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TITLE

PATTERNS IN MOTION: A DYNAMIC SYSTEMS INVESTIGATION OF CAREGIVER-INFANT INTERACTION IN THE CONTEXT OF VISUAL IMPAIRMENT

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ABSTRACT

Rationale. Caregiver-infant interactions can be understood as a dynamic system which self-organises in patterns of coordination that emerge over time. Visual face-to-face engagement and caregiver tactile inputs are fundamental elements of early interaction and may play a role in shaping and maintaining the stability of the system. However, limited knowledge exists regarding the way in which the dyadic organisation unfolds when visual sensory input is reduced. Specifically, the gap is evident in relation to the system's stable coordination patterns, or attractor states. **Objective.** This study aimed to evaluate and compare attractor states in caregiver-infant dyads with and without visual sensory deficit during interaction and subsequent to a dyadic interactive perturbation. Additionally, it aimed to identify and describe emergent attractor states arising from the coordination between infant emotionality and parental touch behaviours. **Methods.** Twenty-four visually impaired (VI) and twenty-one full-sighted (FS) control dyads were videotaped during the Face-to-Face Still-Face Paradigm (Tronick et al., 1978), a 6-min validated procedure organized into three episodes: Play (2-min unconstrained face-to-face interaction), Still-Face (2-min laboratory-induced maternal unresponsiveness), and Reunion (2-min unconstrained face-to-face interaction). The dyadic interaction was micro-analytically coded for infant emotional state (negative, neutral, positive) and caregiver touch function (no touch, playful touch, affective touch). State Space Grid methodology was used to quantify dynamic dyadic organization through Cell Duration, Visit Duration, and Return Visits, and to identify preferred interactional states across Play and Reunion episodes. **Results.** During spontaneous interaction, dyads with VI infants showed a more centralized attractor landscape organized primarily around neutral emotional states, particularly neutral infant emotionality paired with the absence of maternal touch. In contrast, FS dyads exhibited a broader distribution of attractor states involving positive emotionality and playful touch, suggesting greater organizational complexity and diversification of interaction patterns. Consistent with these differences, group effects emerged across multiple indicators of dyadic organization during the Play episode. However, following the Still-Face perturbation, group differences in Cell Duration and Visit Duration were no longer detected, while differences in the overall frequency of return visits remained. **Conclusions.** Caregiver-infant dyads involving VI infants appear to organize around different, rather than impaired, interactional patterns. Although spontaneous interactions are characterized by a more centralized organization, both dyadic systems demonstrate sensitivity to perturbation and comparable abilities to re-establish coordinated interaction. These findings support a dynamic systems perspective of development and highlight the adaptive capacity of early caregiver-infant relationships under altered sensory conditions.

Key words: Visual impairment; Caregiver-infant interaction; State Space Grids; Attractor states; Face-to-Face Still-Face Paradigm.

Chapter 1

EARLY SOCIAL INTERACTION AS A DYNAMIC DYADIC SYSTEM

1.1 Caregiver-Infant Interaction as a Relational and Dyadic System

Contemporary infant research conceptualizes infants as active participants in their own development rather than passive recipients of environmental stimulation. Accordingly, development is understood to emerge through continuous emotional, cognitive, and social exchanges between infants and their caregivers, with both partners actively contributing to the developmental process (Stern, 1985; Lichtenberg, 2014). During the first year of life, caregivers constitute the infant's primary social environment, providing the immediate context through which early experiences are interpreted, regulated, and organised. Within this relational context, caregiver-infant interaction is considered a central mechanism through which emotional, cognitive, and communicative capacities develop (Bowlby, 1982).

A key contribution to this relational perspective came from Louis Sander, who proposed that early caregiver-infant interactions play a fundamental role in shaping subsequent communication and psychological organisation. Drawing on observations of early development, Sander noted that infants and caregivers engage in structured exchanges involving gaze coordination, tactile contact, rhythmic patterns, and regulatory adjustments, even prior to the onset of language development or intentional communication. He referred to these recurring interactional patterns as “pre-communicative structures,” proposing that they provide the foundation from which later communicative and psychological processes emerge (Sander, 1977). This perspective contributed to the growing view that development is organised through ongoing interaction between infant and caregiver rather than arising solely from the individual child, laying the groundwork for conceptualising caregiver-infant interaction as a relational system.

Building on this relational perspective, caregiver-infant interaction came to be understood as an interconnected dyadic system in which both partners continuously influence and respond to one another through reciprocal exchanges. Through repeated exchanges involving gaze, vocalisations, facial expressions, touch, and affective signals, caregiver and infant co-construct patterns of interaction that support early socio-emotional and communicative development (Stern et al., 1985; Trevarthen & Aitken, 2001).

Framing caregiver-infant interaction as a dyadic system shifts the focus away from considering the infant or caregiver as independent individuals and towards the organisation of the exchange between them. In line with this view, Sameroff's transactional model emphasised that development arises through recurrent reciprocal influences between a caregiver and infant, rather than from the child or environment alone (Sameroff, 1975). Similarly, Fogel conceptualised caregiver-infant interaction as an ongoing relational communication system in which both partners continuously co-construct and regulate the flow of interaction across time (Fogel & Thelen., 1987). Together, these perspectives support the view that developmental change emerges through the organisation of caregiver-infant exchanges at the level of the dyad.

1.2 Dynamic Systems Approaches to Caregiver-Infant Interaction

Conceptualising caregiver–infant interaction as a relational and dyadic system requires a theoretical framework capable of explaining how coordinated patterns of interaction emerge and change over time. General Systems Theory first conceptualised development as emerging through the interaction of multiple interdependent components rather than from isolated elements acting independently (Bertalanffy, 1968). These principles later converged with

Dynamic Systems Theory (DST) (Smith & Thelen, 2003), which further conceptualised development as a non-linear process of self-organisation unfolding across time (Howe & Lewis, 2005). Within this framework, caregiver-infant interaction is understood as a dynamic relational system in which behavioural coordination, affective exchange, and synchrony emerge through repeated reciprocal exchanges. Consequently, interaction patterns are viewed as self-organised properties of the dyadic system that develop and reorganise through ongoing interaction (Howe & Lewis, 2005; Provenzi, 2024).

Previous research on caregiver-infant interaction has largely focused on identifying frequencies of behaviours, attachment classifications, or average interaction outcomes (Hollenstein, 2007; Richters et al., 1997). Although these approaches have been very informative, they may overlook how interaction patterns develop and reorganise across time. Dynamic systems approaches are therefore particularly useful for examining caregiver-infant interaction as a continuously evolving relational process rather than as a series of isolated outcomes.

Within DST, dyadic interactions can be understood as moving through a range of different states over time (Hollenstein, 2007). Through repeated interaction, some states may become more recurrent or be occupied for disproportionately longer periods than others, giving rise to preferred modes of organisation often described as attractor states (Guastello et al., 2008; Lunkenheimer & Dishion, 2009). In caregiver-infant interaction, these attractor states may reflect recurring patterns of coordination, emotional responding, or communicative exchange. This stability can support predictability and coherence within the interaction, facilitating coordinated engagement and emotional regulation. Attractor states may develop within real-time interactions across seconds and minutes while also consolidating through repeated experiences over longer developmental timescales. Consequently, caregiver-infant dyads may gradually organise around preferred interaction patterns, such as sensitive coordination and reciprocal engagement or, alternatively, more maladaptive forms of interaction characterised by persistent mismatch or distress. Importantly, attractor states can also be quantified using dynamic measures, such as the duration or recurrence of specific dyadic states over time (Lewis et al., 1999).

At the same time, dynamic systems must remain sufficiently flexible to accommodate change. Although caregiver-infant dyads may gradually organise into stable interaction patterns, they remain inherently open to perturbations, such as social stressors (Chow et al., 2010). Flexibility therefore reflects the capacity of dyads to reorganise interaction patterns and transition between states in response to changing environmental demands (Hollenstein et al., 2004). In this sense, stability and flexibility are complementary properties of caregiver-infant interaction: attractor states support organisation and predictability, whilst flexibility enables adaptation and recovery following disruption (Cerezo et al., 2012, Hollenstein, 2007). Understanding how dyads balance stability with flexibility therefore requires methodological approaches capable of preserving temporal information and capturing moment-to-moment changes in dyadic states. This need has motivated increasing application of dynamic systems methodologies within developmental research.

1.3 Mutual Regulation and Dyadic Coordination

Tronick's Mutual Regulation Model (MRM) further explains this dynamic systems perspective by conceptualising development as emerging through ongoing processes of mutual regulation between infant and caregiver (Tronick, 2003). In contrast to models that predominantly emphasised internal representations of attachment relationships (Bowlby, 1969), the MRM addressed moment-to-moment micro-regulatory processes emerging as a result of the caregiver-infant interaction (Fonagy, 2015). Hence, the model underscores how continuous subtle nonverbal, affective, and socio-emotional exchanges, through which meaning and coherence are co-constructed, support the organization of early relational experiences and developmental outcomes (Tronick, 2018).

The MRM suggests that infants have self-organizing neurobehavioral capacities that eventually enable the regulation of behavioural states and the progressive assembly of a sense of self in the relational environment (Tronick, 2007; Tronick & Beeghly, 2011). However, during infancy these regulatory capacities are still developing and thus need support from a "larger dyadic regulatory system" provided by the caregiver (Tronick, 2007, p. 9). As a result, regulation is achieved through ongoing co-regulation within the dyad. Infants communicate their needs through biopsychological signals, including vocalisations, facial expressions, quality of touch, and changes in body odour. Then the caregiver decodes and responds to these signals contingently and help organise the infant's affective and behavioural state (Fonagy, 2015; Tronick, 2007). Through repeated cycles of coordinated interaction, caregiver and infant gradually begin to organise their responses relative to one another, fostering increasing predictability and coherence within the dyad and supporting emerging expectations about caregiver responsiveness (Fonagy, 2015; Lyons-Ruth et al., 1998).

Significantly, Tronick underscores that healthy caregiver-infant interactions are not cases of uninterrupted synchrony but rather continuous cycles of coordination, mismatch, and repair (Tronick & Cohn, 1989). Within the MRM, mismatches are considered developmentally normative and inevitable components of social interaction (Procissi et al., 2026). In fact, repeated experiences of mismatch and repair support infants' emerging regulatory capacities, resilience, and sense of relational coherence (DiCorcia & Tronick, 2011; Tronick, 2003). Tronick described this ongoing co-constructed process as one of "co-creativity," highlighting the continual negotiation through which dyadic partners reorganise their interactional states within the relational system (Tronick, 2003).

Building on DST, Tronick's MRM suggests that dyadic coordination depends not only on the presence of communicative behaviours, but also on their temporal contingency, whereby each partner's behaviour is shaped by preceding interactional exchanges. Consistent with this view, Philips and colleagues (2023) demonstrated that caregivers adjust their own behaviours contingently in response to the infant and that the infants are behaviourally and neurally sensitive to such contingent responding. Through repeated cycles of contingent exchange, infants gradually develop expectations regarding caregiver responsiveness relational regularities (Gergely & Watson, 1999; Stern, 1999). A common metaphor used to illustrate these moment-to-moment exchanges is that of two partners dancing together. Their movements are coordinated, but not precisely choreographed. These movements represent the micro-temporal rhythms occurring within an interaction between an infant and their caregiver (Provenzi et al., 2018; Tronick and Reck, 2009; Wass et al., 2024). Moreover, these rhythmic interaction patterns may vary in stability over time, with some becoming increasingly organised and recurrent while others remain more flexible and transient.

1.4 Emotional and Tactile Communication in Early Interaction

1.4.1 Infant Emotional Expressions as Regulatory Signals

Within caregiver-infant interaction, emotions are not internal states but also functional signals that guide social exchange. Infants use emotional expressions to communicate needs, direct caregiver attention, and convey their ongoing evaluation of the interaction and surrounding environment. When interactions are experienced as rewarding or goals are being met, infants are more likely to display positive affective states such as interest or joy, which support continued engagement. By contrast, disruptions to caregiver responsiveness or failures to achieve interactional goals may elicit distress, frustration, or withdrawal (Tronick, 1989; Field, 2025; Sorce et al., 1985; Tronick et al., 1978). In this context, infant emotional expressions offer continuous information about the infant's evaluations of interactions and their environment.

However, infants' capacities for independent emotion regulation are still under-developed, poorly coordinated, and limited in early developmental stages. Therefore, emotion regulation is scaffolded within the caregiver-infant relationship. Infants' affective displays help organise caregiver responses, while caregivers' contingent reactions support attempts to maintain or restore engagement within the interaction (Tronick, 1989). Gianino and Tronick (1988) described these affective displays as "other-directed regulatory behaviours," emphasising that infant emotions do not merely reflect internal experience but actively influence caregiver behaviour and contribute to the co-regulation of the dyad. Emotional expression can therefore be understood as a central channel through which infants participate in early social interaction and through which processes of coordination, disruption, and repair become visible.

1.4.2 Parental Touch as a Channel of Co-Regulation

Within the first year of life, caregiver-infant interaction is predominantly characterised by pre-verbal communication, relying not only on visual and vocal signals but also on bodily and sensory channels such as touch (Montirosso & McGlone, 2020). Touch plays a key role in regulating infant arousal, supporting attachment formation, and reinforcing psychophysiological balance within the dyad (Fotopoulou & Tsakiris, 2017; Montirosso & McGlone, 2020). Through behaviours such as holding, caressing, and skin-to-skin contact, caregivers provide continuous tactile input that can soothe distress, sustain engagement, and support the infant's emerging capacity for regulation (Lucia et al., 2024). Therefore, parental touch functions not merely as physical contact, but as a communicative and regulatory resource through which caregivers help organise the infant's emotional state within interaction (Montirosso & McGlone, 2020).

Parental touch comprises multiple communicative functions that support caregiver-infant interaction in different ways. Previous research has distinguished between nurturing, playful, accompaniment, and attention-seeking touch, demonstrating that these forms of tactile behaviour contribute differently to infant emotional regulation and interactional coordination (Jean & Stack, 2009, 2012). Using second-by-second observations during the Face-to-Face Still-Face Paradigm (FFSF), Lowe et al. (2016) further demonstrated that different forms of maternal touch are differentially associated with infant affect, highlighting the importance of considering the functional quality of touch rather than merely its presence or absence. Touch also carries relational meaning. Different forms of tactile interaction can convey comfort, affection, stimulation, or control, making touch an important channel through which caregivers communicate availability and regulate the infant's experience (Hertenstein et al., 2006).

A particularly relevant form of tactile communication is affective touch. Gentle caressing activates the infant's specialized C-tactile afferents and has been linked to emotional regulation, soothing, and social bonding (McGlone et al., 2014; Fotopoulou & Tsakiris, 2017). For example, Van Puyvelde and colleagues (2015, 2019a, 2019b) demonstrated that even a brief period of parental stroking delivered at C-tactile-optimal velocity elicited sustained increases in infants' respiratory sinus arrhythmia (RSA), a component of heart rate variability that reflects physiological self-regulatory capacity. Conversely, limited parental tactile support has been associated with reduced RSA development (Field et al., 1995). Together, these findings suggest that affective touch contributes to the maturation of infants' physiological and emotional regulatory systems and may represent one mechanism through which early nurturing contact promotes secure attachment and healthy socio-emotional development (Fotopoulou et al., 2022; McGlone et al., 2017; Walker et al., 2022). Moreover, touch contributes not only to immediate behavioural regulation but also to the affective quality of the caregiver-infant exchange. Repeated tactile interactions may further support the emergence of interpersonal mutuality and coordinated interactional rhythms from the earliest stages of postnatal development (Montirosso & McGlone, 2020).

Although affective touch has received considerable attention because of its soothing and affiliative properties, playful touch appears to fulfil a complementary function within caregiver-infant interaction. Rather than primarily reducing arousal, playful tactile exchanges encourage active social engagement, shared positive affect, and reciprocal interaction. During the FFSF Paradigm, Lowe et al. (2016) found that playful touch was the only form of maternal touch associated with subsequent increases in infant positive affect. Moreover, mothers increased their use of playful touch during the Reunion episode following the Still-Face stressor, suggesting that this form of tactile interaction may contribute to infant emotion regulation during interaction repair. (Lowe et al., 2016).

Touch can therefore be understood as a vehicle for co-construction of meaning within the dyad through which caregivers respond to infant cues and help scaffold the unfolding interaction across time (Fogel, 2006). Consequently, examining different functional forms of parental touch provides valuable insight into the dynamic processes through which caregivers regulate infant emotional states and sustain coordinated interaction over time.

1.4.3 Emotion and Touch as Interacting Channels of Dyadic Communication

Although maternal touch and infant emotionality have often been studied separately, both constitute central channels through which caregiver-infant co-regulation unfolds. Infant affective displays may signal engagement, distress, or withdrawal and, in doing so, help organise caregiver responses within the dyad (Gianino & Tronick, 1988; Tronick, 1989). In turn, maternal touch shapes the infant's emotional state by soothing distress, sustaining engagement, and supporting emotional responsiveness during interaction (Stack & Muir, 1992; Montirosso & McGlone, 2020).

Taken together, the literature suggests that that infant emotionality and parental touch operate as interdependent channels of communication that jointly contribute to the organisation of early caregiver–infant interaction. Despite this, few studies have examined how these channels unfold together within ongoing dyadic interaction, particularly across moments of disruption and repair. This gap is especially relevant within the Face-to-Face Still-Face (FFSF) paradigm, where dyadic coordination is deliberately perturbed, allowing infant emotional responses and caregiver regulatory behaviours to be examined across changing interactional contexts.

1.5 Studying Dyadic Reorganization Following Perturbation

1.5.1 The Still Face Paradigm

The FFSF procedure, developed by Tronick et al. (1978), is one of the most widely used paradigms to gain insight into the implicit processes unfolding during caregiver-infant interaction. Initially developed to examine whether infants actively contribute to social interaction, the paradigm has since become a central framework for investigating emotional regulation, dyadic coordination, stress responses, and processes of mutual regulation during infancy (Tronick, 1989). Experimentally, the FFSF introduces a brief disruption into caregiver-infant interaction, thereby allowing researchers to examine how dyads respond to perturbation, mismatch, and repair across moment-to-moment exchanges.

The FFSF procedure involves three consecutive 2-minute episodes of face-to-face interaction between an infant and their caregiver. During the first Play episode, the dyad engages in naturalistic recreational play, as they would do at home, to reproduce an ecological interaction. This is followed by the Still-Face episode, during which the caregiver adopts an unresponsive state while maintaining a neutral facial expression. Following this perturbation, during the Reunion episode, the caregiver attempts to re-engage with the infant by initiating the normal interaction once again (Mesman et al., 2009). The paradigm therefore provides a structured context in which dyadic coordination is first established, then perturbed, and finally reopened for repair.

One of the most robust findings associated with the paradigm is the “still-face effect.” When the caregiver becomes emotionally neutral and unresponsive, infants typically increase attempts to re-engage with their caregiver through gaze, vocalizations, or body movements. Because the caregiver remains unresponsive, infants may increasingly display self-regulatory behaviours such as gaze aversion, self-soothing, and negative affect (Mesman et al., 2013; Tronick & Beeghly, 2011). The Still-Face episode therefore functions as a non-harmful social stressor that disrupts the communicative rhythm between the dyadic partners and elicits emotional and physiological stress responses in the infant (Ham et al., 2006).

The Reunion episode offers an opportunity to restore coordinated interaction and emotional reciprocity between the caregiver and infant. However, even after the caregiver resumes interaction, infants may remain distressed or only partially re-engage, a pattern described as the “carry-over-effect” (Carter et al., 1990; Cohn & Tronick, 1983; Nagy et al., 2017; Stoller & Field, 1982). The latency and quality of interactive repair provide important insight into the dyad’s capacity to restore co-regulation and emotional recovery following perturbation (Hu et al., 2025).

1.5.2 Maternal Touch, Infant Emotionality, and the FFSF

A smaller number of studies have examined maternal touch specifically within the FFSF paradigm. This work suggests that the function of maternal touch varies across episodes of the paradigm and may be associated with infants' regulatory and emotional responses. For example, Jean and Stack (2012) found that mothers used different types of touch across the FFSF episodes, with more attention-seeking touch during baseline play and more nurturing or playful touch during reunion. They also reported associations between maternal touch and infants' self-regulatory behaviours. Similarly, Stack and Muir (1992) showed that different forms of maternal touch were linked to different infant emotional responses, while Feldman et al. (2010) found that allowing maternal touch during the still-face episode reduced infants' reactivity to the stressor.

Together, these studies suggest that maternal touch may contribute to how infants respond to disruption and how dyads attempt to restore engagement following perturbation. However, research has only begun to examine how maternal touch and infant emotionality are organised together across the different episodes of the FFSF paradigm. In particular, less is known about how these two channels co-occur dynamically within the dyad, and whether changes in maternal touch are associated with shifts in infant emotional expression across moments of disruption and repair. Examining these processes requires an approach capable of capturing not only whether touch or emotion occur, but how their joint organisation changes across time within the unfolding interaction.

1.6 State Space Grid Methodology in Caregiver-Infant Research

1.6.1 Overview of SSGs

Given the dynamic, non-linear, and temporally evolving nature of caregiver-infant interaction described previously, methodological approaches capable of capturing moment-to-moment changes in dyadic states are required. To address this need, Lewis and colleagues (1999) developed the State Space Grid (SSG) methodology, an innovative graphical and quantitative approach designed to examine dynamic systems as they unfold over time. In the present study, caregiver-infant interaction is conceptualised as a dynamic dyadic system, making SSG methodology particularly appropriate for examining how interactional states are organised across time.

In contrast to methods that rely mainly on behavioural frequency counts or overall interaction ratings, SSGs retain the sequential structure of interactions, enabling researchers to investigate how dyadic states develop, persist, and shift over time (Hollenstein, 2007). This is especially relevant in caregiver-infant research, where interaction unfolds through ongoing cycles of coordination, disruption, and repair, and in paradigms such as the FFSF procedure, where dyads are expected to reorganise their interaction across changing episodes.

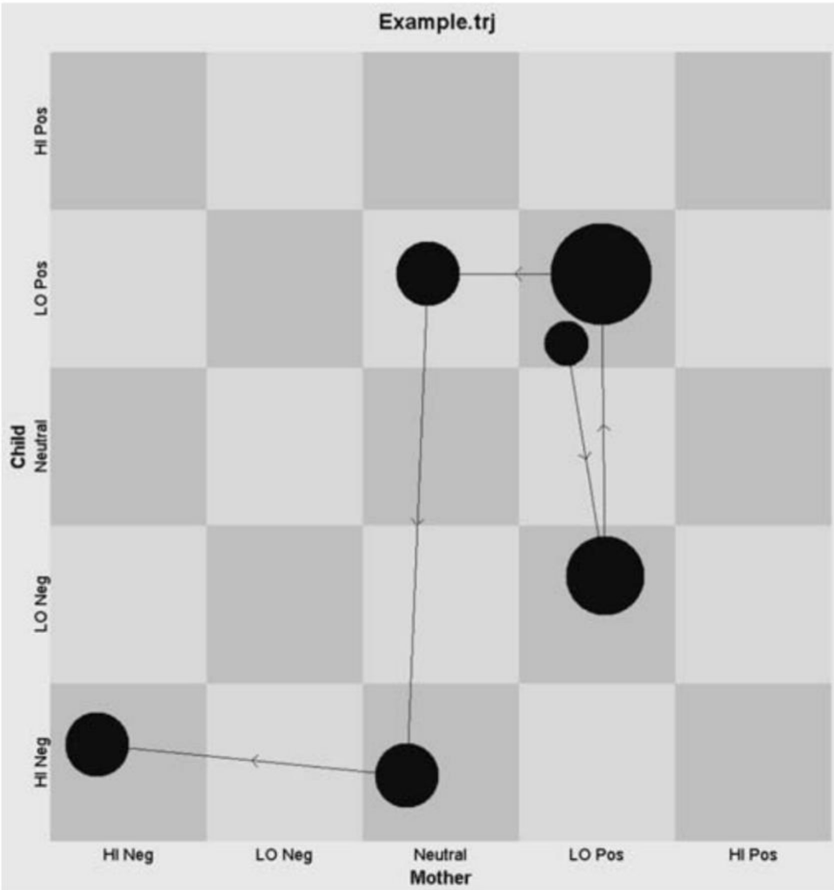
1.6.2 Construction of SSGs

Figure 3 illustrates the basic structure of a State Space Grid. It was created with GridWare 1.1 (Lamey, Hollenstein, Lewis, & Granic, 2004), a free program that can be downloaded from the web (www.statespacegrids. org). This program allows ordinal data to be represented within multidimensional state space (Hollenstein, 2007). Each SSG is constructed by plotting one categorical or ordinal variable on the horizontal x-axis and another on the vertical y-axis, such that the intersection of the two axes forms a grid of all possible dyadic states (Hollenstein et al., 2004). In caregiver-infant research, these axes typically represent one behavioural dimension for the infant and one for the caregiver. Accordingly, each cell within the grid corresponds to a unique dyadic state defined by the simultaneous behavioural configuration of both partners at a given moment.

The variables positioned along each axis derive from micro-analytic coding schemes applied to caregiver and infant behaviour, enabling interaction to be decomposed into discrete behavioural states (Grumi et al., 2022). As the interaction unfolds, the dyad moves across the grid, producing a trajectory that preserves both the sequence and duration of dyadic states over time. This allows SSG methodology to capture the temporal organisation of interaction, including how dyadic states emerge, recur, and shift across the course of an interaction, rather than reducing caregiver-infant exchange to isolated behavioural frequencies alone.

Figure 1.

Example of a State Space Grid Illustrating Caregiver-Infant Interaction.



Note. An example of a state space grid illustrating 15 seconds of a parent-child interaction. The size of the plot point indicates the duration of each dyadic event (Figure taken from Hollenstein, 2007).

Chapter 2

SOCIO-EMOTIONAL DEVELOPMENT AND CAREGIVER-INFANT INTERACTION IN VISUAL IMPAIRMENT

2.1 Socio-Emotional Development in the Context of Visual Impairment

Socio-emotional development includes the development of the different aspects that are crucial for the child to eventually become an active social partner in relationships. Importantly, healthy emotional development is not only a developmental milestone but a process of acquiring fundamental skills that enables success across several functional domains, ranging from academic achievement to the quality of social relationships. Children who are equipped to successfully regulate their emotions are better able to manage stress, actively participate in learning, and establish positive interpersonal relationships (Malti & Dys, 2018). Hence, socio-emotional development is considered to be a crucial relational process that is established from birth and continues to evolve throughout the lifespan (Lang et al., 2017).

Children with visual impairment (VI) face specific developmental challenges as reduced visual input may constrain opportunities to observe, interpret, and respond to social events in the environment. As a result, they experience fewer and less consistent opportunities through which to develop social competence (Roe, 2008). These challenges may be especially relevant in early infancy, when many aspects of social engagement are strongly supported by visual cues. Empirical findings suggest that some domains of socio-emotional development may be particularly vulnerable in infants with VI. Using a standardised parent interview, Dale, Tadić, and Sonksen (2013) found that infants with VI were generally able to participate in social interactions, attract attention, and seek caregiver proximity when distressed, but showed greater difficulties in areas such as joint attention and the coordination of shared interests during play with adults. Similarly, Dote-Kwan and Chen (2010) reported that blind infants showed lower persistence in environmental exploration, less positive mood, and reduced interest in their surroundings than infants with low vision. Together, these findings suggest that VI does not preclude social engagement, however, it may shape the way socio-emotional competencies are expressed and supported in early development. At the same time, socio-emotional development in VI appears to be heterogeneous. Available evidence suggests that developmental processes may be particularly vulnerable in children with more severe VI, although direct comparisons across different degrees of vision loss remain limited. Additionally, infants with VI frequently present with other disabilities, which may further complicate developmental outcomes and contribute to variability in socio-emotional functioning (Hatton et al., 2007).

Importantly, these difficulties should not be understood as inevitable consequences of visual impairment alone. Rather, socio-emotional development in VI unfolds within broader relational and communicative contexts, raising the question of how caregivers and infants adapt their interaction when access to visual information is reduced (Loots et al., 2003).

2.2 Caregiver-Infant Interaction in the Context of Visual Impairment

The quality of caregiver-infant interactions is widely accepted as a crucial factor that influences children's development (Loots et al., 2003). A substantial body of research has highlighted the central role of visual cues in fostering early synchronous and reciprocal infant-caregiver interactions (Brazelton, Tronick, Adamson, Als, &Wise, 1975; Bullowa, 1979; D'Odorico &Levorato, 1990; Stem, Beebe, Jaffe, & Ben-nett, 1977; Trevarthen, 1979). For example, D'Odorico and Levorato (1990) proposed that mutual visual interaction provides the earliest opportunity through which caregivers and infants establish an interactive exchange characterised by shared control. Consequently, investigating caregiver-infant interaction in the context of visual impairment provides a unique opportunity to examine how dyadic communication and coordination become organised when one of the principal communicative channels is altered

Early observational accounts suggested that reduced visual access alters the communicative signals through which infants engage caregivers during interaction. Fraiberg (1979) reported that mothers of infants who were blind often experienced difficulty recognising and interpreting their infants' communicative behaviours because infants displayed fewer facial expressions, spontaneous smiles, and vocalisations that typically initiate reciprocal social exchange. Instead, infants frequently expressed themselves through more subtle motor behaviours, such as hand movements, which were not consistently recognised by caregivers as communicative signals.

These early observations anticipated later findings demonstrating that infants who are blind and their caregivers establish alternative pathways for social interaction and early communication (Perez-Pereira &Conti-Ramsden, 1999). Video recordings of mother-infant interactions have suggested that, when alternative communicative behaviours are taken into account, infants who are blind follow a similar developmental pathway to communication as their sighted peers (Preisler, 1991; Rowland, 1983; Urwin, 1983). Moreover, evidence indicates no differences in the quality and appropriateness of the interactive behaviours of mothers of children with VI when compared to mothers of sighted children. Rather, the differences observed in the mother-infant interactions reflect the appropriate adaptations to the children's sensory losses and developmental levels (Conti-Ramsden &Perez-Pereira, 1999; Dote-Kwan, 1995; Kekelis & Andersen, 1984). In line with this, Conti-Ramsden and Pérez-Pereira (1999) observed that mothers of children who were blind used significantly more descriptive and repeated directives than the mothers of sighted children. The authors argued that these adaptations may play an important role in facilitating joint attention and conversational interactions.

Although these early and observational studies established that caregiver-infant interaction in the context of visual impairment is characterised by adaptation, more recent research has provided a broader understanding of the specific interactional behaviours through which these adaptations emerge. A recent systematic review (Grumi et al., 2021) found that, compared with typically developing peers, infants with VI were less likely to respond to maternal vocalisations with behaviours such as smiling or vocalising. Moreover, they reported that infants with VI showed reduced contingent responding to caregiver verbalisations and touch, together with a more restricted repertoire of emotional expressions (Nagayoshi et al., 2017; Rogers & Puchalski, 1984; Rowland, 1984). Similarly, Tröster and Brambring (1992) observed that 9-month-old blind infants primarily displayed pleasure and anger during interaction and often required more intense stimulation to provoke a response. Collectively, these findings suggest that VI may influence not only the occurrence of communicative behaviours but also the reciprocal processes through which caregiver and infant coordinate their interaction. Reduced responsiveness and a narrower range of emotional expressions may alter the timing and contingency of caregiver-infant exchanges, requiring caregivers to adapt their communicative strategies in order to maintain coordinated interaction.

Despite these interactional differences, the existing literature generally reports no major differences in overall maternal sensitivity or verbal interaction compared with mothers of sighted infants (Nagayoshi et al., 2017; Rogers & Puchalski, 1984). Rather, mothers of infants with VI appear to adapt the ways in which they communicate to accommodate their infant's sensory characteristics. Specifically, they tend to rely less on visually directed behaviours, such as face-directed orientation or requests for visual attention (Campbell, 2003; Rogers & Puchalski, 1984), while increasing behaviours that remain fully accessible to the infant, including conversational initiations, communicative acts, verbal scaffolding, and greater reliance on the verbal channel (Conti-Ramsden & Pérez-Pereira, 1999; Pérez-Pereira & Conti-Ramsden, 2001).

These adaptations may also present new interactional challenges. Reduced reliance on visual communication can result in less optimal reciprocal positioning between caregiver and infant (Rogers & Puchalski, 1984), potentially limiting caregivers' access to facial expressions and other visually mediated indicators of emotional state (Loots et al., 2003). These interactional challenges may be further compounded by neurodevelopmental processes. Reduced visual input during infancy has been proposed to influence the maturation of social-attentional networks, increasing reliance on alternative sensory modalities to support interaction (Gui et al., 2023). Consequently, these factors make it more challenging for caregivers to maintain attunement with their infants' cognitive and emotional states while accurately interpreting their communicative signals during reciprocal interaction (Hughes et al., 1999; Pauker et al., 2018).

Recent evidence indicates that this interactional reorganisation may be particularly evident in the coordination between infant emotionality and caregiver touch. Using the Face-to-Face Still-Face paradigm, Grumi et al. (2025) reported that infants with visual impairment displayed lower levels of positive emotionality during the Play episode than sighted infants, while caregivers in both groups increased nurturing touch during Reunion following the Still-Face perturbation. These findings suggest that although infants with visual impairment remain responsive to social perturbation, caregiver touch may represent an increasingly important resource during interactional repair. However, little is currently known about how these communicative channels become dynamically organised together over time, particularly across episodes of interactional disruption and recovery.

2.3 Towards a Dynamic Understanding of Caregiver-Infant Interaction in Visual Impairment

The literature reviewed throughout this chapter indicates that caregiver-infant interaction in the context of VI is characterised by adaptative reorganisation rather than simple reduction in social engagement (Conti-Ramsden & Pérez-Pereira, 1999; Grumi et al., 2021). Rather than disrupting reciprocal interaction, reduced visual access appears to alter the ways in which caregiver and infant coordinate their behaviour. This highlights the importance of understanding not only which behaviours occur during interaction, but also how these behaviours become organised within the dyad across time.

Despite these advances, important gaps remain in our understanding of how these adaptive processes unfold. Much of the existing literature has focused on caregivers' verbal behaviours, including descriptions, requests, conversational initiations, and language-facilitating strategies (Andersen, et al., 1984; Grumi et al., 2021). While this work has substantially advanced knowledge of language adaptation in caregiver-infant interaction, comparatively less attention has been devoted to non-verbal communicative modalities (Provenzi et al., 2020). Consequently, relatively little is known about how non-verbal communicative behaviours become coordinated within the caregiver-infant dyad, despite their likely importance for maintaining reciprocal interaction under conditions of reduced visual input.

In addition, previous studies have generally examined caregiver and infant behaviours separately or have relied on global behavioural frequencies, summary scores, or broad measures of parental sensitivity. While these methodologies successfully identify which behaviours occur during interaction, they provide limited insight into how caregiver and infant behaviours become coordinated across time (Provenzi et al., 2018). Moreover, these organisational processes are difficult to detect using traditional observational approaches that quantify behaviours without preserving their sequential and temporal structure (Hollenstein, 2007). Consequently, the processes through which caregiver-infant dyads reorganise across interaction and establish stable patterns of engagement remain poorly understood.

Dynamic analytical approaches provide an opportunity to address these limitations by examining interaction as an evolving system rather than as a collection of isolated behaviours. In particular, SSG methodology preserves the temporal organisation of caregiver-infant exchanges and enables caregiver and infant behaviours to be examined simultaneously, allowing researchers to investigate how interaction patterns emerge, stabilise, reorganise, and recover across time (Hollenstein, 2007; Grumi et al., 2022). Although SSG methodologies have been successfully applied to investigate flexibility, coordination, and co-regulation in caregiver-infant interaction across typically developing and clinical populations (Cerezo et al., 2012, 2017, 2019; Lunkenheimer et al., 2012; Sravish et al., 2013), their application to caregiver-infant dyads involving VI remains extremely limited.

The present study therefore aims to address these empirical and methodological gaps by adopting a dynamic systems perspective to investigate the organisation of caregiver-infant interaction in dyads involving infants with VI. Specifically, by examining the moment-to-moment coordination of maternal touch and infant emotionality during the FFSF paradigm using SSG methodology, this study aims to provide new insights into how caregiver-infant dyads reorganise their interaction following social perturbation under conditions of reduced visual access.

Chapter 3

THE CURRENT STUDY

Previous studies have primarily quantified individual communicative behaviours, such as caregivers' verbalisations, maternal sensitivity, or infants' emotional expressions, through behavioural frequencies or global ratings (Conti-Ramsden & Pérez-Pereira, 1999; Nagayoshi et al., 2017; Grumi et al., 2021). While these approaches have substantially advanced our understanding of caregiver-infant interaction in VI, they cannot determine how caregiver and infant behaviours become coordinated across time or how dyads reorganise following interactional disruption. In contrast, SSG methodology preserves the sequential and temporal organisation of interaction, allowing caregiver and infant behaviours to be examined simultaneously as an integrated dyadic system. Consequently, SSG analyses make it possible to investigate not only which behaviours occur, but also how interactional patterns emerge, stabilise, recur, and reorganise following perturbation through the identification of attractor states and indices of flexibility (Hollenstein, 2007).

Moreover, although SSG methodology has been widely applied to investigate caregiver-child interaction in typically developing and other clinical populations (Hollenstein, 2007; Cerezo et al., 2012; Lunkenheimer et al., 2012), its application to caregiver-infant dyads involving infants with VI remains extremely limited. Consequently, it is currently unknown whether the interactional adaptations observed in behavioural studies are also reflected in the dynamic organisation of caregiver-infant exchanges.

The present study explores these gaps in the literature by applying a dynamical systems perspective and utilizing SSG analyses to examine the temporal organisation of caregiver-interaction within the FFSF paradigm. Specifically, it focuses on the coordination between infant emotionality and parental touch behaviours, two fundamental channels of early communication that become particularly important when visual information is limited. This approach permits the identification of preferred and recurrent interaction patterns that may not be noticeable using traditional analytic methods, thereby contributing to both theoretical and clinical understanding of early dyadic interaction.

3.1 Rationale and Study Aim

This study explored the organization of dyadic interaction amongst infants with VI and their mothers within the FFSF paradigm. A SSG methodology was applied to describe the temporal dynamics of coordination between infant emotionality and parental touch behaviours. The specific aims of the study are outlined below:

1. To compare the dynamic organisation of caregiver-infant interaction and its reorganisation following social perturbation during the FFSF paradigm between dyads involving infants with VI and FS infants.
2. To describe emergent attractor states evolving from the coordination between infant emotionality and parental touch behaviours.

3.2 Method

The research was conducted at the Developmental Psychobiology Unit of IRCCS Mondino Foundation in association with the Centre of Child Neuro-ophthalmology of the same scientific institution. The overarching aim of the study was to explore how infants with VI interact with their mothers and denote the central elements of this dyadic interaction. Comparisons were made between this clinical group and a control group constituting typically developing full-sighted age-matched infants. The experiment consisted of one laboratory session where the mother and infant were asked to perform an interaction task in the lab.

3.2.1 Participants

The sample consisted of 45 infant-mother dyads, including 24 infants diagnosed with visual impairment (VI) and 21 full-sighted infants (FS). The infants with VI were recruited from the IRCCS Mondino Foundation Hospital's Paediatric Neuro-ophthalmology clinical centre whereas the control group participants were recruited through public advertisement in the region. At testing, the groups were balanced for sex and age. The inclusion criteria for the VI group required a clinical diagnosis of low vision established through standardized tests (Teller Acuity Cards) and were not eligible to be diagnosed complete blindness. VI could result from peripheral, cerebral, or oculomotor origin, on the condition that it led to reduced grating acuity. Isolated peripheral visual impairment (PVI) is a result of the contribution of the pre-geniculostriate primary visual pathways (i.e. eye and optic nerve) excluding the initial contribution of cerebral structures, as in inherited retinal dystrophy or congenital cataract. Cerebral visual impairment (CVI) involves the retro-geniculostriate visual pathways (i.e. optic radiation, occipital cortex) and/or associative areas, whereas ocular motor impairment (OMI) represents abnormalities of ocular motility (fixation, smooth pursuit, saccades) that can produce reduced grating acuity (i.e. nystagmus, oculo-motor apraxia). The inclusion criteria for the FS group required infants to have no history of VI, other sensory impairments, or neurological conditions, and to have been born at term following an uncomplicated pregnancy.

3.2.2 Procedure

3.2.2.1 Laboratory Session. The session was designed to incorporate the FFSF paradigm (Tronick et al.,1978). The dyads entered a quiet room where they could interact without distractions. The complete procedure was videotaped using two cameras: one capturing the entire body and face of the infant; the other capturing the mother's face and upper body. The experimental room setup consisted of an infant highchair and a stool for the mother, positioned approximately 40 centimetres in front of the highchair. This distance allowed the dyad to interact using visual and tactile contact. The experimental paradigm is organised into three 2-minute episodes known as the play, still-face, and reunion. During the Play and Reunion episodes, mothers were instructed to interact with their infant as they normally would at home, without the use of toys or a pacifier. During the still-face episode, the mother was asked to stop interacting with the infant and sustain a neutral facial expression while looking at the infant, refraining from any communicative signals or behaviours.

3.2.3 Measures

3.2.3.1 Interactive measures. Movavi Video Suite 2020 software (version 20.4.1; https://bit.ly/3PSbGBM) was used to process the FFSF videotapes off-line. The two separate files from the mother and the infant were combined and synchronised into one video file. This newly combined video file was micro-analytically coded in two-second intervals using ELAN Linguistic Annotator software (version 5.9; Max-Planck-Institute for Psycholinguistics, Nijmegen, The Netherlands; https://archive.mdpi.nl/tla/elan).

Infant Behaviour. Infant’s behaviour was coded for emotional status using the Emotionality Coding System (IECS; Brambilla et al. 2020; see Table 1 and Appendix A for the complete coding manual). The coding system is designed to qualitatively assess the infant's emotional state throughout the interaction with the caregiver, rather than the intensity or subtlety of individual emotional expressions. For each FFSF episode, the total duration of each emotional state was calculated for every infant. To account for minor variations in episode length between participants, the duration of each emotional state was divided by the total duration of the corresponding episode and expressed as a percentage of the episode time.

Table 1

Infant emotionality coding system (IECS)

Label	Description
Negative	The infant displays clear negative emotionality. Negative emotionality might be expressed through facial expression (eyes, mouth, general movement of the face muscle and/or of the body), and/or non-verbal communication (cry, to be fussy, stressed, shout). To code 1, there should be clear expressions of positive emotionality.
Neutral	The infant does not display clear positive or negative emotionality through facial expression or other modalities (e.g., the infant is calm, relaxed).
Positive	The infant displays clear positive emotionality. Positive emotionality might be expressed through facial expression (e.g., eyes, mouth, general movement of the face muscle and/or of the body) or vocalizations (e.g., laughing). To code 3, there should be clear expressions of positive emotionality.

Maternal Behaviour. Maternal touch was coded using the Parental Touch Coding System (PTCS, Brambilla et al., 2020; see Table 2 and Appendix A). This coding system is based on denoting the different types and functions of maternal touch. It does not intend to measure the intensity or place of maternal tactile stimulations. In parallel to the infant's measures, maternal behavioural codes were also reported as percentages of time for each FFSF episode.

The present study focused on three cell-based measures extracted separately for each dyadic state, as these capture complementary aspects of dyadic organisation. The first measure, Cell Duration, represents the total amount of time spent within a given dyadic state across an entire FFSF episode. Longer cell durations indicate that the dyad remained in a particular behavioural configuration for a greater proportion of the interaction. Consequently, this measure provides an index of the relative stability or dominance of individual dyadic states during the interaction. Visit Duration was the following measure that was extracted from each dyadic state. It represents the average duration of each individual visit to a particular cell. Whereas Cell Duration reflects the cumulative time spent within a state, Visit Duration indicates how long the dyad typically remained in that state before transitioning to another interactional configuration. Consequently, this measure reflects the persistence of individual interactional episodes independently of how frequently the state occurred. Lastly, Cell Return Visits represents the number of times the dyad re-entered a previously occupied interactional state after transitioning to other states. Greater numbers of return visits indicate that a particular interactional configuration was repeatedly revisited throughout the interaction, providing information regarding the recurrence of specific dyadic states and the temporal organisation of caregiver-infant interaction.

Each of these measures provide a multidimensional description of caregiver-infant interaction by capturing the stability, persistence, and recurrence of specific interactional states across time. In doing so, they offer a more comprehensive characterisation of dyadic organisation than traditional frequency-based behavioural analyses, which quantify behaviours but do not preserve their sequential and temporal organisation.

Table 2

Parental touch coding system (PTCS)

Label	Description
No touch	The parent does not touch the infant.
Playful touch	Parent touch characterized by high-paced, dynamic, repetitive, fast cinematic features. The parent may tickle, shake, squeeze, lift, move fingers on the infant's belly like a little ant, move the hands or legs of the infant. Typically, the goal is provoking fun in the infant.
Affective touch	Parent touch is characterized by a sense of closeness or by the goal of soothing and calming the infant. The parent may be kissing, stroking, or massaging the infant with affectionate intent or to regulate negative emotional states.

3.2.3.2 SSG measures. The present study focused on three cell-based measures extracted separately for each dyadic state, as these capture complementary aspects of dyadic organisation. The first measure, Cell Duration, represents the total amount of time spent within a given dyadic state across an entire FFSF episode. Longer cell durations indicate that the dyad remained in a particular behavioural configuration for a greater proportion of the interaction. Consequently, this measure provides an index of the relative stability or dominance of individual dyadic states during the interaction. Visit Duration was the following measure that was extracted from each dyadic state. It represents the average duration of each individual visit to a particular cell. Whereas Cell Duration reflects the cumulative time spent within a state, Visit Duration indicates how long the dyad typically remained in that state before transitioning to another interactional configuration. Consequently, this measure reflects the persistence of individual interactional episodes independently of how frequently the state occurred. Lastly, Cell Return Visits represents the number of times the dyad re-entered a previously occupied interactional state after transitioning to other states. Greater numbers of return visits indicate that a particular interactional configuration was repeatedly revisited throughout the interaction, providing information regarding the recurrence of specific dyadic states and the temporal organisation of caregiver-infant interaction.

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3.2.4 SSG Data Extraction

Following behavioural coding, caregiver touch and infant emotionality codes were combined to generate individual caregiver-infant trajectories, which were imported into GridWare Version 1.1 (Lamey et al., 2004) for SSG analysis. Within each grid, infant emotionality (negative, neutral, positive) was plotted on the horizontal axis and caregiver touch behaviours (no touch, playful touch, affective touch) were represented on the vertical axis, producing a 3 × 3 state space comprising nine possible dyadic states. GridWare represents each dyad as a continuous trajectory moving through these states. Each caregiver-infant trajectory represented the moment-to-moment movement of the dyad across these states throughout the interaction.

GridWare automatically computes quantitative measures, which in the present study are Cell Duration, Visit Duration, and Cell Return Visits, from each caregiver-infant trajectory that describe different properties of the dyadic system. These measures preserve the sequential and temporal organisation of caregiver-infant interaction, allowing the stability, recurrence, and organisation of interactional patterns to be examined over time (Hollenstein, 2007). Within

GridWare, a cell corresponds to one unique combination of infant emotionality and caregiver touch behaviours, whereas a visit refers to a continuous period during which the dyad remains within that cell before transitioning to another interactional state. Consequently, the same cell may be visited multiple times throughout a single interaction.

3.2.5 Plan of Analyses

The measures on which statistical analysis were done were extracted from the GridWare software (version 1.15b; Lamey, Hollenstein, Lewis, & Granic, 2004) and Jamovi 2.2.5 (version 2.2, The Jamovi Project, 2021; https://www.jamovi.org) was used to run the statistical analysis. The level of significance was set at $p < 0.05$.

3.2.5.1 Goal 1. To address the first aim, the extracted SSG measures (Cell Duration, Visit Duration, and Cell Return Visits) were compared between caregiver-infant dyads involving infants with VI and FS infants during the Play and Reunion episodes of the FFSF paradigm. Cell duration and visit duration were analysed using repeated-measures ANOVAs, while cell return visits were analysed using linear mixed-effects models (LMMs).

Repeated-measures ANOVAs were carried out separately for the Play and Reunion episodes. In these analyses, Cell (e.g., Ineg_Pno – Ipos_Paff) was included as a within-subject factor, and Group (VI vs FS dyads) as a between-subject factor. These analyses were conducted for both cell duration and visit duration measures, investigating main effects of cell and group, along with their interaction (cell x group), to further assess variability in dyadic organization across interactional states. Additionally, LMMs were conducted separately for the Play and Reunion episodes to analyse Cell Return Visits. LMMs were selected because return visit data contained structural missing values, as some dyads never visited particular interactional states. Unlike repeated-measures ANOVA, LMMs allow repeated observations with incomplete data while accounting for the dependency of observations within participants. Group, Cell, and the Group × Cell interaction was entered as fixed effects, whereas participant ID was included as a random intercept to account for repeated observations within caregiver-infant dyads.

3.2.5.2 Goal 2. To investigate the second aim, specifically the identification of emergent attractor states emerging from the coordination between infant emotionality and parental touch, a descriptive analytic approach was implemented within the SSG framework. Dyadic states were characterized by the integration of infant emotionality (negative, neutral, positive) and parental touch behaviours (no touch, playful touch, affective touch). For each state, mean values of cell duration were calculated to quantify the relative amount of time dyads spent in each interactional organization.

To identify attractor states, the overall mean Cell Duration was calculated across all dyadic states separately for each group and interaction episode. This overall mean served as a descriptive reference against which the mean Cell Duration of each individual dyadic state was compared. Dyadic states with mean Cell Duration values exceeding the overall mean were identified as attractor states, representing interactional configurations that were preferred by the dyadic system, as reflected by the greater amount of time spent in those states. Conversely, dyadic states with mean Cell Duration values below the overall mean represented interactional configurations that were occupied for relatively shorter periods of time.

3.3 Results

3.3.1 Sample Description

The groups of infants (VI and FS) were comparable in terms of sex distribution (VI: 18 males, 63%; FS: 14 males, 66%, χ^2 (1) = 0.38, $p = 0.538$) and age at testing (VI mean age = 11.2 months, SD = 1.08; FS mean age = 11.1, SD = 1.06, $t(43) = -0.19$, $p = 0.852$). Descriptive statistics for parental touch behaviours during the play and reunion episodes are presented in Table 3. Across both groups, periods of no touch accounted for the largest proportion of interaction time.

Table 3

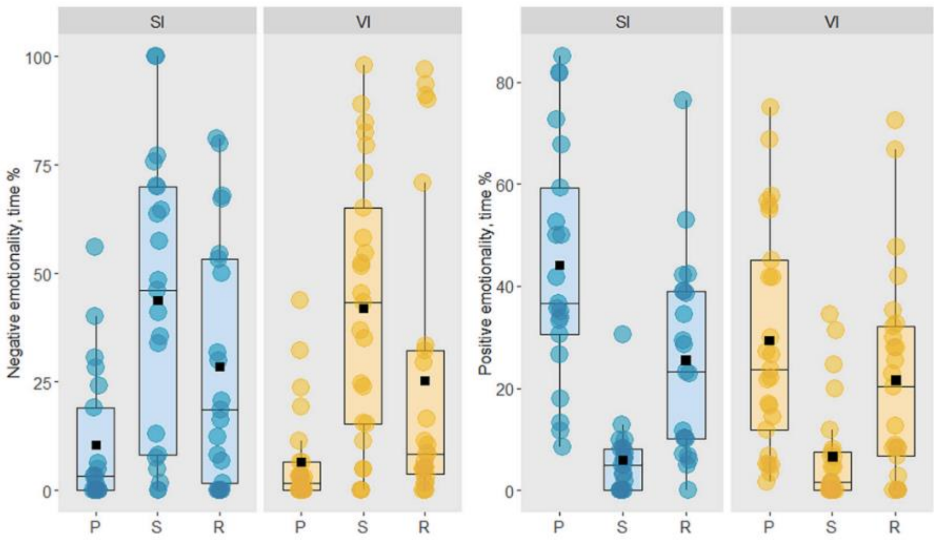
Descriptive Statistics and Group Differences (FS vs. VI) in Maternal Measures.

Episode	Variable	Group	N	Mean	SD	Minimum	Maximum
Play	No touch	FS	21	45.49	16.68	14.89	74.60
		VI	25	48.08	27.91	0.00	96.70
	Playful touch	FS	21	25.84	12.41	1.67	51.70
		VI	25	24.02	19.68	0.00	73.30
	Affective touch	FS	21	6.28	8.10	0.00	27.10
		VI	25	9.80	10.21	0.00	28.30
Reunion	No touch	FS	21	34.64	22.01	0.00	83.60
		VI	25	37.18	25.44	0.00	80.60
	Playful touch	FS	21	23.16	18.89	0.00	67.30
		VI	25	27.03	13.72	3.28	48.30
	Affective touch	FS	21	13.98	14.37	0.00	45.20
		VI	25	14.14	19.51	0.00	84.80

Infant emotionality throughout the FFSF procedure is presented in Figure 2. For negative emotionality, a significant Episode effect was observed, $F(2, 86) = 29.32$, $p < .001$, $\eta p^2 = 0.405$, with no significant effect for Group, $F(1, 43) = 0.30$, $p = .588$, $\eta p^2 = 0.007$, nor a significant Episode*Group interaction, $F(2, 86) = 0.02$, $p = .982$, $\eta p^2 = <0.001$. Planned contrasts indicated that, across both groups, aggregated negative emotionality was significantly greater during the Still-Face episode than during both the Play, $t(43) = -8.00$, $p < .001$, and Reunion episodes, $t(43) = 3.07$, $p = .004$. Across both groups, negative emotionality remained higher during the Reunion episode compared with the Play episode, $t(43) = -18.70$, $p < .001$. For positive emotionality, a significant Episode effect also emerged, $F(2, 86) = 45.54$, $p < .001$, $\eta p^2 = 0.514$. Group effect was not statistically significant, $F(1, 43) = 3.31$, $p = .076$, $\eta p^2 = 0.072$. The Episode effect was further characterised by a significant Episode*Group interaction effect, $F(2, 86) = 3.95$, $p = .023$, $\eta p^2 = 0.084$. Post-hoc comparisons revealed that infants with VI showed lower positive emotionality than FS infants during the Play episode, $t(43) = 2.45$, $p = .018$.

Figure 2.

Negative and Positive Infant Emotionality across the Face-to-Face Still-Face Procedure Infants with Visual Impairment (VI) and Full-Sighted (FS) Infants.



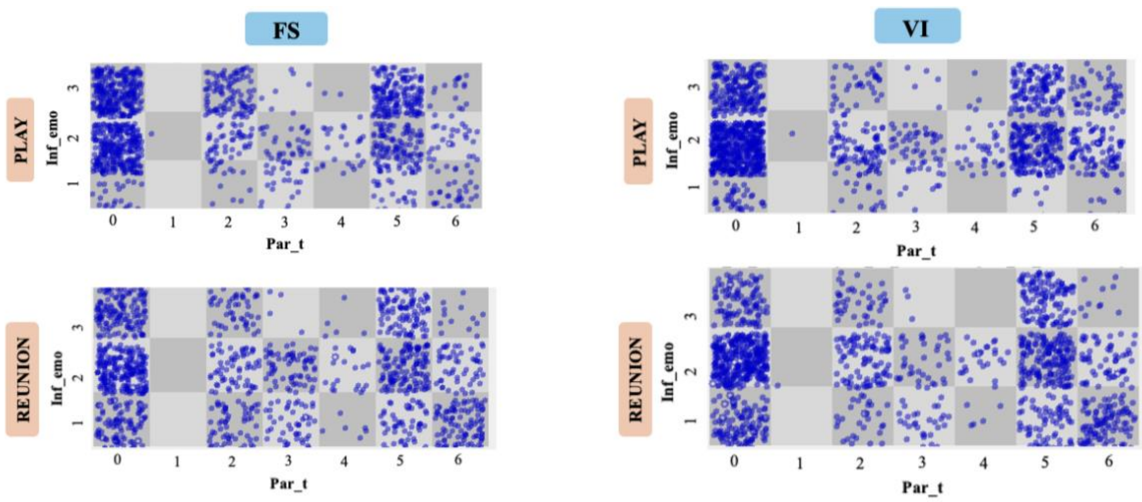
Note. P, Play; S, Still-Face; R, Reunion. Black square represents the mean. Reproduced from Grumi et al. (2025).

3.3.2 Goal 1: Dynamic Organisation and Reorganisation of Dyadic Interaction.

Figure 3 presents representative SSG trajectories for caregiver-infant dyads involving FS and VI infants during both interactional episodes. Visual inspection suggests that interaction was concentrated within particular regions of the state space in both groups, indicating that some dyadic states were occupied more frequently than others. The quantitative analyses reported below examine these interactional patterns using the extracted SSG measures.

Figure 3.

Representative State Space Grid (SSG) Trajectories during the Play and Reunion Episodes for Caregiver-Infant Dyads involving Full-Sighted (FS) and Visually Impaired (VI) Infants.



Note. Each point represents one observed dyadic state defined by the combination of infant emotionality (y-axis) and caregiver touch behaviour (x-axis). Regions containing a greater concentration of observations indicate dyadic states that were occupied more frequently during the interaction.

3.3.2.1 Cell Duration. A significant main effect of Cell was found for Cell Duration during the Play episode, $F(8, 344) = 26.63$, $p < .001$. Importantly, a significant Cell*Group interaction was observed, $F(8, 344) = 2.54$, $p = .011$. The main effect of Group was not significant, $F(1, 43) = 1.23$, $p = .273$. Post hoc comparisons revealed a significant difference between groups only for the dyadic state characterised by neutral infant emotionality and affective touch (Ineut_Paff), with dyads including infants with VI showing longer Cell Durations than FS dyads, $t(43) = 2.22$, $p = .032$. Trend-level differences suggested that FS dyads showed longer Cell Durations for the state characterised by negative infant emotionality and playful touch (Ineg_Pplay), whereas VI dyads tended to show longer Cell Durations for the state characterised by neutral infant emotionality and no touch (Ineut_Pno), $t(43)=1.73$, $p=.091$. All remaining comparisons were not statistically significant (all $p \geq .121$).

For the Reunion episode, a significant main effect of Cell was found for Cell Duration, $F(8, 344) = 9.61$, $p < .001$. However, the Cell*Group interaction was not significant, $F(8, 344) = 0.53$, $p = .836$, and no significant main effect of Group was observed, $F(1, 43) = 0.05$, $p = .820$. Post hoc comparisons further indicated that states characterised by neutral infant emotionality and no touch (Ineut_Pno) showed significantly longer Cell Durations than states involving neutral infant emotionality with affectionate touch (Ineut_Paff), $t(43) = 4.74$, $p < .001$, positive infant emotionality with no touch (Ipos_Pno), $t(43) = 3.52$, $p = .026$, positive infant emotionality with playful touch (Ipos_Pplay), $t(43) = 3.35$, $p = .041$, and positive infant emotionality with affectionate touch (Ipos_Paff), $t(43) = 5.96$, $p < .001$. In addition, the dyadic states characterised by neutral infant emotionality with playful touch (Ineut_Pplay) showed significantly longer Cell Durations than neutral infant emotionality with affectionate touch (Ineut_Paff), $t(43) = 3.69$, $p = .016$, and positive infant emotionality with affectionate touch (Ipos_Paff), $t(43) = 6.04$, $p < .001$. All remaining comparisons were not statistically significant (all $p \geq .075$).

Figure 4.

Mean Cell Duration Across Dyadic States in VI (clinical) And FS (control) Caregiver-Infant Dyads During the Play Episode

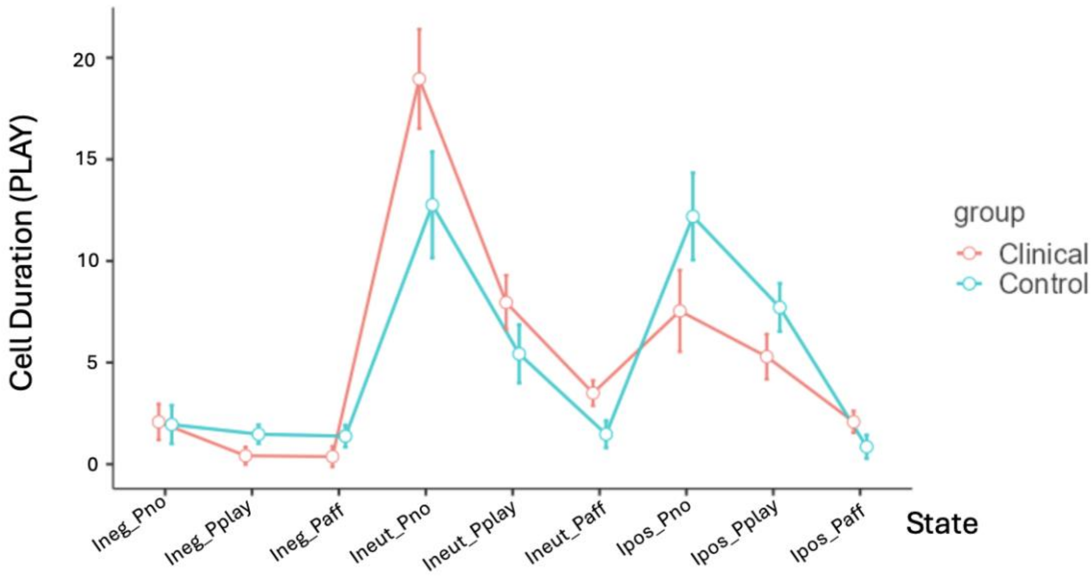
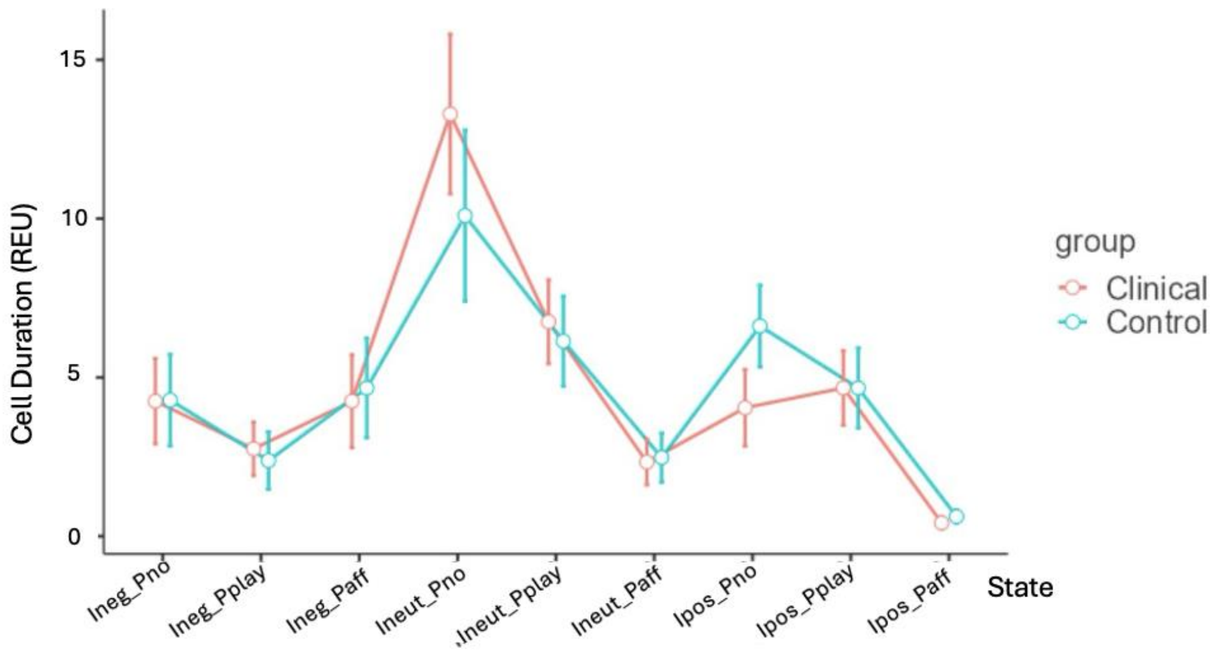


Figure 5.

Mean Cell Duration Across Dyadic States in VI (clinical) And FS (control) Caregiver-Infant Dyads During the Reunion Episode



3.3.2.2 Visit Duration. A significant main effect of Cell was found for visit duration during the Play episode, F (8, 344) = 19.09, p < .001. Importantly, a significant Cell*Group interaction was observed, F (8, 344) = 2.01, p = .044. The main effect of Group was not significant, F (1, 43) = 0.37, p = .547. Post hoc comparisons revealed that dyads involving infants with VI showed significantly longer visit durations than FS dyads in the states characterised by neutral infant emotionality with no touch (Ineut_Pno), t (43) = 5.34, p < .001, and neutral infant emotionality with playful touch (Ineut_Pplay), t (43) = 4.21, p = .013. Conversely, FS dyads showed significantly longer visit durations than VI dyads in the states characterised by positive infant emotionality with no touch (Ipos_Pno), t (43) = 4.61, p = .004, and positive infant emotionality with playful touch (Ipos_Pplay), $t(43) = 4.30$, $p = .010$. All remaining comparisons were not statistically significant (all $p \geq .090$).

For the Reunion episode, a significant main effect of Cell was found for visit duration, $F(8, 344) = 6.67$, $p < .001$. However, the Cell*Group interaction was not significant, $F(8, 344) = 0.32$, $p = .957$, and no significant main effect of Group was observed, $F(1, 43) = 0.083$, $p = .775$. Post hoc comparisons further indicated that the state characterised by neutral infant emotionality and no touch (Ineut_Pno) showed significantly longer visit durations than states involving neutral infant emotionality with affectionate touch (Ineut_Paff), $t(43) = 4.74$, $p < .001$, positive infant emotionality with no touch (Ipos_Pno), $t(43) = 3.52$, $p = .026$, positive infant emotionality with playful touch (Ipos_Pplay), $t(43) = 3.35$, $p = .041$, and positive infant emotionality with affectionate touch (Ipos_Paff), $t(43) = 5.96$, $p < .001$. In addition, states characterised by neutral infant emotionality with playful touch (Ineut_Pplay) showed longer visit durations than neutral infant emotionality with affectionate touch (Ineut_Paff), $t(43) = 3.69$, $p = .016$, and positive infant emotionality with affectionate touch (Ipos_Paff), $t(43) = 6.04$, $p < .001$. All remaining comparisons were not statistically significant (all $p \geq .075$).

Figure 6.

Mean Visit Duration Across Dyadic States in VI (clinical) And FS (control) Caregiver-Infant Dyads During the Play Episode

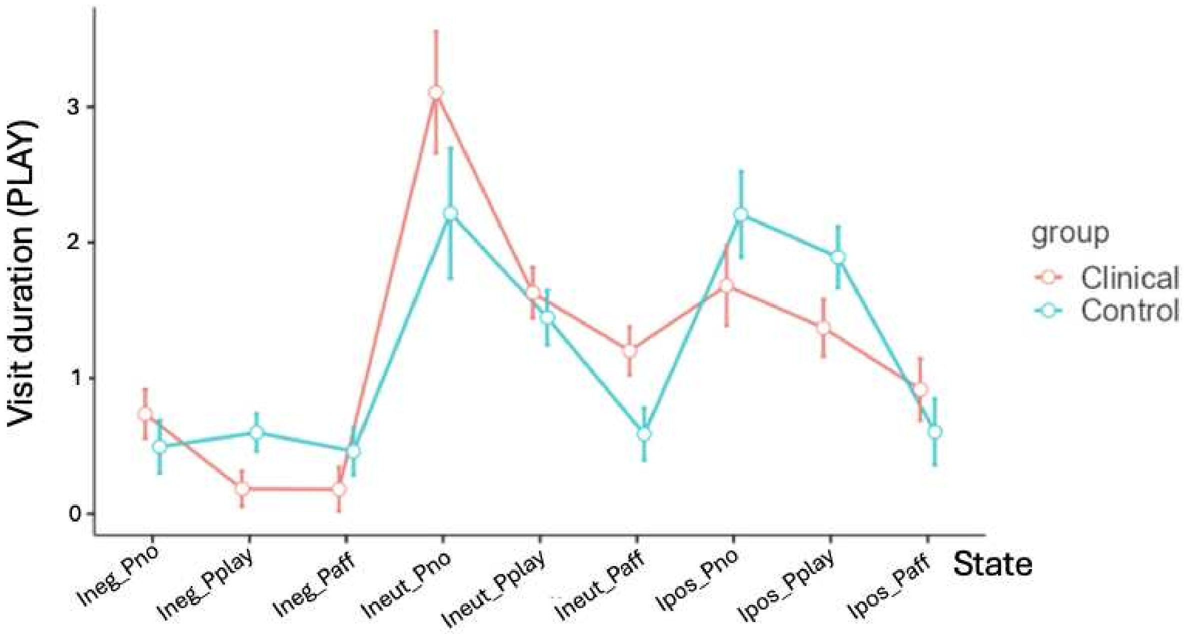
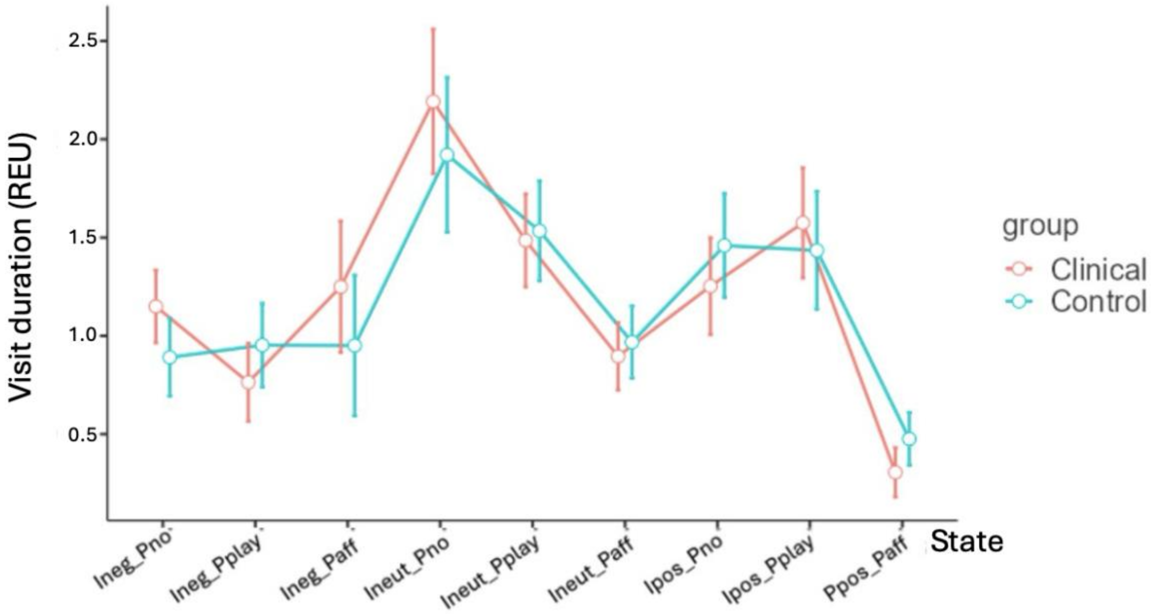


Figure 7.

Mean Visit Duration Across Dyadic States in VI (clinical) And FS (control) Caregiver-Infant Dyads During the Reunion Episode



3.3.2.3 Cell Return Visits. For the Play episode, a significant main effect of Cell was observed F (8, 162) = 3.07, p=.003. Post hoc comparisons indicated that the dyadic state characterised by neutral infant emotionality with no touch (Ineut_Pno) showed significantly fewer return visits than the dyadic states characterised by neutral infant emotionality with playful touch (Ineut_Pplay), $t(162) = -2.86$, $p = .005$, neutral infant emotionality with affective touch (Ineut_Paff), $t(162) = -3.86$, $p < .001$, and positive infant emotionality with affective touch (Ipos_Paff), $t(162) = -3.27$, $p = .001$. In addition, the dyadic state characterised by neutral infant emotionality with affective touch (Ineut_Paff) showed significantly more return visits than the states characterised by positive infant emotionality with no touch (Ipos_Pno), $t(162) = 2.40$, $p = .017$, and positive infant emotionality with playful touch (Ipos_Pplay), t(162) =

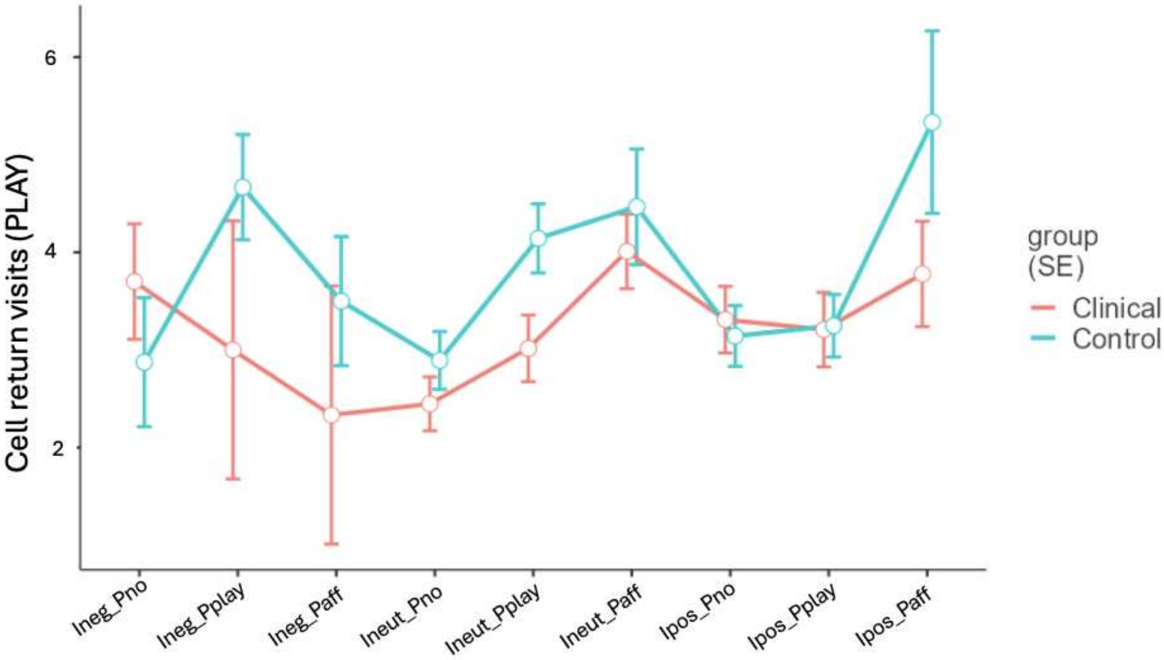
2.34, $p = .020$. The dyadic state characterised by positive infant emotionality with affective touch (Ipos_Paff) also showed significantly more return visits than the states characterised by positive infant emotionality with no touch (Ipos_Pno), $t(162) = 2.26$, $p = .025$, and positive infant emotionality with playful touch (Ipos_Pplay), $t(162) = 2.23$, $p = .027$. All remaining comparisons were not statistically significant (all $p \geq .071$).

A significant main effect of Group was also observed, $F(1, 162) = 3.96$, $p = .048$, indicating that, FS dyads showed a higher overall frequency of return visits than dyads involving infants with VI. However, the interaction between Cell*Group was not significant $F(8, 162) = 1.04$, $p=.406$.

For the Reunion episode, the main effect of Cell was not significant, $F(8, 137.4) = 1.40$, $p=.200$. A significant main effect of Group was observed, $F(1, 60.5) = 5.15$, $p = .027$, indicating that FS dyads showed a higher overall frequency of return visits than dyads involving infants with VI. The Cell*Group interaction was not significant, $F(8, 137.4) = 1.84$, $p=.074$.

Figure 8.

Mean Cell Return Visits Across Dyadic States During Play in VI And FS Caregiver-Infant Dyads



3.3.3 Goal 2: Emergent Attractor States

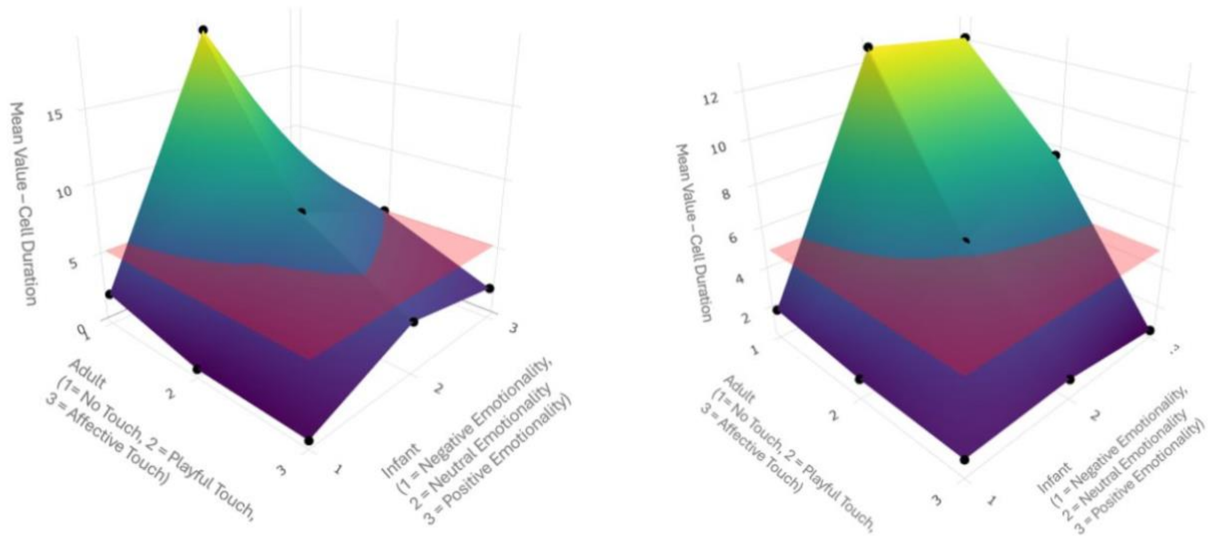
Throughout the Play episode, both VI and FS caregiver-infant dyads demonstrated attractor states, identified as dyadic configurations with mean Cell Duration values exceeding the overall mean (Figure 9).

Among dyads involving infants with VI, the most prominent attractor state was characterised by neutral infant emotionality and the absence of parental touch (Ineut_Pno). Additional elevations above the overall mean were observed for neutral infant emotionality paired with playful touch (Ineut_Pplay) and, to a lesser extent, positive infant emotionality paired with no touch (Ipos_Pno). Overall, the attractor landscape appeared concentrated around dyadic states involving neutral infant emotionality.

In contrast, FS dyads demonstrated attractor peaks across a broader range of dyadic states. As in the VI group, neutral infant emotionality paired with no touch (Ineut_Pno) emerged as a prominent attractor. However, additional attractor states were observed for positive infant emotionality paired with no touch (Ipos_Pno) and positive infant emotionality paired with playful touch (Ipos_Pplay). Visual inspection of the three-dimensional state-space plots indicated that attractor peaks were distributed across a wider range of dyadic states in FS dyads than in dyads involving infants with VI.

Figure 9.

Three-Dimensional Attractor Landscapes Based on Mean Cell Duration During the Play Episode for Caregiver-Infant Dyads Involving VI And FS Infants



(A) Caregiver-infant dyads involving infants withVI

(B) Caregiver-infant dyads involving FS infants

Note. Mean Cell Duration across dyadic states during the Play episode for (A) caregiver-infant dyads involving infants with VI and (B) caregiver-infant dyads involving FS infants. The red plane indicates the overall mean cell duration across all dyadic states. The x-axis represents infant emotionality (1 = negative, 2 = neutral, 3 = positive), the y-axis represents caregiver touch behaviours (1 = no touch, 2 = playful touch, 3 = affective touch), and the z-axis represents mean Cell Duration. Peaks extending above the overall mean indicate attractor states, corresponding to dyadic configurations with relatively greater temporal stability during the interaction.

Chapter 4

DISCUSSIONS AND CONCLUSIONS

4. Discussion

4.1 Understanding Caregiver-Infant Interaction in the Context of Visual Impairment

This study intended to explore the dynamic organisation of caregiver-infant interaction in dyads with and without visual impairment, with a specific focus on how interactions develop and reorganise succeeding social perturbation. The coordination between infant emotionality and maternal touch behaviours were investigated through a dynamic system lens using the state space grid approach to encompass the moment-to-moment structure of dyadic interaction.

Caregiver-infant interaction constitutes the primary context through which infants acquire the foundations of socio-emotional regulation during the first year of life. Through repeated cycles of mutual responsiveness, mismatch, and repair, caregivers and infants progressively establish coordinated patterns of interaction that support emotional regulation, social engagement, and the development of increasingly stable expectations about the social world (Tronick & Beeghly, 2011; Feldman, 2007; Provenzi et al., 2018). These processes are particularly important to study in the context of visual impairment, where reduced access to visual communicative cues may alter the pathways through which caregiver and infant establish reciprocal engagement. Visual impairment necessitates a reorganisation of communication through alternative sensory modalities, including touch, vocalisations, and emotional expression, rendering these dyads a theoretically significant population for examining how early interaction is shaped and sustained in the absence of a primary regulatory channel (Grumi et al., 2021; Gui et al., 2023; Rattray & Zeedyk, 2005).

Despite growing evidence describing adaptive communicative behaviours in VI dyads, relatively little is known about how caregiver and infant behaviours become coordinated throughout moment-to-moment interaction, or how these interactions reorganise following social perturbation. Addressing these questions requires moving beyond traditional frequency-based approaches, which treat caregiver and infant behaviours as independent variables, towards methodologies capable of capturing the temporal organisation of caregiver-infant exchanges as dynamic and reciprocal processes (Hollenstein, 2007; Smith & Thelen, 2003). Dyadic measures are therefore essential, as they preserve the bidirectional, time-structured nature of early social exchanges that cannot be adequately represented by unidimensional approaches.

4.2 Patterns of Dyadic Engagement During Social Interaction

With regards to the first aim of the study, results indicated that caregiver-infant dyads involving infants with VI and FS differed in the organisation of spontaneous interaction during the Play episode of the FFSF paradigm but were no longer detected following the Still-Face perturbation. During Play, dyads involving infants with VI spent significantly longer periods in states characterised by neutral infant emotionality paired with affective touch. They also presented with longer visit duration characterised by neutral infant emotionality paired with either no touch or playful touch. In contrast, dyads involving FS infants showed longer visit duration characterised by positive infant emotionality paired with either no touch or playful touch. Although the overall frequency of return visits differed between groups during the Play episode, the absence of a Cell*Group interaction suggests that this difference was not specific to particular dyadic states. Rather, FS dyads showed a generally higher tendency to revisit interactional states than dyads involving infants with VI, without evidence of group differences in the distribution of return visits across dyadic states. Taken together, these findings suggest that group differences during the Play episode were primarily reflected in the affective content of interaction rather than in the overall pattern of transitions between interactional states. The present findings are consistent with previous work by Grumi and colleagues (2025), as they reported lower levels of positive emotionality during the Play episode of the FFSF paradigm in infants with VI, despite qualitatively similar behavioural responses to the subsequent social perturbation.

This finding suggests that throughout early social exchanges, visual impairment could disrupt or at least partially restrict socioemotional engagement. This could potentially occur because infants with visual impairment have less access to visual interactive cues, such as facial expressions and eye contact, that are critical for recognizing and responding to social signals (Dale et al., 2014). Reduced access to these cues may make it more challenging for infants to develop contingent expectations about social interactions, a process considered fundamental for effective socioemotional stress regulation. One possible explanation is that, in the absence of visual scaffolding provided by the caregiver, infants with visual impairment may have fewer opportunities to develop positive affective responses during social exchanges, as their ability to perceive, interpret, and respond to visual social cues is altered (Gui et al., 2023). Although further research is needed to understand these mechanisms, the findings suggest that interventions supporting adaptive caregiver-infant interactions may be particularly beneficial for promoting socioemotional development.

4.3 Regulation and Reorganisation Following Social Perturbation

The first goal of the study was further addressed by examining the reorganisation of caregiver-infant interaction following the Still-Face episode. As opposed to the differences between clinical and control groups observed during the Play episode, no significant group differences were detected in cell duration or visit duration during the Reunion episode.

Similarly, Grumi et al. (2025) reported that both infants with visual impairment and full-sighted infants exhibited the typical Still-Face effect and showed comparable patterns of recovery during the Reunion episode. Another study examined free parent-child interaction, rather than caregiver-infant interaction within the FFSF paradigm, and their findings similarly suggest that reduced access to visual information does not necessarily diminish children's capacity to engage in social interaction. Specifically, the authors reported no differences in the overall time that totally blind and partially blind children spent displaying joint engagement behaviours, despite differences in gaze-related behaviours (Gui et al., 2023). Together with the present findings, this supports the view that visual impairment may alter the modalities through which interaction is organised rather than reducing infants' capacity to participate in reciprocal exchanges.

The absence of significant group differences in cell duration and visit duration during the Reunion episode may reflect the greater co-regulatory demands imposed by this episode of the FFSF paradigm (Coppola et al., 2015; DiCorcia & Tronick, 2011). Whereas the Play episode captures the dyad's spontaneous interactional organisation, the Reunion episode requires caregiver and infant to reorganise their interaction following the social perturbation introduced by the Still-Face procedure. One possible interpretation of the present study's findings is that these increased regulatory demands may reduce the expression of group-specific interactional patterns, as both members of the dyad adapt their behaviour to restore coordinated interaction. This interpretation is consistent with transactional models of development (Sameroff, 2010), which propose that caregiver and infant continuously adapt to one another in response to changing interactional demands. More broadly, the present findings support the growing view that caregiver-infant adaptation in the context of visual impairment is characterised by interactional reorganisation rather than interactional deficit (Grumi et al., 2021).

VI and FS dyads differed in the overall frequency of return visits during the Reunion episode, however, there was no evidence that this difference varied across specific dyadic states. Although previous studies have not examined return visits using a State Space Grid approach, these findings are broadly consistent with evidence indicating that infants and young children with visual impairment often show reduced responsiveness and contingent reactions to caregivers' communicative signals, such as touch and verbalisations (Nagayoshi et al., 2017; Rogers & Puchalski, 1984; Rowland, 1984; Tröster & Brambring, 1992). One possible hypothesis for the reduced frequency of return visits observed in the present study is that caregiver-infant dyads involving infants with VI reorganise their interactions according to a different temporal pattern following the Still-Face perturbation, rather than a reduced motivation or capacity to engage socially (Conti-Ramsden & Pérez-Pereira, 1999; Nagayoshi et al., 2017; Grumi et al., 2021). However, further research is needed to determine whether the lower frequency of return visits observed in the present study reflects differences in interactional timing, responsiveness, or other aspects of dyadic organisation.

Notably, the present findings highlight the importance of considering interactional context when interpreting caregiver-infant dynamics in the context of VI. The presence of differences within a particular interactional episode should not be generalised as evidence supporting globally altered interactional functioning across contexts. Instead, the findings indicate that dyadic interaction in the context of VI may be context-dependent, with unique interactional patterns emerging depending on the emotional and regulatory demands of the situation.

From a clinical perspective, these findings could support important implications for early intervention and caregiver support. The absence of significant group differences in cell duration and visit duration during the Reunion episode suggest that dyads involving infants with VI may benefit from regulatory strategies similar to those frequently used to support interaction and repair in typically developing caregiver-infant dyads. Simultaneously, the variation in interactional patterns across contexts underscores the significance of flexibility within intervention approaches, as dyadic differences may become more or less pronounced depending on the emotional and regulatory demands of the interaction. Therefore, the present study further supports recent calls for family-centred interventions that build upon caregivers' adaptive regulatory capacities while accommodating the sensory characteristics of infants with visual impairment (Morelli et al., 2020; Provenzi et al., 2022).

4.4 Emergent Patterns of Interaction: Attractor States in Early Dyadic Systems

The second goal of the study was to identify emergent attractor states arising from the coordination between infant emotionality and maternal touch. Although preferred states of interacting were present in both groups, differences emerged in the organisation of the attractor landscape. Dyads comprising of infants with VI established a more centralised attractor landscape. The most prominent attractor state for this clinical group was characterised by neutral infant emotionality and the absence of maternal touch. Contrastingly, FS dyads exhibited a broader attractor landscape, with attractor states disseminated across both neutral and positively valanced interactional configurations. Specifically states including positive infant emotionality paired with no touch or playful touch surfaced as prominent attractors. These findings extend the results of the SSG analyses by demonstrating that group differences were evident not only in the duration of specific dyadic states but also in the overall organisation of interactional patterns over time.

Although theorists have argued for the importance of understanding dynamic patterns such as preferred states of interaction across contexts (Thelen & Smith, 1998), we have little empirical evidence with which to answer these questions. Dynamic systems perspectives propose that flexibility in caregiver-infant interaction supports socioemotional development by allowing dyads to adapt to changing interactional demands (Bremner & Wachs, 2010; Zeanah et al., 1997). Although flexibility was not directly measured in the present study, the more centralised attractor landscape observed in VI dyads may suggest that interaction became organised around a narrower repertoire of preferred interactional states. Importantly, this pattern should not be interpreted as evidence of poorer interactional functioning. Rather, dynamic systems theory proposes that developmental functioning emerges through the ongoing interactions among multiple components of the dyadic system, rather than being determined by individual attractor states alone (Smith & Thelen, 2003).

4.5 Limitations

The present study had a relatively small sample size which was heterogenous in terms of clinical conditions included in the VI group. The clinical group included infants with peripheral, cerebral or oculomotor impairment. Consequently, it was not possible to determine whether distinct patterns of interaction were associated with specific types of visual impairment. Future studies including larger and more homogeneous samples may provide a more detailed understanding of how different visual conditions influence the organisation and regulation of early caregiver-infant interactions. Another limitation concerns the study's cross-sectional design, which provided insight into caregiver-infant interactions at a single developmental time point. Therefore, longitudinal research is needed to investigate how these interactional processes emerge and change throughout infancy in dyads involving infants with VI, as well as their implications for later socio-emotional development. Finally, although the FFSF paradigm (Tronick et al., 1978) is a well-established method for examining dyadic regulation and responses to social perturbation, laboratory-based observations may not fully capture the complexity of everyday caregiver-infant exchanges. Future studies may therefore benefit from incorporating more naturalistic observational approaches or combining the FFSF paradigm with complementary methodologies to obtain a richer understanding of caregiver-infant interaction in the context of VI.

4.6 Conclusion

This study aimed to better understand caregiver-infant dynamics in the context of visual impairment by examining how infant emotionality and parental touch contribute to the organisation of dyadic engagement. Using a dynamic systems framework and State Space Grid methodology, the study explored how interactional patterns emerged and reorganised across the Face-to-Face Still-Face paradigm.

The findings indicate that caregiver-infant dyads composed of infants with VI developed organised and coherent patterns of interaction, despite early visual impairment. During free play, however, these dyads showed a more centralised organisation of interaction, characterised by longer engagement in neutral interactional states and a narrower repertoire of preferred interactional states than FS dyads. Following the Still-Face perturbation, group differences in the organisation of interaction were no longer detected, suggesting that both groups were able to reorganise their interactions following social perturbation. The study also demonstrated the value of State Space Grid methodology for examining caregiver–infant interaction. By capturing the temporal organisation of dyadic behaviour, this approach identified patterns of interaction that would have been difficult to detect using traditional variable-centred analyses, providing a more comprehensive understanding of how caregiver and infant behaviours become organised over time.

These findings contribute to the growing literature adopting a dynamic systems perspective to understand early caregiver-infant interaction in the context of visual impairment.

Understanding these interactions is crucial because they provide a fundamental context through which infants learn to regulate emotions, communicate, and engage with the social world. By demonstrating the value of State Space Grid methodology for capturing the temporal organisation of dyadic behaviour, the present study provides a foundation for future research integrating dynamic systems approaches with other established observational paradigms. Such work may offer a more comprehensive understanding of caregiver-infant interaction in visual impairment and help identify the aspects of dyadic functioning that are most relevant for informing early intervention and family-centred support.

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APPENDICES

Appendix A: Parent-Infant Coding System, PICS

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Parent-Infant Coding System, PICS

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This manual is meant to guide the micro-analytic coding of videotaped parent-infant interaction. The focus is on specific infants' and parent's behaviors that can be discretely depicted in 1- or 2-sec micro-analytical coding. The infant components are:

- Infant Emotionality Coding System (IECS)
- Infant Attention-focus Coding System (IACS)

The parent components are:

- Parent Touch Coding System (PTCS)
- Parent Voice Coding System (PVCS)

The coding systems have been derived from previous systems to maximize the balance among simplicity of use, simplicity of training, and sensitivity to relevant behavioral dimensions of parent-infant interaction. The first two components of infant behavior (IECS and IACS) can be also adapted to code maternal emotionality (MECS) and attention-focus (MACS), in order to obtain at post-hoc a sequence of matched and non-matched dyadic states of emotional states and gaze.
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IECS

INFANT EMOTIONALITY CODING SYSTEM

The Infant Emotionality Coding System (IECS) is a tool to assess the micro-analytical display of emotional states by infants during a parent-infant interaction. It is not meant to capture the degree of emotional expression nuances; rather it provides an immediate and qualitative distinction among positive, neutral, and negative emotional states.

It includes four mutually exclusive codes.

CODING	LABEL	DESCRIPTION
0	Cannot see	The infant face is covered or it is only partially evident (e.g., the infant look at the other side of the camera and the face is only half-visible) and is not possible to code the facial emotional expression. Use this code also for cases in which the emotional expression of the infant cannot be clearly coded due to technical issues.
1	Negative	The infant displays clear negative emotionality. Negative emotionality might be expressed through facial expression (eyes, mouth, general movement of the face muscle and/or of the body), and/or non-verbal communication (cry, to be fussy, stressed, shout). To code 1, there should be clear expressions of positive emotionality.
2	Neutral	The infant does not display clear positive or negative emotionality through facial expression or other modalities (e.g., the infant is calm, relaxed).
3	Positive	The infant displays clear positive emotionality. Positive emotionality might be expressed through facial expression (e.g., eyes, mouth, general movement of the face muscle and/or of the body) or vocalizations (e.g., laughing). To code 3, there should be clear expressions of positive emotionality.

Disentangling notes

(*i*) If positive and negative emotionality occurs in the same interval, please code the emotion that lasts longer.

(*ii*) If negative and neutral emotionality occurs in the same interval, please code negative emotion.

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PTCS

PARENT TOUCH CODING SYSTEM

The Parent Touch Coding System (PTCS) is a tool to assess the occurrences of parental touch characterized by different cinematic features or functions.

It includes nine mutually exclusive codes.

CODING	LABEL	DESCRIPTION
0	No touch	The parent does not touch the infant.
1	Cannot see OR Unspecified	It is not possible to be sure if the parent touched the infant (because the sight of the physical contact is only partially or completely not visible). If unsure on the type of touch (Unspecified), also score 1.
2	Harsh OR Negative OR Non-contingent	Parent touch is somehow intrusive and provokes negative responses and stress in the infant. The touch may be intrusive, awkward, overwhelming, rough, etc.
3	Accidental	The parent is moving and accidentally touches the infant with no intrinsic touch-related intentional purposes OR the infant starts the tactile contact with the parent.
4	Static	Passive contact type where the parent just leaves a hand resting on the body of the infant. No movement is detected.
5	Intentional instrumental / utilitarian	Parent touch used to accomplish a specific non-relational task (e.g., removing infants' hands from the mouth, adjusting infant's position on the infant-seat, adjusting infant's dress, cleaning the mouth of the child, etc.).
6	Intentional attention getting	Parent touch used to get the infant's attention toward the parent. Touch may be: tapping, patting, squeezing, pinching, stroking, etc. To code 6, the infant should not be focused on the parent. This type of touch may (or not) be accompanied by attention getting vocal productions.
7	Intentional playful	Parent touch characterized by high-paced, dynamic, repetitive, fast cinematic features. The parent may tickle, shake, squeeze, lift, move fingers on the infant's belly like little ant, move the hands or legs of the infant. Typically, the goal is provoking fun in the infant.

8	Intentional affectionate / nurturing	Parent touch characterized by a sense of closeness or by the goal of soothing and calm the infant. The parent may be kissing, stroking, or massaging the infant with affectionate intent or to regulate negative emotional states.

Disentangling notes

(*i*) To code 2, the infant must display a negative response. Otherwise, chose other touch types.

(*ii*) If multiple touch types co-occur in a single segment, code the one with higher coding number.

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