray et al., 2018). However, to our knowledge no studies have directly compared facial mirroring with mirroring in other modalities, and so the extent to which the visual/facial channel is necessary — as opposed to sufficient, or one of several viable routes — for the development of facial feedback mechanisms remains an open question.

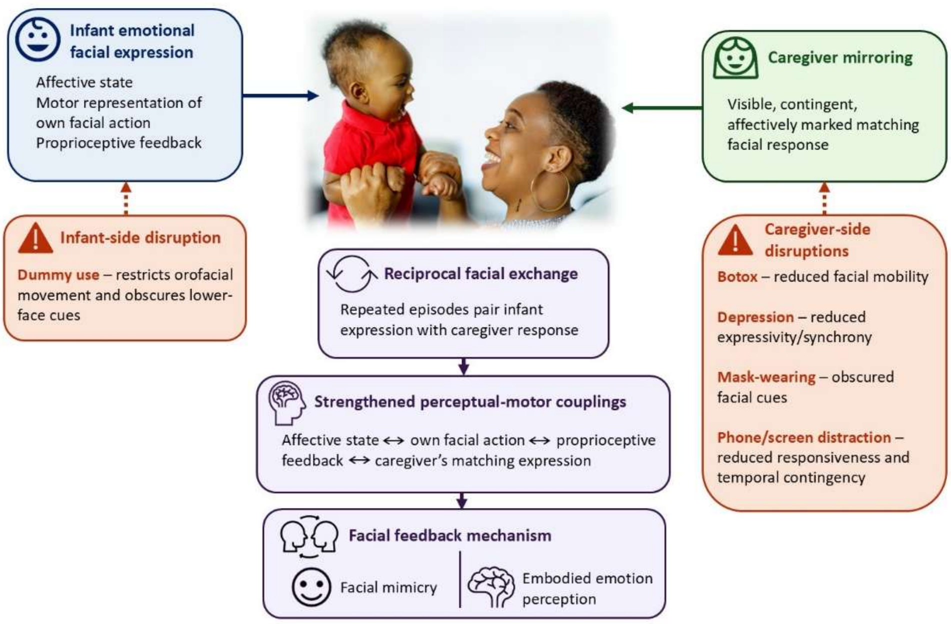
This idea is further supported by later work by Murray and colleagues (2018) that examined communicative development in infants with cleft lip. These infants showed a slower rate of communicative behaviour development compared to infants without a cleft lip, and this group difference was mediated by reduced maternal mirroring of infant expressions. This reduction in mirroring was itself partly explained by lower maternal gaze to the infant's mouth region. This finding is particularly informative because it suggests that changes in infants' facial cues, and caregivers' access to those cues, may affect communicative development through their impact on maternal mirroring. It is worth noting that the reduction in mirroring in this study was not fully explained by reduced maternal gaze alone. Cleft severity and maternal self-blame also independently predicted mirroring, suggesting that broader disruptions to caregiver responsiveness, alongside changes to the clarity of the infant's facial signal itself, likely also contribute to this effect. Evidence from a different population points to a similar conclusion. Three-year-old children of depressed mothers - who have also been shown to imitate their infants' facial expressions less frequently (Murray et al., 1996) - are less accurate in labelling facial expressions compared to children of non-depressed mothers (Székely et al., 2014). Together, these findings suggest that disruptions to early caregiver mirroring may have downstream consequences for children's emotion processing.

Comparative evidence offers further, albeit indirect support. In rhesus macaques, facial expression processing skills are predicted by positive social contact with the mother during infancy (O'Callaghan et al., 2025), consistent with the idea that early social experience shapes the development of facial expression processing across primate species. Relatedly, macaques that imitate lip smacking in the first week of life have been shown to exhibit more dominant behaviour, lower anxiety, and greater social engagement at one year of age compared to non-imitators (Kaburu et al., 2016), suggesting that early facial imitation may be a meaningful predictor of later social competence. It should be noted, however, that these comparative findings do not map directly onto the specific developmental mechanism proposed here. Macaque lip smacking is primarily an affiliative communicative signal and the longitudinal associations observed could reflect stable individual differences in sociality rather than a causal effect of early imitation experience per se. These cross-species comparisons should therefore be interpreted with appropriate caution.

Taken together, these findings are consistent with the proposal that early mirroring experience contributes to the development of later emotion processing. However, this evidence is indirect: the studies reviewed above link caregiver mirroring and early social experience with infant facial mimicry, facial expressiveness, social competence, and emotion-related outcomes, but none directly examined facial feedback mechanisms. Moreover, because this research is correlational, determining whether early mirroring causally shapes later facial mimicry responses — and whether the resulting proprioceptive feedback in turn contributes to emotion perception — remains an important avenue for future research.

Figure 1

Proposed Role of Caregiver Mirroring in the Development of Facial Feedback Mechanisms



Note. Proposed developmental pathway through which caregiver mirroring may support the emergence of facial feedback mechanisms. Across repeated episodes of reciprocal facial exchange, the infant's expressions are paired with the caregiver's responses, strengthening associations between the infant's own affective state, facial actions, proprioceptive feedback, and the caregiver's matching expression. These couplings are proposed to support later facial feedback mechanisms, including facial mimicry and embodied emotion perception. Blue indicates infant-side components, green indicates caregiver-side components, purple indicates the proposed developmental mechanism, and orange indicates potential disruptions to the process.

IV. Neural Mechanisms

The account outlined above raises an important question: what are the neural mechanisms through which associative links between facial action, proprioception, and affect become instantiated in the developing brain? It is well-established that observing another person's actions activates motor representations in the observer that overlap with those involved in producing the same action (Rizzolatti & Craighero, 2004). Seeing someone's facial expression is thus thought to activate a similar motor representation in the observer, often resulting in subtle activation of the corresponding facial muscles. Indeed, motor activation during the observation of facial expressions has been shown to correlate with facial mimicry responses as measured by facial electromyography (EMG) (Likowski et al., 2012). A longstanding view regarding the ontogeny of this coupling between perception and action is that it is inborn (e.g. Lepage & Théoret, 2007; Meltzoff & Decety, 2003), and supports infants' ability to copy others' facial actions from birth (Meltzoff, 2002; e.g. Simpson, Murray, et al., 2014). However, the evidence for this idea remains contested, with recent work highlighting methodological and interpretive challenges surrounding neonatal imitation effects (Meltzoff et al., 2018; Oostenbroek et al., 2016; Slaughter, 2021). An alternative account instead proposes that these perceptual-motor couplings emerge through associative learning during correlated sensorimotor experience (Heyes, 2001; Keysers & Perrett, 2004) and recent studies have provided evidence for this idea. For example, Rayson et al., (2017) showed that maternal imitation of infants' facial expressions at two months was positively associated with infants' motor cortex activation during the observation of facial expressions seven months later. Similarly, Richmond et al., (2026) found that two weeks of mirror training enhanced four-month-old infants' motor cortex activation during the observation of others' facial actions. Together, these studies suggest that the extent to which infants activate their sensorimotor cortex when observing others' facial expressions is related to the amount of sensorimotor experience they have had with these actions – either through parental imitation (Rayson et al., 2017) or through mirror exposure (Richmond et al., 2026).

Some have argued that innate and learned accounts need not be competing, and it remains possible that some innate predispositions provide an initial scaffold on which postnatal experience subsequently builds (Simpson, Fox, et al., 2014). Although the present account does not exclude this possibility, it focuses on the contribution of caregiver mirroring because direct longitudinal and experimental evidence currently links postnatal sensorimotor experience to the development of these couplings (Rayson et al., 2017; Richmond et al., 2026).

The predictive coding framework may offer a mechanistic account of how these perceptual-motor couplings established through early mirroring experience may support emotion processing. Within this framework, the brain continuously generates expectations about incoming sensory input and updates its internal models on the basis of prediction error: the discrepancy between what was expected and what actually occurred (Friston, 2012; Kilner et al., 2007). It has recently been proposed that mimicry serves as a mechanism that reduces prediction error when observing others' emotional expressions (Diana & Kret, 2025; Kret & Akyüz, 2022). When we observe another person's facial expression, we may generate a prediction about their likely emotional state based on context or prior experience with that individual. By simultaneously mimicking their expression, we generate a proprioceptive signal that – through its association with specific emotional states – constitutes an additional source of evidence about the emotional meaning of the observed expression. Thus, rather than relying only on the visual input from the observed face, the brain can draw on the felt sense of producing a similar expression itself, reducing uncertainty about the emotional state being expressed and thereby minimising prediction error (Diana & Kret, 2025; Kret & Akyüz, 2022).

Our account extends this argument developmentally, proposing that it is the repeated episodes of caregiver facial mirroring in infancy that establish the perceptual-motor couplings on which these predictive processes later depend. These bottom-up visual-motor associations may be especially important in early development, as young infants have limited prior experience of the world and therefore a limited basis on which to generate top-down predictions about others' emotional states from context alone. Moreover, predictive accounts of action observation suggest that when an observed action lacks a clear instrumental goal – as is the case for facial expressions, which unlike reaching or grasping have no obvious end-state – direct associations between visual and motor representations are likely to constitute the primary mechanism supporting prediction of the observed kinematics (Csibra, 2007). This suggests that the perceptual-motor associations established through early caregiver mirroring may be especially important for infants, providing the primary mechanism for decoding the emotional expressions of others at a point when top-down contextual knowledge is still limited. Therefore, disruptions to the development of this process early in life seem especially relevant, and they are the focus of the following sections.

V. Disruptions to Maternal Mirroring

If our proposal is correct, then factors that impede or reduce infant facial expressiveness or caregiver mirroring are expected to have a negative effect on both facial mimicry and emotion processing. In this section, we focus primarily on naturalistic, non-pathological, and potentially reversible disruptions to caregiver mirroring. Dummy use, caregiver Botox treatment, mask-wearing, and technoference are useful examples because they occur in otherwise typical caregiving contexts and may affect infant facial expressiveness, caregiver facial mobility, visual access to facial cues, or the timing of caregiver responses. Clinical conditions affecting infant facial expressivity or caregiver access to facial cues, such as cleft lip and Moebius syndrome, are also theoretically relevant to the present account, but rarer and are therefore not discussed in this section (but see section VII).

A. Dummy use

Despite being a widely used and helpful tool in soothing infants (Sexton & Natale, 2009) and potentially lowering the risk of sudden infant death syndrome (Hauck et al., 2005), extended dummy use during awake time may have a negative impact on the development of facial mimicry through two related mechanisms. Firstly, by occupying the mouth and engaging the facial muscles, dummies can restrict or alter infants' production of lower-face expressions such as smiling, mouth opening, and lip movements, thereby reducing opportunities for caregiver facial mirroring during early interaction. Secondly, the part of the dummy that sits outside the infant's mouth can hide their mouth from view, further disrupting the mirroring process. Evidence for this second mechanism comes from a study by Rychlowska et al. (2014), in which female participants viewed photographs of infants with and without dummies, or with the mouth region obscured by a white square. When the mouth was hidden, either by a dummy or a white square, participants showed reduced zygomaticus major (the main smiling muscle) activation in response to infant smiles, perceived less happiness in smiling faces, and less sadness in sad faces. Crucially, the absence of significant differences between the dummy and white square conditions suggests that these effects were driven by the loss of perceptual information rather than by negative associations with dummies per se, pointing to facial visibility as the key mechanism disrupting caregiver mirroring.

If dummy use disrupts early facial mirroring through either or both of these mechanisms, our account would predict downstream consequences for facial mimicry and emotion processing. Consistent with this, Niedenthal et al. (2012) found that longer dummy use in infancy and toddlerhood was associated with reduced spontaneous facial mimicry in seven-year-old boys, and with lower perspective taking and emotional intelligence in young adult males, with no equivalent effects observed in females. While Niedenthal and colleagues attribute these effects primarily to the restriction of the infant's own facial movement, they also note that reduced caregiver mirroring is a likely contributing factor. Future research will need to empirically test the relative contributions of these two mechanisms.

B. Parental botulinum toxin (Botox) treatment

Another relevant factor possibly impacting caregiver mirroring is botulinum toxin, commonly known by the brand name Botox. Botox is a powerful neurotoxin used cosmetically to temporarily reduce facial muscle movement, by blocking nerve signals to the injected muscle, thereby preventing the formation of facial wrinkles caused by frequent facial contractions (de Boulle et al., 2010). It is currently the most common non-surgical cosmetic procedure worldwide (International Society of Aesthetic Plastic Surgery, 2025), and is most prevalent among women aged 25-44 (Department of Health and Social Care, 2025) – an age group that overlaps substantially with the age range of caregivers of young infants. In the context of the present account, Botox is relevant because it may influence caregiver mirroring through two related pathways. First, the reduced facial mobility induced by Botox may reduce caregivers' emotional expressivity and the salience of their mirroring responses. Caregiver mirroring responses are typically exaggerated or modified versions of the infant's own expression, making them more salient and easier for infants to recognise as responses to their own behaviour (Gergely & Watson, 1999). This marking function depends, at least in part, on the caregiver's ability to produce visible and differentiated facial movements. However, studies have shown that upper-face Botox treatment reduces the perceived expressiveness of treated faces, with observers less likely to attribute anger and surprise to recipients' expressions (Aktar Ugurlu et al., 2024; Eilert et al., 2026).

Second, and perhaps less obviously, Botox may also reduce caregivers' sensitivity to infants' own subtle facial expressions. In line with this, Baumeister et al. (2016) found that Botox users rated mildly emotional facial expressions as less emotional following treatment, with no equivalent effects for strongly emotional or neutral stimuli. If caregivers who have regular Botox treatment are less sensitive to subtle or ambiguous infant expressions, they may be less likely to mirror them in the first place, and they may also have reduced capacity to produce the facial movements needed to do so even when they are detected. Furthermore, there is evidence that Botox may delay emotional processing more broadly (Havas et al., 2010), suggesting that caregiver responses may not only be less visually salient but also less temporally contingent, a particularly important consideration given that infants are highly sensitive to the timing of caregiver responses (Devouche & Gratier, 2019). Taken together, these pathways suggest that caregivers' mirroring responses may be delayed or less visually salient after Botox treatment. This would in turn make it harder for infants to detect the correspondence between their own expressions and the caregiver's response, and potentially disrupt the sensorimotor contingencies through which we propose facial feedback mechanisms develop.

C. Other disruptions: depression, mask-wearing, and technoference

Other naturally occurring disruptions may also be informative for understanding how caregiver mirroring supports the development of facial feedback mechanisms. In this section we discuss caregiver depression, mask-wearing, and technoference as examples. Postnatal depression is perhaps the most extensively studied, and is also among the most prevalent: postnatal depression affects approximately 13-19% of mothers (O'Hara & McCabe, 2013) and ~8% of fathers (Cameron et al., 2016). Beyond its well-documented effects on caregiver wellbeing, postnatal depression has been shown to alter the quality of early caregiver-infant interaction in ways that are directly relevant to the present account. Depressed caregivers often show reduced engagement, lower levels of positive affect, and diminished sensitivity during interaction, including fewer smiles and vocalisations (Field, 2010; Murray et al., 1996). Higher parental depressive symptoms are also associated with shorter durations of positive facial expressions and more negative affect during parent-infant interaction (Costantini et al., 2025). These changes matter for the present account, because a less expressive or less positively engaged caregiver may provide fewer clear, affectively congruent facial responses for the infant to map onto their own facial actions and emotional states. Depression may also disrupt the temporal coordination of caregiver-infant interaction. Mothers with a history of depression show reduced synchrony of positive facial affect with their children, suggesting depressive symptoms can alter the moment-to-moment coupling of facial behaviour (Kudinova et al., 2019). Relatedly, maternal depression has been associated with biases in the perception of infant facial expressions, including heightened sensitivity to negative affect (Stein et al., 2010), which may further alter which infant expressions are noticed and whether they are mirrored contingently. If caregiver facial responses are less frequent, less positive, or less temporally aligned with the infant's expressions, infants may receive fewer opportunities to link their own facial movements, proprioceptive feedback, and the corresponding facial expressions of others. Consistent with this, infants of mothers with depressive symptoms have been reported to show reduced facial expressivity and diminished responses to modelled expressions from birth (Lundy et al., 1996), and maternal depression has been associated with reduced infant imitation at 12 months (Perra et al., 2015).

Face mask-wearing – e.g. to protect others and/or oneself from airborne disease – provides a different kind of disruption to those discussed above, because rather than reducing caregiver responsiveness per se, it reduces the infant's visual access to the caregiver's face. By covering the lower face, face masks obscure facial movements that are important for perceiving smiles, mouth openings, and other orofacial expressions. Adult research suggests that masks impair emotion recognition and attenuate facial mimicry, particularly for expressions that rely heavily on the mouth region (Kastendieck et al., 2023). In the context of the present account, the concern is that prolonged mask-wearing during face-to-face caregiving could reduce infants' opportunities to see their own mouth-based expressions reflected in the caregiver's face. This may be especially relevant for infants in hospital settings or with compromised immunity, where caregivers and clinical staff may wear masks for extended periods. The COVID-19 pandemic also created conditions in which many infants experienced substantially increased exposure to masked faces during a critical period of social and emotional development, raising the question of whether cohorts of infants raised during this period show any measurable differences in facial mimicry or emotion processing. This is an empirical question, though a challenging one: any such effects would need to be distinguished from other pandemic-related disruptions, including parental stress, reduced social contact, and changes in daily routines, that may independently affect socio-emotional development. It is also worth noting that for many infants, mask exposure may have been limited to outside the home, meaning that the primary caregiving context may have preserved substantial opportunities for unmasked facial interaction. Mask-wearing is therefore best understood as a potential constraint on caregiver mirroring in specific contexts, and the extent to which it constitutes a meaningful disruption to the developmental mechanism proposed here remains an open question.

A final disruption worth noting is parental smartphone use during face-to-face interaction. Unlike the disruptions discussed above, this does not necessarily alter the caregiver's facial expressivity or the infant's visual access to the caregiver's face, but may instead compromise the temporal contingency of caregiver responses (Kildare & Middlemiss, 2017). When caregivers are distracted by a smartphone or when interaction is interrupted, the timing, frequency, and responsiveness of their facial reactions may be reduced. This so called 'technoference' (McDaniel & Radesky, 2018) has been associated with lower responsiveness and sensitivity, though the evidence remains largely correlational (Abels et al., 2018; Braune-Krickau et al., 2021; Vanden Abeele et al., 2020). Infants appear sensitive to these kinds of interruptions in real-time interaction, showing increased protest behaviour and reduced engagement when caregiver interaction is disrupted (Tidemann & Melinder, 2022). For the present account, the predicted effect is that even if the caregiver remains facially expressive overall, if responses are delayed, absent, or poorly timed they may provide less effective input for developing the perceptual-motor couplings through which facial feedback mechanisms are proposed to develop. While the evidence base is currently limited, parental smartphone use represents a prevalent and potentially modifiable disruption to early face-to-face interaction that warrants further empirical attention.

VI. Implications for intervention

The theoretical account developed in this paper has potential implications for early interventions targeting caregiver-infant interaction. Existing approaches, particularly video-feedback approaches such as video intervention to promote positive parenting (VIPP), aim to enhance caregiver sensitivity and responsiveness by helping caregivers notice infant signals and reflect on their responses (Klein Velderman et al., 2006). Meta-analytic evidence suggests that such approaches can improve parenting behaviour and caregiver-infant interaction, although effects on child outcomes are typically smaller and more variable (Fukkink, 2008). However, a notable gap in existing programmes is that facial mirroring itself is rarely identified as a specific target for intervention. That is, caregivers may be encouraged to notice and respond to infant cues, but less attention is usually given to the form of those responses: whether caregivers visibly mirror, exaggerate, or affectively mark infants' facial expressions in ways that make the response salient to the infant. If, as we propose, it is these facial mirroring responses that scaffold the development of facial feedback mechanisms, then making them an explicit focus of intervention may enhance the benefits of existing approaches. Future interventions could therefore incorporate more explicit attention to the quality of caregiver facial mirroring. Video feedback could be used to highlight moments where caregivers successfully match infants' expressions, drawing attention to the timing, clarity, and visibility of these responses. Structured imitation-based activities (e.g., simple "mirror games" in which caregivers are encouraged to copy and exaggerate infant facial expressions) may also provide opportunities to practise contingent facial responding in a naturalistic context.

Such approaches may be especially useful in contexts where caregiver mirroring is most likely to be reduced or disrupted. For example, for caregivers experiencing postnatal depression, targeted support that helps caregivers notice and respond to infants' expressions could complement existing sensitivity-focused interventions. Infants at elevated likelihood of developing autism spectrum condition (ASC), such as those with an older sibling or caregiver with the condition, may represent another relevant population. This condition is characterised by reduced orienting to social stimuli and faces from an early age (Chawarska et al., 2013; Osterling & Dawson, 1994), which may limit opportunities for the kind of correlated sensorimotor experience that our account proposes is central to the development of facial feedback mechanisms. And indeed autistic individuals have been show to demonstrate reduced or atypical facial mimicry (McIntosh et al., 2006; Oberman et al., 2009) as well as differences in facial feedback effects (Stel et al., 2008) and emotion processing (for a review see Yeung, 2022). It is important to note that this account does not implicate caregiver behaviour as a cause of these developmental differences. Rather, it suggests that differences in infant face-directed attention may reduce the frequency of mirroring exchanges. Indeed, mirroring-focused interventions in these populations appear to provide measurable benefits for socio-emotional development (Morris et al., 2021), but have yet to be applied specifically in the context of facial expressions.

VII. Discussion and Future Directions

The present paper has proposed that the facial feedback mechanisms supporting emotion processing in adulthood have their developmental origins in early caregiver mirroring. Drawing on sensorimotor learning accounts (Heyes, 2001; Keysers & Perrett, 2004) and the social biofeedback theory of parental affect-mirroring (Gergely & Watson, 1996, 1999), we have argued that repeated episodes of caregiver facial imitation provide infants with the sensorimotor experience through which facial muscle activity becomes linked to affective states and visual representations of others' actions, laying the groundwork for the embodied recognition of emotion.

While we believe this account is consistent with the available evidence, it is important to be clear about the limitations of the current evidence base and the empirical work that will be needed to test it directly. The most significant limitation is that although there is support for the idea that caregiver mirroring plays an important role in the development of social responsiveness in both human and macaque infants, direct evidence linking this to facial feedback mechanisms is currently lacking. Additionally, the research that has demonstrated a relationship between early mirroring and later social responsiveness (e.g. in macaques Kaburu et al., 2016; or in infants with cleft lip Murray et al., 2018) is correlational in nature, meaning that causal claims cannot be made. This limitation also applies to naturally occurring variations such as caregiver Botox or infant dummy use that could otherwise serve as informative test cases for the proposed framework. These variations are likely confounded with other factors such as socioeconomic status or differences in caregiving style that could independently influence infant social and emotional development. Future research that experimentally manipulates caregiver mirroring – for example through mirroring or dummy interventions – will therefore be important for isolating its specific contribution. Such work should examine whether caregiver mirroring shapes children's later facial mimicry and whether facial movement itself contributes to emotion processing.

The proposed account also generates predictions about asymmetries in facial mimicry across emotional valence. Research in adults has shown that negative emotions are mimicked less frequently, less quickly, and less indiscriminately than positive emotions, a pattern that has been interpreted to reflect the affiliative and context-dependent nature of mimicry (Hess & Fischer, 2014). While this interpretation may well be correct, the pattern is also consistent with our account: caregivers may be more likely to reciprocate or directly match infants' positive expressions, whereas negative expressions such as sadness or anger may be more often responded to with regulatory or marked responses (Gergely & Watson, 1996). Moreover, even when caregivers do mirror negative expressions, infants in a distressed state may be less able to attend to or learn from this input. If caregiver mirroring helps calibrate links between facial action, proprioceptive feedback, affective state, and observed facial expressions, these links may become stronger for emotional expressions that are more consistently mirrored early in life. An important test of this specificity would be to examine whether the emotions that caregivers tend to mirror most consistently are the same emotions their children show the strongest mimicry responses to later in development, as well as whether these mimicry responses are also associated with differences in emotion processing. Even in a correlational design, such a finding would provide meaningful support for the proposed account.

A further question concerns the developmental timing of the proposed mechanism. We suggest that caregiver mirroring may be especially influential during the first six months of life when infants are not yet mobile. Head-camera studies show that during this time, faces are frequent and persistent in infants' visual environments but become less prominent as infants grow older and more mobile (Jayaraman et al., 2015, 2017; Jayaraman & Smith, 2019). This early concentration of face experience may provide an especially rich context for establishing links between infants' own affective states, facial actions, proprioceptive feedback, and caregivers' matching expressions. The account is therefore consistent with a sensitive-period view, in which the influence of caregiver mirroring is strongest while these sensorimotor mappings are still being formed.

One way to test this timing hypothesis would be to examine infants who experience early but reversible disruption to face-related visual input because of congenital cataracts. Even when treated within the first months of life, early visual deprivation from birth is associated with long-lasting impairments in configural face processing (Le Grand et al., 2001) and altered activation and connectivity within the face-processing network (Grady et al., 2014). Although congenital cataracts do not selectively disrupt caregiver mirroring, they demonstrate that early access to patterned visual input, including faces, can shape the subsequent development of face processing abilities. Future work could therefore examine whether the timing of restored visual access predicts later sensitivity to caregiver mirroring, facial mimicry, or the influence of facial movement on emotion processing.

Cleft lip may provide a complementary test case, because it affects the visibility and interpretability of infants' own mouth-based expressions rather than the infant's access to others' faces. Cleft lip repair is commonly carried out in early infancy, often around 3-6 months (National Health Service, 2017), and variation in the timing of repair may provide a useful opportunity to examine whether earlier restoration of visible facial cues alters caregiver mirroring and later socioemotional outcomes. Consistent with this possibility, Murray et al. (2008) found that early interaction difficulties mediated the effects of late cleft lip repair on infant cognitive outcome.

Moebius syndrome, in which facial reanimation surgery can restore some expressive movement later in childhood (typically from around age five; e.g. Panzenbeck et al., 2025), offers a further natural test case. Affected infants cannot produce visible facial expressions in infancy, and children with Moebius syndrome show reduced autonomic modulation during emotion processing and mild difficulties in emotion recognition (De Stefani et al., 2019). Because reanimation surgery falls well outside the proposed early sensitive period, a before-and-after comparison of facial feedback sensitivity would not be informative about the role of early mirroring specifically. It could, however, test how time-limited this developmental window is. If children go on to develop facial feedback sensitivity once their faces become expressive and caregivers can start mirroring them, that would fit a sensitive-period account rather than a strict critical period. If deficits persist regardless, that would suggest the early window matters more than later experience can make up for. More broadly, comparing disruptions that occur in the first six months with those occurring later in infancy would help determine whether there is a sensitive period during which caregiver mirroring is especially important for the development of facial feedback mechanisms.

Although the present account focuses primarily on the initial formation of facial feedback mechanisms during infancy, through the sensorimotor contingencies provided by early caregiver mirroring, the associative learning processes we describe are unlikely to be confined to this early period. Later in development, caregivers, peers, and others may further enrich these facial-affective mappings by attaching verbal labels to specific emotional expressions (Denham & Kochanoff, 2002), providing an additional route through which facial muscle activation becomes linked to affective meaning. In this view, emotion labels may themselves become integrated into the representational network linking facial action, proprioceptive feedback, and affective states, further strengthening and elaborating the mappings established through early mirroring experience. This idea is supported by Hess and colleagues (2014) who found that emotion labels alone were sufficient to elicit congruent facial muscle responses in observers, even in the absence of any visible emotional expression in the stimulus, pointing to a bidirectional relationship between emotion labels and facial muscle responses.

Self-observation may offer another route to enriching facial-affective mappings in adulthood: mirrors and, increasingly, video calls provide frequent opportunities to see one's own facial expressions as one produces them, a form of sensorimotor experience similar to the mirror-training manipulation shown to enhance perceptual-motor couplings for facial actions in infancy (Richmond et al., 2026). Unlike caregiver mirroring, however, this self-generated feedback lacks the contingent, socially responsive quality of an attuned social partner's matching response, and it remains an open question whether self-observation alone is sufficient to establish or merely to refine facial-affective mappings that are otherwise shaped by early social experience. The development of facial feedback mechanisms may therefore be best understood as a continuous process, with early sensorimotor experience providing the foundation on which later linguistic, social, and sensorimotor learning builds.

Another limitation of the current paper concerns the generalisability of the proposed account across caregiving relationships. Although we have used the term ‘caregiver’ throughout the paper to reflect the range of individuals who may fulfil a primary caregiving role in an infant's life, the studies most directly relevant to our account have focused almost exclusively on mothers. Relatively little is known about the frequency, form, or developmental consequences of facial mirroring by fathers or other primary caregivers. Whether the same developmental mechanisms operate across different caregiving relationships, and whether variation in mirroring across caregivers within the same family has cumulative or compensatory effects, remains an open question. Addressing this gap will require studies that sample more broadly across caregiving relationships and that consider the infant’s full social environment rather than the mother-infant dyad alone.

VIII. Conclusion

In conclusion, this paper has proposed a novel developmental account of facial feedback mechanisms, arguing that the sensorimotor links between facial action, proprioceptive feedback, and affective states that underpin embodied emotion processing in adulthood are established through early social experience. Specifically, we have proposed that repeated caregiver mirroring of their infants' facial expressions provides the sensorimotor experience through which facial movement, proprioceptive feedback, and affective states become linked, gradually calibrating facial movement as an emotionally meaningful signal. We hope that this account will motivate empirical work that directly tests the proposed developmental pathway, and that it will encourage researchers working on facial feedback, early caregiver interaction, and socio-emotional development to consider the connections between these often separate literatures. Ultimately, understanding how the capacity for embodied emotional understanding develops, and what supports or disrupts it, has implications not only for theories of emotion and social cognition, but also for how we think about the foundational role of early caregiving in shaping the developing mind.

Declaration of generative AI and AI-assisted technologies

During the preparation of this manuscript, the authors used ChatGPT (GPT-5.5; OpenAI) and Claude (Sonnet 5; Anthropic) to assist with language editing. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the final content presented in the manuscript.

References

Abels, M., Abeele, M. V., van Telgen, T., & van Meijl, H. (2018). *Nod, nod, ignore: An exploratory observational study on the relation between parental mobile media use and parental responsiveness towards young children*.

Adelmann, K., & Zajonc, R. B. (1989). Facial efference and the experience of emotion. *Annual Review of Psychology*.

Aktar Ugurlu, G., Ugurlu, B. N., & Yalcinkaya, M. (2024). Evaluating the Impact of BoNT-A Injections on Facial Expressions: A Deep Learning Analysis. *Aesthetic Surgery Journal*, *45*(1), NP1–NP7. https://doi.org/10.1093/asj/sjae204

Baker, J., Ngo, H., Efthimiou, T. N., Elsenaar, A., Mehu, M., & Korb, S. (2025). Electrical stimulation of smiling muscles reduces visual processing load and enhances happiness perception in neutral faces. *Communications Psychology*, *3*(1), 94. https://doi.org/10.1038/s44271-025-00281-y

Bate, S., Cook, S. J., Mole, J., & Cole, J. (2013). First Report of Generalized Face Processing Difficulties in Möbius Sequence. *PLOS ONE*, *8*(4), e62656. https://doi.org/10.1371/journal.pone.0062656

Baumeister, J.-C., Papa, G., & Foroni, F. (2016). Deeper than skin deep—The effect of botulinum toxin-A on emotion processing. *Toxicon: Official Journal of the International Society on Toxinology*, *118*, 86–90. https://doi.org/10.1016/j.toxicon.2016.04.044

Braune-Krickau, K., Schneebeli, L., Pehlke-Milde, J., Gemperle, M., Koch, R., & Von Wyl, A. (2021). Smartphones in the nursery: Parental smartphone use and parental sensitivity and responsiveness within parent–child interaction in early childhood (0–5 years): A scoping review. *Infant Mental Health Journal*, *42*(2), 161–175. https://doi.org/10.1002/imhj.21908

Calder, A. J., Keane, J., Manes, F., Antoun, N., & Young, A. W. (2000). Impaired recognition and experience of disgust following brain injury. *Nature Neuroscience*, *3*(11), 1077–1078.

Cameron, E. E., Sedov, I. D., & Tomfohr-Madsen, L. M. (2016). Prevalence of paternal depression in pregnancy and the postpartum: An updated meta-analysis. *Journal of Affective Disorders*, *206*, 189–203. https://doi.org/10.1016/j.jad.2016.07.044

Censullo, M., Lester, B., & Hoffman, J. (1985). Rhythmic patterning in mother-newborn interaction. *Nursing Research*, *34*(6), 342–346.

Chawarska, K., Macari, S., & Shic, F. (2013). Decreased Spontaneous Attention to Social Scenes in 6-Month-Old Infants Later Diagnosed with Autism Spectrum Disorders. *Biological Psychiatry*, *74*(3), 195–203. https://doi.org/10.1016/j.biopsych.2012.11.022

Coles, N. A., Larsen, J. T., & Lench, H. C. (2019). A meta-analysis of the facial feedback literature: Effects of facial feedback on emotional experience are small and variable. *Psychological Bulletin*, *145*(6), 610–651. https://doi.org/10.1037/bul0000194

Coles, N. A., March, D. S., Marmolejo-Ramos, F., Larsen, J. T., Arinze, N. C., Ndukaihe, I. L. G., Willis, M. L., Foroni, F., Reggev, N., Mokady, A., Forscher, P. S., Hunter, J. F., Kaminski, G., Yüvrük, E., Kapucu, A., Nagy, T., Hajdu, N., Tejada, J., Freitag, R. M. K., … Liuzza, M. T. (2022). A multi-lab test of the facial feedback hypothesis by the Many Smiles Collaboration. *Nature Human Behaviour*, *6*(12), 1731–1742. https://doi.org/10.1038/s41562-022-01458-9

Costa, S., Schiano Lomoriello, A., Quettier, T., Caruana, F., Ferrari, P. F., & Sessa, P. (2025). Facial expressions selectively modulate P300 somatosensory evoked-potential, but emotional scenes do not: Electrophysiological evidence for sensorimotor simulation. *NeuroImage*, *317*, 121322. https://doi.org/10.1016/j.neuroimage.2025.121322

Costantini, I., Kounali, D., Culpin, I., Bornstein, M. H., & Pearson, R. M. (2025). Longitudinal associations between parental mental health and the duration of visual attention and facial expressions during at-home parent–infant interactions: A UK birth cohort study. *Frontiers in Child and Adolescent Psychiatry*, *4*, 1638234. https://doi.org/10.3389/frcha.2025.1638234

Csibra, G. (2007). Action mirroring and action understanding: An alternative account. In P. Haggard, Y. Rossetti, & M. Kawato (Eds), *Sensorimotor Foundations of Higher Cognition* (pp. 435–459). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199231447.001.0001

Darwin, C. (1872). *The expression of the emotions in man and animals*. John Murray.

de Boulle, K., Fagien, S., Sommer, B., & Glogau, R. (2010). Treating glabellar lines with botulinum toxin type A-hemagglutinin complex: A review of the science, the clinical data, and patient satisfaction. *Clinical Interventions in Aging*, *5*, 101–118. https://doi.org/10.2147/CIA.S9338

de Klerk, C. C. J. M., Lamy-Yang, I., & Southgate, V. (2019). The role of sensorimotor experience in the development of mimicry in infancy. *Developmental Science*, *22*(3), e12771. https://doi.org/10.1111/desc.12771

De Stefani, E., Ardizzi, M., Nicolini, Y., Belluardo, M., Barbot, A., Bertolini, C., Garofalo, G., Bianchi, B., Coudé, G., Murray, L., & Ferrari, P. F. (2019). Children with facial paralysis due to Moebius syndrome exhibit reduced autonomic modulation during emotion processing. *Journal of Neurodevelopmental Disorders*, *11*(1), 12. https://doi.org/10.1186/s11689-019-9272-2

Denham, S., & Kochanoff, A. T. (2002). Parental Contributions to Preschoolers' Understanding of Emotion. *Marriage & Family Review*, *34*(3–4), 311–343. https://doi.org/10.1300/J002v34n03_06

Department of Health and Social Care. (2025). *The licensing of non-surgical cosmetic procedures in England: Consultation response*. GOV.UK. https://www.gov.uk/government/consultations/licensing-of-non-surgical-cosmetic-procedures/outcome/the-licensing-of-non-surgical-cosmetic-procedures-in-england-consultation-response

Devouche, E., & Gratier, M. (2019). The Beginning of Parent-Infant Communication. In G. Apter, E. Devouche, & M. Gratier (Eds), *Early Interaction and Developmental Psychopathology:*

Volume I: Infancy (pp. 21–33). Springer International Publishing. https://doi.org/10.1007/978-3-030-04769-6_2

Diana, F., & Kret, M. E. (2025). First predict, then bond: Rethinking the function of mimicry from prediction to affiliation in human and non-human animals. *Neuroscience & Biobehavioral Reviews*, *168*, 105950. https://doi.org/10.1016/j.neubiorev.2024.105950

Dimberg, U. (1982). Facial Reactions to Facial Expressions. *Psychophysiology*, *19*(6), 643–647. https://doi.org/10.1111/j.1469-8986.1982.tb02516.x

Drimalla, H., Baskow, I., Behnia, B., Roepke, S., & Dziobek, I. (2021). Imitation and recognition of facial emotions in autism: A computer vision approach. *Molecular Autism*, *12*(1), 27. https://doi.org/10.1186/s13229-021-00430-0

Drimalla, H., Landwehr, N., Hess, U., & Dziobek, I. (2019). From face to face: The contribution of facial mimicry to cognitive and emotional empathy. *Cognition and Emotion*, *33*(8), 1672–1686. https://doi.org/10.1080/02699931.2019.1596068

Efthimiou, T. N., Baker, J., Clarke, A., Elsenaar, A., Mehu, M., & Korb, S. (2024). Zygomaticus activation through facial neuromuscular electrical stimulation (fNMES) induces happiness perception in ambiguous facial expressions and affects neural correlates of face processing. *Social Cognitive and Affective Neuroscience*, *19*(1), nsae013. https://doi.org/10.1093/scan/nsae013

Efthimiou, T. N., Perusquía-Hernández, M., Elsenaar, A., Mehu, M., & Korb, S. (2024). Application of facial neuromuscular electrical stimulation (fNMES) in psychophysiological research: Practical recommendations based on a systematic review of the literature. *Behavior Research Methods*, *56*(4), 2941–2976. https://doi.org/10.3758/s13428-023-02262-7

Eilert, D. W., Hopf, A. G. M., Alfertshofer, M., Prinz, V., Friedrich, M., & Cajkovsky, M. (2026). Botulinum Toxin and Social Perception: Effects of Upper-Face Treatment on Facial Emotion Attribution. *Aesthetic Surgery Journal*, sjag037. https://doi.org/10.1093/asj/sjag037

Field, T. (2010). Postpartum depression effects on early interactions, parenting, and safety practices: A review. *Infant Behavior and Development*, *33*(1), 1–6. https://doi.org/10.1016/j.infbeh.2009.10.005

Friston, K. (2012). The history of the future of the Bayesian brain. *NeuroImage*, *62*(2), 1230–1233. https://doi.org/10.1016/j.neuroimage.2011.10.004

Fukkink, R. G. (2008). Video feedback in widescreen: A meta-analysis of family programs. *Clinical Psychology Review*, *28*(6), 904–916. https://doi.org/10.1016/j.cpr.2008.01.003

Gergely, G., & Watson, J. S. (1996). *The social biofeedback model of parental affect-mirroring*. The International Journal of Psycho-Analysis. https://www.proquest.com/openview/6dae5eb9694afa251058797d2c1b8af6/1?cbl=1818729&loginDisplay=true&pq-origsite=gscholar

Gergely, G., & Watson, J. S. (1999). Early socio-emotional development: Contingency perception and the social-biofeedback model. In P. Rochat (Ed.), *Early Social Cognition: Understanding Others in the First Months of Life* (0 edn, pp. 101–136). Psychology Press. https://doi.org/10.4324/9781410604194 (Original work published Lawrence Erlbaum Associates Publishers)

Grady, C. L., Mondloch, C. J., Lewis, T. L., & Maurer, D. (2014). Early visual deprivation from congenital cataracts disrupts activity and functional connectivity in the face network. *Neuropsychologia*, *57*, 122–139. https://doi.org/10.1016/j.neuropsychologia.2014.03.005

Hatfield, E., Cacioppo, J. T., & Rapson, R. L. (1993). Emotional Contagion. *Current Directions in Psychological Science*, *2*(3), 96–100. https://doi.org/10.1111/1467-8721.ep10770953

Hauck, F. R., Omojokun, O. O., & Siadaty, M. S. (2005). Do Pacifiers Reduce the Risk of Sudden Infant Death Syndrome? A Meta-analysis. *Pediatrics*, *116*(5), e716–e723. https://doi.org/10.1542/peds.2004-2631

Havas, D. A., Glenberg, A. M., Gutowski, K. A., Lucarelli, M. J., & Davidson, R. J. (2010). Cosmetic Use of Botulinum Toxin-A Affects Processing of Emotional Language. *Psychological Science*, *21*(7), 895–900. https://doi.org/10.1177/0956797610374742

Hess, U., & Fischer, A. (2014). Emotional Mimicry: Why and When We Mimic Emotions. *Social and Personality Psychology Compass*, *8*(2), 45–57. https://doi.org/10.1111/spc3.12083

Hess, U., Houde, S., & Fischer, A. (2014). Do we mimic what we see or what we know? In C. Von Scheve & M. Salmela (Eds), *Collective Emotions* (pp. 94–107). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199659180.003.0007

Heyes, C. (2001). Causes and consequences of imitation. *Trends in Cognitive Sciences*, *5*(6), 253–261. https://doi.org/10.1016/S1364-6613(00)01661-2

Holland, A. C., O'Connell, G., & Dziobek, I. (2021). Facial mimicry, empathy, and emotion recognition: A meta-analysis of correlations. *Cognition and Emotion*, *35*(1), 150–168. https://doi.org/10.1080/02699931.2020.1815655

International Society of Aesthetic Plastic Surgery. (2025). *ISAPS International Survey on Aesthetic/Cosmetic Procedures Performed in 2024* [Global survey report]. International Society of Aesthetic Plastic Surgery. https://www.isaps.org/discover/about-isaps/global-statistics/global-survey-2024-full-report-and-press-releases/

James, W. (1884). What is an Emotion? *Mind*, *9*(34), 188–205.

Japee, S. (2024). On the Role of Sensorimotor Experience in Facial Expression Perception. *Journal of Cognitive Neuroscience*, *36*(12), 2780–2792. https://doi.org/10.1162/jocn_a_02148

Japee, S., Jordan, J., Licht, J., Lokey, S., Chen, G., Snow, J., Jabs, E. W., Webb, B. D., Engle, E. C., Manoli, I., Baker, C., & Ungerleider, L. G. (2023). Inability to move one's face dampens facial expression perception. *Cortex*, *169*, 35–49. https://doi.org/10.1016/j.cortex.2023.08.014

Jayaraman, S., Fausey, C. M., & Smith, L. B. (2015). The Faces in Infant-Perspective Scenes Change over the First Year of Life. *PLOS ONE*, *10*(5), e0123780. https://doi.org/10.1371/journal.pone.0123780

Jayaraman, S., Fausey, C. M., & Smith, L. B. (2017). Why are faces denser in the visual experiences of younger than older infants? *Developmental Psychology*, *53*(1), 38–49. https://doi.org/10.1037/dev0000230

Jayaraman, S., & Smith, L. B. (2019). Faces in early visual environments are persistent not just frequent. *Vision Research, Face Perception: Experience, Models and Neural Mechanisms*, *157*, 213–221. https://doi.org/10.1016/j.visres.2018.05.005

Jones, S. S. (2009). The development of imitation in infancy. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1528), 2325–2335. https://doi.org/10.1098/rstb.2009.0045

Kaburu, S. S. K., Paukner, A., Simpson, E. A., Suomi, S. J., & Ferrari, P. F. (2016). Neonatal imitation predicts infant rhesus macaque (Macaca mulatta) social and anxiety-related behaviours at one year. *Scientific Reports*, *6*(1), 34997. https://doi.org/10.1038/srep34997

Kastendieck, T., Dippel, N., Asbrand, J., & Hess, U. (2023). Influence of child and adult faces with face masks on emotion perception and facial mimicry. *Scientific Reports*, *13*(1), 14848. https://doi.org/10.1038/s41598-023-40007-w

Keller, H., Borke, J., Lamm, B., Lohaus, A., & Dzeaye Yovsi, R. (2011). Developing patterns of parenting in two cultural communities. *International Journal of Behavioral Development*, *35*(3), 233–245. https://doi.org/10.1177/0165025410380652

Keysers, C., & Perrett, D. I. (2004). Demystifying social cognition: A Hebbian perspective. *Trends in Cognitive Sciences*, *8*(11), 501–507. https://doi.org/10.1016/j.tics.2004.09.005

Kildare, C. A., & Middlemiss, W. (2017). Impact of parents mobile device use on parent-child interaction: A literature review. *Computers in Human Behavior*, *75*, 579–593. https://doi.org/10.1016/j.chb.2017.06.003

Kilner, J. M., Friston, K. J., & Frith, C. D. (2007). Predictive coding: An account of the mirror neuron system. *Cognitive Processing*, *8*(3), 159–166. https://doi.org/10.1007/s10339-007-0170-2

Klein Velderman, M., Bakermans-Kranenburg, M. J., Juffer, F., & Van IJzendoorn, M. H. (2006). Effects of attachment-based interventions on maternal sensitivity and infant attachment: Differential susceptibility of highly reactive infants. *Journal of Family Psychology*, *20*(2), 266–274. https://doi.org/10.1037/0893-3200.20.2.266

Kret, M. E., & Akyüz, R. (2022). Mimicry eases prediction and thereby smoothens social interactions. *Cognition and Emotion*, *36*(5), 794–798. https://doi.org/10.1080/02699931.2022.2110452

Kudinova, A. Y., Woody, M. L., James, K. M., Burkhouse, K. L., Feurer, C., Foster, C. E., & Gibb, B. E. (2019). Maternal major depression and synchrony of facial affect during mother-child interactions. *Journal of Abnormal Psychology*, *128*(4), 284–294. https://doi.org/10.1037/abn0000411

Kuehne, M., Zaehle, T., & Lobmaier, J. S. (2021). Effects of posed smiling on memory for happy and sad facial expressions. *Scientific Reports*, *11*(1), 10477. https://doi.org/10.1038/s41598-021-89828-7

Le Grand, R., Mondloch, C. J., Maurer, D., & Brent, H. P. (2001). Early visual experience and face processing. *Nature*, *410*(6831), 890–890. https://doi.org/10.1038/35073749

Lepage, J., & Théoret, H. (2007). The mirror neuron system: Grasping others' actions from birth? *Developmental Science*, *10*(5), 513–523. https://doi.org/10.1111/j.1467-7687.2007.00631.x

Likowski, K. U., Mühlberger, A., Gerdes, A. B. M., Wieser, M. J., Pauli, P., & Weyers, P. (2012). Facial mimicry and the mirror neuron system: Simultaneous acquisition of facial electromyography and functional magnetic resonance imaging. *Frontiers in Human Neuroscience*, *6*, 214. https://doi.org/10.3389/fnhum.2012.00214

Lundy, B., Field, T., & Pickens, J. (1996). Newborns of mothers with depressive symptoms are less expressive. *Infant Behavior and Development*, *19*(4), 419–424. https://doi.org/10.1016/S0163-6383(96)90003-X

Marmolejo-Ramos, F., Murata, A., Sasaki, K., Yamada, Y., Ikeda, A., Hinojosa, J. A., Watanabe, K., Parzuchowski, M., Tirado, C., & Ospina, R. (2020). Your face and moves seem happier when I smile: Facial action influences the perception of emotional faces and biological motion stimuli. *Experimental Psychology*, *67*(1), 14–22. https://doi.org/10.1027/1618-3169/a000470

McDaniel, B. T., & Radesky, J. S. (2018). Technoference: Parent Distraction With Technology and Associations With Child Behavior Problems. *Child Development*, *89*(1), 100–109. https://doi.org/10.1111/cdev.12822

McIntosh, D. N. (1996). Facial feedback hypotheses: Evidence, implications, and directions. *Motivation and Emotion*, *20*(2), 121–147. https://doi.org/10.1007/BF02253868

McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: Deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. *Developmental Science*, *9*(3), 295–302. https://doi.org/10.1111/j.1467-7687.2006.00492.x

Meltzoff, A. N. (2002). Elements of a developmental theory of imitation. In A. N. Meltzoff & W. Prinz (Eds), *The Imitative Mind: Development, Evolution and Brain Bases* (pp. 19–41). Cambridge University Press. https://doi.org/10.1017/CBO9780511489969.002

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: A rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *358*(1431), 491–500. https://doi.org/10.1098/rstb.2002.1261

Meltzoff, A. N., Murray, L., Simpson, E., Heimann, M., Nagy, E., Nadel, J., Pedersen, E. J., Brooks, R., Messinger, D. S., Pascalis, L. D., Subiaul, F., Paukner, A., & Ferrari, P. F.

(2018). Re-examination of Oostenbroek et al. (2016): Evidence for neonatal imitation of tongue protrusion. *Developmental Science*, *21*(4), e12609. https://doi.org/10.1111/desc.12609

Moran, G., Krupka, A., Tutton, A., & Symons, D. (1987). Patterns of maternal and infant imitation during play. *Infant Behavior and Development*, *10*(4), 477–491. https://doi.org/10.1016/0163-6383(87)90044-0

Morris, P., Hope, E., Foulsham, T., & Mills, J. P. (2021). The Effectiveness of Mirroring- and Rhythm-Based Interventions for Children with Autism Spectrum Disorder: A Systematic Review. *Review Journal of Autism and Developmental Disorders*, *8*(4), 541–561. https://doi.org/10.1007/s40489-021-00236-z

Murray, L., Bozicevic, L., Ferrari, P. F., Vaillancourt, K., Dalton, L., Goodacre, T., Chakrabarti, B., Bicknell, S., Cooper, P., Stein, A., & De Pascalis, L. (2018). The Effects of Maternal Mirroring on the Development of Infant Social Expressiveness: The Case of Infant Cleft Lip. *Neural Plasticity*, *2018*(1), 5314657. https://doi.org/10.1155/2018/5314657

Murray, L., De Pascalis, L., Bozicevic, L., Hawkins, L., Sclafani, V., & Ferrari, P. F. (2016). The functional architecture of mother-infant communication, and the development of infant social expressiveness in the first two months. *Scientific Reports*, *6*(1), 39019. https://doi.org/10.1038/srep39019

Murray, L., Fiori-Cowley, A., Hooper, R., & Cooper, P. (1996). The Impact of Postnatal Depression and Associated Adversity on Early Mother-Infant Interactions and Later Infant Outcome. *Child Development*, *67*(5), 2512–2526. https://doi.org/10.2307/1131637

Murray, L., Hentges, F., Hill, J., Karpf, J., Mistry, B., Kreutz, M., Woodall, P., Moss, T., Goodacre, T., & the Cleft Lip and Palate Study team. (2008). The effect of cleft lip and palate, and the timing of lip repair on mother–infant interactions and infant development. *Journal of Child Psychology and Psychiatry*, *49*(2), 115–123. https://doi.org/10.1111/j.1469-7610.2007.01833.x

National Health Service. (2017, October 19). *Cleft lip and palate—Treatment*. Nhs.Uk. https://www.nhs.uk/conditions/cleft-lip-and-palate/treatment/

Niedenthal, P. M. (2007). Embodying Emotion. *Science*, *316*(5827), 1002–1005. https://doi.org/10.1126/science.1136930

Niedenthal, P. M., Augustinova, M., Rychlowska, M., Droit-Volet, S., Zinner, L., Knafo, A., & Brauer, M. (2012). Negative Relations Between Pacifier Use and Emotional Competence. *Basic and Applied Social Psychology*, *34*(5), 387–394. https://doi.org/10.1080/01973533.2012.712019

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in Attitudes, Social Perception, and Emotion. *Personality and Social Psychology Review*, *9*(3), 184–211. https://doi.org/10.1207/s15327957pspr0903_1

Niedenthal, P. M., Mermillod, M., Maringer, M., & Hess, U. (2010). The Simulation of Smiles (SIMS) model: Embodied simulation and the meaning of facial expression. *Behavioral and Brain Sciences*, *33*(6), 417–433. https://doi.org/10.1017/S0140525X10000865

Noah, T., Schul, Y., & Mayo, R. (2018). When both the original study and its failed replication are correct: Feeling observed eliminates the facial-feedback effect. *Journal of Personality and Social Psychology*, *114*(5), 657–664. https://doi.org/10.1037/pspa0000121

Oberman, L. M., Winkielman, P., & Ramachandran, V. S. (2009). Slow echo: Facial EMG evidence for the delay of spontaneous, but not voluntary, emotional mimicry in children with autism spectrum disorders. *Developmental Science*, *12*(4), 510–520. https://doi.org/10.1111/j.1467-7687.2008.00796.x

O'Callaghan, O., Whitehouse, J., Paukner, A., Witham, C. L., & Waller, B. M. (2025). Maternal care predicts facial expression processing in macaques. *iScience*, *28*(4), 112179. https://doi.org/10.1016/j.isci.2025.112179

O'Hara, M. W., & McCabe, J. E. (2013). Postpartum Depression: Current Status and Future Directions. *Annual Review of Clinical Psychology*, *9*(Volume 9, 2013), 379–407. https://doi.org/10.1146/annurev-clinpsy-050212-185612

Oostenbroek, J., Suddendorf, T., Nielsen, M., Redshaw, J., Kennedy-Costantini, S., Davis, J., Clark, S., & Slaughter, V. (2016). Comprehensive Longitudinal Study Challenges the Existence of Neonatal Imitation in Humans. *Current Biology*, *26*(10), 1334–1338. https://doi.org/10.1016/j.cub.2016.03.047

Osterling, J., & Dawson, G. (1994). Early recognition of children with autism: A study of first birthday home videotapes. *Journal of Autism and Developmental Disorders*, *24*(3), 247–257. https://doi.org/10.1007/BF02172225

Panzenbeck, P., Zubler, C., de Buitleir, E., Grobbelaar, A. O., & Leckenby, J. I. (2025). Facial reanimation in Moebius syndrome – 25-Year experience in treating bilateral facial paralysis. *Journal of Plastic, Reconstructive & Aesthetic Surgery*, *106*, 238–245. https://doi.org/10.1016/j.bjps.2025.05.013

Pereira, S., & Vannuscorps, G. (2025). Effortless facial expression recognition without motor simulation. *Scientific Reports*, *16*(1), 195. https://doi.org/10.1038/s41598-025-29209-6

Perra, O., Phillips, R., Fyfield, R., Waters, C., & Hay, D. F. (2015). Does mothers' postnatal depression influence the development of imitation? *Journal of Child Psychology and Psychiatry*, *56*(11), 1231–1238. https://doi.org/10.1111/jcpp.12413

Prinz, W. (2017). Modeling self on others: An import theory of subjectivity and selfhood. *Consciousness and Cognition*, *49*, 347–362. https://doi.org/10.1016/j.concog.2017.01.020

Quettier, T., Maffei, A., Gambarota, F., Ferrari, P. F., & Sessa, P. (2023). Testing EEG functional connectivity between sensorimotor and face processing visual regions in individuals with congenital facial palsy. *Frontiers in Systems Neuroscience*, *17*. https://doi.org/10.3389/fnsys.2023.1123221

Rayson, H., Bonaiuto, J. J., Ferrari, P. F., & Murray, L. (2017). Early maternal mirroring predicts infant motor system activation during facial expression observation. *Scientific Reports*, *7*(1), 11738. https://doi.org/10.1038/s41598-017-12097-w

Richmond, C., Parrett, L., Tye, E., & De Klerk, C. C. J. M. (2026). Two Weeks of Mirror Exposure Enhances Sensorimotor Cortex Activation but not Facial Mimicry in 4-Month-old Infants. *Developmental Science*, *29*(4), e70221. https://doi.org/10.1111/desc.70221

Rives Bogart, K., & Matsumoto, D. (2010). Facial mimicry is not necessary to recognize emotion: Facial expression recognition by people with Moebius syndrome. *Social Neuroscience*, *5*(2), 241. https://doi.org/10.1080/17470910903395692

Rizzolatti, G., & Craighero, L. (2004). THE MIRROR-NEURON SYSTEM. *Annual Review of Neuroscience*, *27*(1), 169. https://doi.org/10.1146/ANNUREV.NEURO.27.070203.144230

Rychlowska, M., Korb, S., Brauer, M., Droit-Volet, S., Augustinova, M., Zinner, L., & Niedenthal, P. M. (2014). Pacifiers Disrupt Adults' Responses to Infants' Emotions. *Basic and Applied Social Psychology*, *36*(4), 299–308. https://doi.org/10.1080/01973533.2014.915217

Schiano Lomoriello, A., Caperna, G., Carta, A., De Stefani, E., Ferrari, P. F., & Sessa, P. (2023). Sensitivity to basic emotional expressions and the emotion perception space in the absence of facial mimicry: The case of individuals with congenital facial palsy. *Emotion (Washington, D.C.)*. https://doi.org/10.1037/emo0001275

Sessa, P., Schiano Lomoriello, A., Duma, G. M., Mento, G., De Stefani, E., & Ferrari, P. F. (2022). Degenerate pathway for processing smile and other emotional expressions in congenital facial palsy: An hdEEG investigation. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *377*(1863), 20210190. https://doi.org/10.1098/rstb.2021.0190

Sexton, S., & Natale, R. (2009). Risks and Benefits of Pacifiers. *American Family Physician*.

Simpson, E. A., Fox, N. A., Tramacere, A., & Ferrari, P. F. (2014). Neonatal imitation and an epigenetic account of mirror neuron development. *The Behavioral and Brain Sciences*, *37*(2), 220. https://doi.org/10.1017/S0140525X13002495

Simpson, E. A., Murray, L., Paukner, A., & Ferrari, P. F. (2014). The mirror neuron system as revealed through neonatal imitation: Presence from birth, predictive power and evidence of plasticity. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1644), 20130289. https://doi.org/10.1098/rstb.2013.0289

Slaughter, V. (2021). Do Newborns Have the Ability to Imitate? *Trends in Cognitive Sciences*, *25*(5), 377–387. https://doi.org/10.1016/j.tics.2021.02.006

Sonnby–Borgström, M. (2002). Automatic mimicry reactions as related to differences in emotional empathy. *Scandinavian Journal of Psychology*, *43*(5), 433–443. https://doi.org/10.1111/1467-9450.00312

Sroufe, L. A. (1997). *Emotional Development: The Organization of Emotional Life in the Early Years*. Cambridge University Press.

Stein, A., Arteche, A., Lehtonen, A., Craske, M., Harvey, A., Counsell, N., & Murray, L. (2010). Interpretation of infant facial expression in the context of maternal postnatal depression. *Infant Behavior and Development*, *33*(3), 273–278. https://doi.org/10.1016/j.infbeh.2010.03.002

Stel, M., van den Heuvel, C., & Smeets, R. C. (2008). Facial Feedback Mechanisms in Autistic Spectrum Disorders. *Journal of Autism and Developmental Disorders*, *38*(7), 1250–1258. https://doi.org/10.1007/s10803-007-0505-y

Steward, B. A., Mewton, P., Palermo, R., & Dawel, A. (2025). Interactions between faces and visual context in emotion perception: A meta-analysis. *Psychonomic Bulletin & Review*, *32*(5), 1987–2003. https://doi.org/10.3758/s13423-025-02678-6

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. *Journal of Personality and Social Psychology*, *54*(5), 768–777.

Székely, E., Lucassen, N., Tiemeier, H., bakermans-kranenburg, M., van IJzendoorn, M., Kok, R., Jaddoe, V., Hofman, A., Verhulst, F., & Herba, C. (2014). Maternal depressive symptoms and sensitivity are related to young children's facial expression recognition: The Generation R Study. *Development and Psychopathology*, *26*, 1–13. https://doi.org/10.1017/S0954579413001028

Tidemann, I. T., & Melinder, A. M. D. (2022). Infant behavioural effects of smartphone interrupted PARENT-INFANT interaction. *British Journal of Developmental Psychology*, *40*(3), 384–397. https://doi.org/10.1111/bjdp.12416

Tronick, E., Als, H., Adamson, L., Wise, S., & Brazelton, T. B. (1978). The Infant's Response to Entrapment between Contradictory Messages in Face-to-Face Interaction. *Journal of the American Academy of Child Psychiatry*, *17*(1), 1–13. https://doi.org/10.1016/S0002-7138(09)62273-1

Vanden Abeele, M. M. P., Abels, M., & Hendrickson, A. T. (2020). Are Parents Less Responsive to Young Children When They Are on Their Phones? A Systematic Naturalistic Observation Study. *Cyberpsychology, Behavior, and Social Networking*, *23*(6), 363–370. https://doi.org/10.1089/cyber.2019.0472

Vannuscorps, G., Andres, M., & Caramazza, A. (2020). Efficient recognition of facial expressions does not require motor simulation. *eLife*, *9*, e54687. https://doi.org/10.7554/eLife.54687

Wagenmakers, E.-J., Beek, T., Dijkhoff, L., Gronau, Q. F., Acosta, A., Adams, R. B., Albohn, D. N., Allard, E. S., Benning, S. D., Blouin-Hudon, E.-M., Bulnes, L. C., Caldwell, T. L., Calin-Jageman, R. J., Capaldi, C. A., Carfagno, N. S., Chasten, K. T., Cleeremans, A., Connell, L., DeCicco, J. M., … Zwaan, R. A. (2016). Registered Replication Report Strack, Martin, & Stepper (1988). *Perspectives on Psychological Science*, *11*(6), 917–928. https://doi.org/10.1177/1745691616674458

Wood, A., Lupyan, G., Sherrin, S., & Niedenthal, P. (2016). Altering sensorimotor feedback disrupts visual discrimination of facial expressions. *Psychonomic Bulletin & Review*, *23*(4), 1150–1156. https://doi.org/10.3758/s13423-015-0974-5

Wood, A., Rychlowska, M., Korb, S., & Niedenthal, P. (2016). Fashioning the Face: Sensorimotor Simulation Contributes to Facial Expression Recognition. *Trends in Cognitive Sciences*, *20*(3), 227–240. https://doi.org/10.1016/j.tics.2015.12.010

Yeung, M. K. (2022). A systematic review and meta-analysis of facial emotion recognition in autism spectrum disorder: The specificity of deficits and the role of task characteristics. *Neuroscience & Biobehavioral Reviews*, *133*, 104518. https://doi.org/10.1016/j.neubiorev.2021.104518