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# Exploring Maternal Unpredictability in the Context of Children with Neurodevelopmental Disabilities

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**INDEX**

*What is the Meaning of Infancy? What is the meaning of the fact that man is born into the world more helpless than any other creature, and needs for a much longer season than any other living thing the tender care and wise counsel of his elders?* - John Fiske, 1883/1909, p.1

# Abstract

Early caregiving constitutes a critical context for infant neurodevelopment, shaping cognitive, emotional and neurobiological outcomes across development. Within this context, the temporal organisation of maternal sensory signals has been identified as a distinct and developmentally relevant dimension of caregiving in typically developing populations. However, its role in the context of neurodevelopmental disabilities (ND) remains unexplored. The present study aimed to examine maternal unpredictability, operationalised as entropy rate, in a sample of 61 mother-child dyads including children with ND and typically developing children, exploring group differences in entropy rate, the role of infant sex and age, and associations with maternal well-being. Maternal sensory signals were coded from five-minute video-recorded free-play interactions and entropy rate was calculated for each mother. Maternal well-being was assessed through standardised self-report questionnaires. No significant group difference in entropy rate was found, and infant sex was not associated with entropy rate in either group. However, a significant interaction between group and age revealed that infant age significantly predicted entropy rate in the control group, while no significant association was observed in the clinical group. In the clinical group only, entropy rate was significantly associated with concurrent maternal state anxiety. These findings suggest that the challenge in the context of ND may not lie in elevated unpredictability per se, but in a failure to develop progressively more organised caregiving patterns over time, joining a growing body of research on the role of maternal caregiving behaviour in early development and highlighting potential implications for family-centred early intervention.

# Introduction

Understanding how early caregiving shapes infant development has been a central question in developmental sciences for decades. The first years of life represent a period of extraordinary neural plasticity, during which the brain is actively shaped by experience, and caregivers constitute the primary source of that experience. The ways in which caregivers respond to, organise, and structure their interactions with infants have been shown to carry lasting consequences for cognitive, emotional, and neurobiological development. While much of this research has focused on the quality and emotional responsiveness of caregiving, the temporal predictability of maternal sensory signals has been emerging as a dimension worthy of further exploration. Whether the sequences of a caregiver's behaviour are structured in ways that are learnable and anticipable for the infant may constitute an independent and developmentally significant aspect of early caregiving.

This question takes on relevance when considered in the context of neurodevelopmental disabilities (ND). Families of children with ND face unique and sustained caregiving challenges and understanding the early environment of these children is especially important given that they already face significant developmental vulnerabilities. Despite growing evidence on the role of maternal unpredictability in typically developing populations, this dimension of caregiving remains unexplored in the context of ND.

The present thesis addresses this gap by integrating theoretical, empirical and clinical perspectives. It begins by examining the foundations of early caregiver-infant interaction, tracing the evolution of key constructs from maternal sensitivity and contingent responsiveness to the temporal organization of maternal sensory signals and its developmental consequences. It then turns to the specific context of ND, examining how parent-infant interaction is shaped by the child's developmental profile, the challenges

caregivers face, and the interventions developed to support them. Building on this foundation, an original empirical study will be presented, examining maternal unpredictability in a sample of mother-child dyads including children with ND and typically developing children, recruited from the IRCCS Mondino Foundation in Pavia. The findings reveal that maternal entropy rate did not differ significantly between groups overall, suggesting that the child's clinical status may not fundamentally alter the mother's characteristic level of caregiving unpredictability. However, the developmental trajectory of entropy rate across infant age differed significantly between groups. While infant age was a significant negative predictor of entropy rate in the control group, no significant association was observed in the clinical group, suggesting that the progressive organisation of caregiving patterns over time may not emerge in the same way in the context of ND. Additionally, in the clinical group only, entropy rate was significantly associated with concurrent maternal state anxiety, pointing to the potential role of maternal emotional well-being in shaping the temporal organisation of caregiving in this context.

# Chapter 1
# Early Parent-Infant Interaction

## 1.1 Early Development and Sensitive Periods

Human infants are born in a highly immature state. Unlike the offspring of most other primates, newborns lack the physiological, motor and cognitive capacities required for independent survival, relying entirely on caregivers to meet their basic needs such as feeding, warmth and protection (Rosenberg, 2021). This prolonged dependence creates a unique developmental window during which the brain undergoes a rapid growth and is actively shaped by experience. Caregivers are the infant's primary source of experience, providing not only physical care, but the emotional, social and sensory input essential for healthy development (Bowlby, 1969/1982; Greenough et al., 1987).

Early childhood, particularly the first years of life, is characterized by rapid developmental change underpinned by exceptional levels of neural plasticity. The brain is capable of modifying its structure and connectivity in response to experience (Tierney & Nelson, 2009; Knudsen 2004). At the cellular level, this plasticity is driven by synaptogenesis, through which neurons form connections at a remarkable rate during infancy, generating an initial overabundance of synaptic links. This overproduction is followed by a process of synaptic pruning, through which infrequently activated connections are selectively eliminated, while those that are regularly used are consolidated and strengthened. Critically, this pruning process is experience-dependent, including sensory, affective and social input provided by caregivers, and determines which neural pathways are retained and which are discarded (Greenough et al., 1987). The architecture of the developing brain does not emerge from a genetic blueprint, it is actively sculpted by the relational world the infant inhabits.

Embedded within this broader landscape of neural plasticity are sensitive periods. These are developmental windows during which specific neural circuits are particularly responsive to environmental input, allowing experience to exert especially strong and lasting effects on brain organisation and behaviour (Knudsen, 2004; Bornstein 1989). These windows represent both an opportunity and a vulnerability, meaning that the same heightened plasticity that allows responsive caregiving to powerfully support development, can also mean that adverse or inconsistent experiences can cause disproportionate harm (Bornstein, 1989). Repeated caregiving interactions during this period do not only shape neural architecture, but they also shape the infant's earliest expectations about relationships. Ainsworth (1979) demonstrated that sensitive maternal responsiveness enables infants to build expectations of the caregiver as accessible and responsive, gradually constructing an internal representation of the relationship. According to Bowlby (1969/1982), these repeated experiences give rise to internal working models, which are internal representations of self and others that guide emotional and behavioural regulation across development (Sroufe, 2000).

The developmental significance of early caregiving experience is powerfully illustrated by research examining children raised in conditions of environmental deprivation. The Bucharest Early Intervention Project demonstrated that children who experienced early institutional care, characterised by impoverished social stimulation and inconsistent caregiving, showed significant delays across cognitive, language, and socio-emotional domains compared to children raised in family settings (Zeanah et al., 2003; Nelson et al., 2007). These findings confirm that the developing brain requires specific forms of interpersonal input, particularly during sensitive periods, to develop along a healthy trajectory. Importantly, this relationship is not deterministic, early life plasticity is itself

an adaptive mechanism, and the effects of early adversity can be modulated by subsequent relational experience (Fawcett & Frankenhuis, 2015).

Within this framework, caregiver-infant interaction emerges as one of the most powerful environmental contexts shaping early development (Sroufe 2000). During the first years of life, caregivers regulate the infant's exposure to sensory, emotional, and social experiences. Because infants have a limited capacity for self-regulation, caregivers also play a role in modulating physiological arousal, emotional states and attentional processes through processes of co-regulation, constituting the infant's first models for patterns of self-regulation (Feldman 2007; Sroufe 2000). Early relationship experiences are foundational because they constitute the infant's first models of self-regulation patterns. Infants incorporate their experiences and generalise from them, building expectations about whether others will respond and if their own action will be effective (Sroufe, 2000). Importantly, caregiving is not defined solely by the presence of interactions, but also by its quality, consistency, predictability and responsiveness to the infant's signals (Ainsworth et al., 1978; Ainsworth, 1979). Research confirms that children with histories of responsive care and secure attachment show greater self-reliance, emotional flexibility and behavioural organisation in later development (Sroufe, 2000). Understanding how caregivers perceive, interpret and respond to infants' cues becomes central to understanding how early relational experiences support, or disrupt, healthy development.

### 1.2 Parental Sensitivity and Contingent Responsiveness

Although early caregiving experiences are fundamental for development, developmental processes do not emerge within the infant in isolation, they emerge within the caregiver-infant relationship. From the earliest moments of life, infants participate in dynamic exchanges with caregivers through gaze, vocalisations, facial expressions, affective

signals, and attentional behaviours. Caregivers, in turn, continuously perceive, interpret, and respond to these signals, creating organised patterns of mutual influence across time (Tronick, 1989; Feldman, 2007). Early interaction is therefore fundamentally dyadic and reciprocal, indeed both infant and caregiver actively contribute to the organisation and regulation of the interaction. Infants are not passive recipients of stimulation but active participants whose behaviours shape caregiver responses, while caregiver responses simultaneously shape infant behaviour and emotional organisation.

Several developmental theorists emphasised that early interactions function as processes of co-regulation, through which caregivers help infants regulate physiological arousal, emotional states, and behavioural organisation before infants are capable of doing so independently (Tronick, 1989; Sroufe, 2000). Infant emotions and emotional communications are far more organised than previously assumed. From early in life, infants display discrete affective expressions that are appropriate to the nature of events and their context, and they are sensitive to the emotional meaning of caregivers' affective display (Tronick, 1989). Early interaction depends on the emotional expression of both infant and caregiver to mutually regulate their dyadic exchange, naturally unfolding through ongoing cycles of coordination, miscoordination and repair. A healthy interaction does not require a perfect coordination, but the way in which repair occurs impacts the infant's development. A positive development is associated with the caregiver's capacity to recognise disruptions and restore coordination across repeated exchanges, helping the infant recover from dysregulated or negatively aroused states and reestablish coordinated interaction (Tronick, 1989).

One of the most influential concepts to understand caregiving quality is maternal sensitivity, originally defined by Ainsworth and colleagues (1978) as the caregiver's

ability to accurately perceive infant signals, interpret them correctly and respond promptly and appropriately to the infant's needs. Sensitive caregiving, in this formulation, begins with perception and proceeds through accurate interpretation and prompt, adequate, and contingent responding. Ainsworth (1979) demonstrated that mothers of securely attached infants were consistently more sensitively responsive to their baby's signals throughout the first year of life, across a variety of interactional contexts including feeding, close bodily contact and face-to-face interaction. In contrast caregivers who disregarded infant signals, responded belatedly, or reacted in grossly inappropriate ways provided infants with no basis for developing expectations of accessibility and responsiveness, contributing to anxiety within the attachment relationship.

Since the foundational work of Ainsworth, the construct of maternal sensitivity has been substantially elaborated and refined. A systematic review by Deans (2018) identified four core attributes of the modern definition of sensitivity: it is a process involving maternal abilities; it involves reciprocal give-and-take between caregiver and infant; it is dynamic and responsive to changes in infant behaviour; and it includes multiple dimensions including appropriateness, situational awareness, expressiveness, emotional availability and timing. Pederson and colleagues (2014) further argue that sensitivity is best understood from a relationship perspective, instead of a fixed maternal trait or isolated behaviour. Sensitivity describes the caregiver's role in fostering a relationship in which the infant experiences the caregiver as a secure base from which to explore and a safe haven for comfort. From this perspective, infants develop relationship-based expectancies of caregiver behaviour based on past interactional experiences, which inform their subsequent reactions to engage with caregivers (Pederson et al., 2014). This multidimensional understanding reflects an evolution from earlier and narrower conceptualizations of sensitivity. Rather than referring to sensitivity as a single caregiving

behaviour, it is now understood as a relational capacity that manifests differently depending on the infant's developmental stage, temperament, communicative style and interactional context (Deans 2018; Pederson et al., 2014). Beyond attachment outcomes, maternal sensitivity has been associated with outcomes across multiple developmental domains, including cognitive development, language acquisition, physical factors and socio-emotional adjustment (Deans, 2018).

Closely related to parental sensitivity is contingent responsiveness, which refers more specifically to the temporal and behavioural coordination between infant signals and caregiver responses. Contingency involves responding to infant behaviours in ways that are temporally appropriate, behaviourally relevant, and coordinated with the infant's ongoing affective and attentional state (Bigelow, 1998; Keller et al., 1999). Contingent responses are therefore dependent upon the infant's moment-to-moment cues and immediate needs, desires, intentions, and focus of attention (Campi et al., 2024). Importantly, contingency does not simply involve frequent responding but responding in ways that are meaningfully linked to the infant's specific behaviour and immediate internal state. Keller and colleagues (1999) describe responsiveness as involving attentive, warm, and behaviourally coordinated parental reactions, while also noting that contingency may occur independently from affective warmth (Keller et al., 1999; Keller et al., 2004). This distinction highlights that caregiver-infant interactions are organized not only through its emotional qualities, but also through its temporal structure.

The developmental significance of contingent responsiveness lies in the infant's growing ability to detect regularities between their own actions and caregiver responses. Through repeated contingent interactions, infants gradually develop a sense of self-efficacy and agency, understanding that their own actions can influence the social environment

(Bigelow, 1998; Keller et al., 1999). Even very young infants are sensitive to contingent social interactions and capable of detecting disruptions in familiar patterns of responsiveness (Bigelow, 1998). Zmyj and colleagues (2017) showed that maternal contingent responsiveness is associated with infants' capacity to detect sensorimotor contingencies between their own movements and sensory feedback, as well as with the development of self-awareness in later infancy.

Beyond contingent responding, researchers have emphasised the importance of synchrony within caregiver–infant interaction. Feldman (2007) defines synchrony as the coordinated matching of behaviours, emotional states, physiological processes, and communicative signals between caregiver and infant across time. These repeated synchronous interactions support emotional regulation, physiological stability, and social engagement, while also contributing to the infant's emerging understanding of reciprocal communication. Feldman (2007) further proposed that the temporal regulation of affective communication during infancy may support later symbolic competence, including language development and the capacity to understand internal states.

Importantly, caregiving interaction does not unfold identically across cultural contexts. Cross-cultural research suggests that although parental sensitivity is broadly associated with healthy development, the specific behaviours through which sensitivity is expressed may vary according to cultural values, caregiving practices, and developmental goals (Keller et al., 1999; Keller et al., 2004). Some caregiving environments emphasise face-to-face interaction and verbal responsiveness, whereas others prioritise body contact, proximity, or non-verbal forms of co-regulation. These findings highlight the importance of understanding caregiver–infant interaction as both biologically grounded and culturally embedded, avoiding overly universal definitions of optimal caregiving.

Taken together, these findings suggest that the developmental significance of caregiver–infant interaction lies not only in the presence of caregiving stimulation, but in its organisation, timing, consistency, and predictability over time. Through repeated patterns of sensitive, contingent, and synchronous interactions, infants gradually construct expectations regarding caregiver responsiveness and the structure of the social world. These interactional processes provide an important conceptual foundation for understanding how predictable and unpredictable patterns of caregiving may differentially shape infants' emerging expectation, regulatory capacities, and developmental trajectories.

### 1.3 Predictability in Parent-Infant Interaction

Infants do not experience caregiving as isolated events, they are continuously exposed to repeated patterns of responses, emotional signals, and interactional rhythms from which they gradually acquire structure and meaning about the social world. A dimension that runs through all these processes, and which deserves to be examined in its own, is predictability. In the context of infant-caregiver interaction, predictability refers to the extent to which caregiver behaviour unfolds in stable and recognisable patterns across repeated exchanges, allowing infants to gradually form expectations regarding how, when and in what sequence caregivers are likely to respond (Beebe et al., 1997; Davis et al., 2017). Although predictability is related to sensitivity and contingency, it is conceptually distinct from both. A caregiver may be emotionally available, and responsive to infant signals, while still behaving inconsistently across time. Predictability reflects the broader temporal organisation of caregiving interactions, emerging through reliable interactional regularities that allow the infant, not only to react, but to anticipate caregiver behaviour.

The importance of interactional predictability is particularly evident in the Face-to-Face Still-Face paradigm developed by Tronick and colleagues (1978). During a typical still-face procedure, caregivers initially engage in normal face-to-face interaction before suddenly adopting a neutral and emotionally unresponsive expression. Infants rapidly react to this disruption by attempting to re-establish the interaction through smiling, vocalising, and attentional bids. When these attempts fail, they typically show increased negative affect, gaze aversion, and self-regulatory behaviours (Tronick et al., 1978). These responses suggest that infants had already formed expectations regarding the temporal and emotional structure of the interaction and experienced the abrupt violation of these expectations as dysregulating. However, the distress observed during the still-face episode is not simply a response to the absence of stimulation, but to the disruption of an anticipated pattern of reciprocal exchange. Importantly, the still-face effect often persists into the reunion episode, indicating that violations of interactional predictability may have regulatory consequences that extend beyond the immediate moment of disruption (Tronick et al., 1978).

Predictable caregiving may support development not only because it facilitates learning, but because it allows the caregiver to become established as a reliable source of safety and regulation. Through repeated exposure to stable and responsive interactional patterns, infants learn that caregiver signals are associated with comfort, protection, and attenuation of distress. In this sense, predictability may function as a relational safety cue, allowing emotional and physiological states to become increasingly organised around expected caregiver responses (Gee & Cohodes, 2021; Bowlby, 1969/1982).

The infant's capacity to anticipate caregiver behaviour, is grounded in the early developing mechanisms of statistical learning. Research has shown that from birth infants

are sensitive to transitional probabilities and recurrent patterns in sensory input (Saffran et al., 1996; Aslin, 2017). Growing evidence suggests that similar learning mechanisms operate in the social domain, allowing infant to extract structure from the behavioural sequences of their caregivers. Caregiving interactions are inherently sequential, with each caregiving action shaping the context that follows. Through repeated exposure, infants gradually build expectations about what their caregiver is likely to do next. Importantly, this does not mean that greater predictability is always developmentally optimal. Microanalytic research suggests that adaptive outcomes are associated with moderate rather than excessive interactional coordination, providing sufficient regularities to support expectation formation while preserving the variability necessary for engagement and learning (Beebe et al., 2010).

Evidence from both human and animal studies suggests that predictability of early caregiving carries significant developmental weight, shaping cognitive outcomes, and influencing the maturation of neural systems involved in learning and emotion regulation (Davis et al., 2017; Gee & Cohodes, 2021). These effects appear to contribute to developmental outcomes over and above what maternal sensitivity alone explains (Davis et al, 2017). Taken together, predictability is not merely a background feature of caregiving, but an organising property of early relational experience, one whose developmental significance becomes most apparent when it is disrupted.

## 1.4 Maternal Unpredictability

### 1.4.1 Conceptualization of Maternal Unpredictability

It was already established that predictability functions as an organising property of early caregiving experience, one that shapes how infants learn to anticipate, regulate and engage in the social world. Research over the past decade has begun to identify maternal

unpredictability as a distinct dimension of caregiving, one with its own conceptual definition, measurement framework, and developmental consequences that are not fully captured by existing constructs of caregiving quality (Baram et al., 2012; Davis et al., 2017)

Maternal unpredictability does not refer to the occasional disruptions or momentary misattunements, which are considered a normative feature of a healthy interaction (Tronick, 1989). It refers to a chronic pattern in which the temporal organization of a caregiver's auditory, visual, and tactile signals becomes fragmented, inconsistent and difficult for the infant to anticipate across repeated interactions. A caregiver may be warm, emotionally available and broadly responsive to her infant's needs, while simultaneously providing sensory signals whose sequence and timing remain difficult to predict. In this sense, unpredictability concerns the organisation of caregiving signals over time, rather than their emotional valence or overall quality (Baram et al., 2012; Davis et al., 2017). This distinction is conceptually important, meaning that a caregiver can score high on conventional measures of sensitivity while creating an interactional environment that is difficult for the infant to model.

This conceptual independence between unpredictability and sensitivity has been empirically supported (Davis et al., 2017, 2019; Holmberg et al., 2022). Davis and colleagues (2017) developed an observational approach in which maternal auditory, visual, and tactile behaviours during naturalistic play interactions are coded continuously and quantified using entropy rates. The entropy rate reflects the degree to which one maternal behaviour fails to predict the next: high entropy rate indicates that transitions between caregiving behaviours are inconsistent and difficult to anticipate, whereas low entropy rate indicates more structured, predictable, and learnable behavioural sequences (Davis et al., 2017). Entropy rate was found to be only moderately correlated with

maternal sensitivity and to account for unique variance in child cognitive outcomes after sensitivity was controlled, supporting evidence of its conceptualization as a distinct dimension of caregiving (Davis et al., 2017). This distinction has been replicated across longitudinal and culturally diverse cohorts (Davis et al., 2019; Holmberg et al., 2022). Notably, evidence shows that maternal depressive and anxiety symptoms were more consistently associated with lower maternal sensitivity than unpredictability, suggesting that unpredictability captures aspects of caregiving organisation that are not fully explained by maternal emotional functioning (Takio et al., 2026; Holmberg et al. 2022).

Longitudinal research further suggests that individual differences in maternal unpredictability show moderate stability across development. Holmberg and colleagues (2022) observed that unpredictability remained relatively stable from infancy to toddlerhood despite a small average decreased over time, suggesting that caregiving unpredictability may decrease gradually as caregiver-child interaction become more established. Extending these findings into preschool years, Takio and colleagues (2026) similarly reported a modest, but significant decrease in entropy rate between 8 months, 2.5 years and 5 years of age, while individual differences remained moderately stable across all timepoints.

Alongside observational approaches, the Questionnaire of Unpredictability in Childhood (QUIC) was created as a self-report measure designed to assess exposure to unpredictability across social, emotional and physical domains during childhood (Glynn et al., 2019). Importantly, the QUIC demonstrated strong psychometric properties and scores were positively correlated with prospectively observed indicators of unpredictable maternal sensory signals, supporting convergent validity across measurement approaches. The development of this instrument reflects a broader recognition that early-life unpredictability constitutes a qualitatively distinct dimension of adversity, not

reducible to poverty, trauma, or parenting quality, and one that requires its own measurement framework for both research and clinical purposes.

### 1.4.2 Developmental and Neural Implications

Having established maternal unpredictability as a measurable and conceptual distinct caregiving dimension, the question becomes what chronic exposure to unpredictable caregiving actually does to a developing infant. The answer, emerging from converging evidence across multiple domains, populations, and species, is that the consequences are specific, lasting, and independent of caregiving quality more broadly (Davis & Glynn, 2024).

At the cognitive level, the most consistent and replicated finding concerns memory and executive function. Davis and colleagues (2017) demonstrated that higher maternal entropy during infancy predicted poorer cognitive performance at age two and lower scores on hippocampus-dependent delayed recall memory at age six and a half. These effects persisted after controlling for maternal sensitivity, depressive symptoms, and socioeconomic status. Crucially, unpredictability was the only caregiving measure to specifically predict hippocampus-dependent outcomes, suggesting it leaves a biological trace in memory circuits that global indices of caregiving quality do not capture. This finding has been replicated across species, with parallel memory deficits documented in rodents and non-human primates exposed to unpredictable maternal signals (Davis et al., 2022), supporting the argument that sensitivity to patterning of early caregiving reflects an evolutionarily conserved developmental process.

The effects of maternal unpredictability on self-regulation and executive functions are equally well-documented and extend beyond infancy. Across two demographically distinct cohorts in California and Finland, Davis and colleagues (2019) found that

unpredictable maternal signals during infancy were consistently associated with poorer effortful control from infancy into middle childhood, with effects persisting up to nine and half years of age in the American cohort (Davis et al., 2019). Holmberg and colleagues (2022) extended these findings, showing that higher entropy at eight months predicted poorer effortful control at the age of five, particularly pronounced among boys and strongest at very high levels of unpredictability. Takio and colleagues (2026) demonstrate in a large population-based cohort that trajectories of maternal unpredictability across the first five years of life predicted distinct executive function profiles at age five. Children exposed to lower unpredictability are substantially more likely to show stronger working memory performance, effects persisting after controlling for maternal sensitivity. The picture that emerges is one of an extended developmental window, during which structural consistency of caregiving interactions continues to shape the maturation of self-regulatory systems and executive functions.

The emotional consequences of early unpredictability are less studied but equally important. Aran and colleagues (2024) examined three independent longitudinal cohorts spanning infancy, early childhood, and middle childhood, across the United States and Finland, finding that greater maternal entropy predicted higher levels of child fearfulness and anxiety across development in all three, above and beyond maternal sensitivity and sociodemographic factors. Associations with sadness and depression were weaker and less consistent, and the authors suggest that anxiety related phenotypes may represent the primary early emotional sequela of unpredictable caregiving, with depressive outcomes potentially emerging later. At the physiological level, infants exposed to more unpredictable maternal signals, showed a reduced cortisol response to a painful stressor. Rather than indicating lower stress, a blunted cortisol response may reflect alterations in the regulation of the hypothalamic-pituitary-adrenal (HPA) axis, suggesting that early

exposure to unpredictable caregiving becomes embedded within developing stress-response systems (Noroña-Zhou et al., 2020).

Understanding why unpredictable caregiving influences developmental outcomes requires consideration of the neural mechanisms. Neuroimaging evidence suggests that unpredictable sensory signals may shape the maturation of corticolimbic circuits involved in memory, stress regulation, and emotional processing. Granger and colleagues (2021) found that greater maternal unpredictability during infancy was associated with differences in the relative maturation of the uncinate fasciculus and hippocampal cingulum, two white matter pathways connecting limbic and prefrontal regions. Importantly, this imbalance partially mediated the association between early unpredictability and poorer episodic memory performance in late childhood (Granger et al., 2021). Experimental rodent studies reviewed by Davis and colleagues (2022) provide complementary mechanistic evidence, indicating that exposure to unpredictable maternal signals is associated with alterations in hippocampal synaptic plasticity, impoverished dendritic organisation, and microglial-mediated circuit refinement, processes that are critical for memory development. These findings are consistent with the theoretical accounts proposing that chronic unpredictability may influence the timing of corticolimbic maturation during sensitive developmental periods (Gee & Cohodes, 2021). Gee and colleagues (2021) propose that predictable, safety-associated caregiving during infancy actively maintains prolonged corticolimbic plasticity, supporting the window during which caregiver inputs can most powerfully modulate the infant's developing regulatory systems. Chronic unpredictability may promote accelerated maturation of these circuits as an adaptive response to environmental uncertainty, potentially reducing opportunities for caregiver buffering and increasing vulnerability to later difficulties in emotion regulation and learning.

Taken together, the available evidence indicates that maternal unpredictability constitutes a distinct and developmentally meaningful dimension of caregiving that shapes cognitive, emotional, physiological and neurobiological development. These effects have been observed across species and cultural contexts, and emerge independently of maternal sensitivity and socioeconomic adversity, suggesting that the temporal organisation of caregiving signals represents a unique pathway through which early caregiving experiences become biologically embedded. Understanding how this dimension of caregiving manifests in contexts characterised by additional challenges, including neurodevelopmental disabilities in the child, and whether it can be modified through targeted intervention, constitutes an important direction for the chapters that follow.

# Chapter 2

# Parenting in the Context of Disabilities

## 2.1 Parent-Infant Interaction in Developmental Disabilities

Developmental disabilities constitute a broad umbrella of conditions resulting from impairments that affect the child's physical, cognitive, behavioural and learning functioning, emerging early in life and carrying lasting consequences across the life course (Olusanya et al., 2018). Their global scope is substantial and estimates that approximately 240 million children worldwide live with some form of developmental disability (Olusanya et al., 2023). Within this broad category, conditions arising from atypical neurodevelopment, commonly referred to as neurodevelopmental disabilities (ND), have received research attention. These encompass a range of conditions including sensory impairments, epilepsy, cerebral palsy, autism spectrum disorder (ASD), intellectual disability, attention-deficit/hyperactivity disorder, genetic syndromes, and other learning and motor disorders (Olusanya et al., 2023; Provenzi et al., 2021). Neurodevelopmental disabilities affect the acquisition of basic developmental skills across cognitive, communicative, motor, and socio-emotional domains, and frequently co-occur. The boundaries between diagnostic categories are often permeable and many children present with profiles that span multiple conditions simultaneously (Giusti et al., 2018).

Understanding what ND mean for a developing child, however, requires a conceptual orientation that goes beyond diagnostic categories. Contemporary frameworks emphasise that these conditions shape, without limiting, the trajectory of a child's development, unfolding within the context of a family that is also developing and adapting (Rosenbaum & Novak-Pavlic, 2021). A child with a ND is, first and foremost, a child, in the process

of being, becoming and belonging and subject to the same developing processes, relational needs and sensitive periods that characterise early life (Rosenbaum & Novak-Pavlic, 2021). What changes is the context, the specific constraints and the degrees of freedom that each child's condition creates for the caregiving system, and the ways in which both the child and caregiver must navigate in their interaction.

One of the most consistent consequences of ND for early parent-infant interactions is that they alter the communicative signals that infants provide to caregivers. Infants with ND frequently display reduced responsiveness, attenuated or atypical affective signals, limited social engagement, and diminished capacity for reciprocal interaction (Castagna et al., 2024; Provenzi et al., 2021). Their emotional and social cues are less clear, less frequent, and less predictable than typically developing infants, and their capacity for self-regulation is often significantly reduced. These interactional characteristics do not eliminate the infant's participation in the dyadic relationship, even infants with significant developmental impairments remain sensitive to caregiver responsiveness and are capable of organising other-directed regulatory behaviours when the interaction conditions support them (Giusti et al., 2018). What they alter is the legibility of the interaction, making it more challenging for caregivers to recognise, interpret, and respond to their infant's signals.

In addition to differences in communication and social engagement, infants with ND exhibit a higher risk of developing emotional and behavioural problems, including externalizing and internalizing symptoms (Hauser-Cram & Woodman, 2016). Evidence suggests that it is the co-occurrence of ND and externalizing problems, rather than the disability alone, that places great demands on the caregiving system, with significant

implications for parental well-being and the quality of caregiving interactions (Lach et al., 2009; Azad et al., 2013).

Faced with reduced communicative clarity and higher behavioural demands, caregivers of children with ND often adapt their interactional style in ways that reflect the child's profile and needs and to maintain engagement. These adaptations may include increased directiveness, greater scaffolding, and more explicit communicative support, particularly when the infant displays lower levels of communicative competence (Guralnick et al., 2008). Research confirms that mothers of children with ND show reduced responsiveness and fewer teaching behaviours, such as cognitive stimulation, labelling, and joint attention, compared with mothers of typically developing infants, with these effects becoming more pronounced as developmental impairment increases in severity (Castagna et al., 2024). These patterns persist after controlling for maternal stress, suggesting they reflect adaptations to the child's characteristics, rather than simply the emotional burden of caregiving (Castagna et al., 2024). Such adaptations are not limited to verbal and attentional behaviours. Mothers of children with ND have been found to make more use of facilitating and holding touch, possibly reflecting efforts to support attention, and physical engagement during the interaction. The social functions of touch also appear to differ across groups, whereas affectionate touch is more strongly associated with social orienting in typically developing children, playful touch appears to be more strongly associated with gaze towards the caregiver in children with ND (Provenzi et al., 2020a). These findings suggest that caregivers actively reorganise the modalities through which they communicate with their child, seeking alternative pathways for connection and regulation when conventional interaction channels are less available.

Despite these challenges, parenting remains one of the most powerful protective factors available to children with ND. Evidence indicates that positive caregiver-infant interactions are associated with more favourable cognitive, emotional, and socio-interactive outcomes, even in the presence of developmental impairment (Innocenti et al., 2013). Importantly, the impact of the caregiving environment appears to be particularly pronounced among children with disabilities, suggesting that developmentally vulnerable children may be especially sensitive to the quality of caregiving experiences (Innocenti et al., 2013). Similarly, longitudinal research confirms that sensitive and supportive maternal responses to children's distress in early childhood are associated with more favourable behavioural trajectories across development, whereas higher maternal depressive symptoms constitute an important risk factor for later internalising and externalising difficulties in children with ND (Hauser-Cram & Woodman, 2016). Consistent with this perspective, evidence from infants at high risk of cerebral palsy has increasingly emphasised the importance of family of interventions that actively involve caregivers and target the parent-infant relationship (Festante et al., 2019). Taken together, these findings suggest that ND should be understood as conditions that reshape the relational environment in which development occurs, highlighting the need to consider not only the child, but also the caregivers and family system within which adaptation and development occur.

### 2.2 Parental Challenges

Raising a child with ND places extraordinary and sustained demands on caregivers. Beyond the ordinary tasks of parenting, caregivers are required to coordinate a complex network of medical, therapeutic, and educational services. Frequently caregivers must advocate for their child in systems that are difficult to navigate and manage the

uncertainty of the child's developmental trajectory (Murphy et al., 2007). These responsibilities are continuous, often extending across years, and reshape the social, financial, and emotional dynamic of a family life. Many caregivers report limited time for self-care, rest, leisure activities, and the maintenance of personal relationships (Murphy et al., 2007). Daily caregiving demands include assisting their child's developmental needs and coexist with employment responsibilities and the needs of other family members, creating a cumulative burden that can affect the entire family system.

Importantly, as Rosenbaum and Novak-Pavlic (2021) observe, the sources of parental distress do not arise solely from the child's condition. Caregivers often encounter barriers when seeking services, fragmented systems of care, inadequate professional support, social stigma, discrimination and the persistent experience of having a child whose needs are poorly understood by educational and social institutions. Consequently, parental challenges are shaped not only by direct caregiving responsibilities but also by the broader environmental and social context within which the family lives.

The physical consequences of sustained caregiving can be substantial. Caregivers of children with ND report higher rates of chronic physical conditions, including back pain, migraine, arthritis, fatigue, sleep disturbances, and activity limitations (Lach et al., 2009; Murphy et al., 2007). These physical costs accumulate over time, particularly when caregivers deprioritise their own health in response to the relentless demands of the caregiving role. Despite recognising the negative impact of caregiving on their own health, many parents report that they postpone their own medical care because the need of their child consistently takes precedence, creating a pattern with implications for their well-being and for the sustainability of care they can provide (Murphy et al., 2007).

The psychological consequences are equally significant and have been extensively documented. Caregivers consistently report higher levels of parenting stress, depressive symptoms, anxiety, and reduced psychological well-being, compared to parents of typically developing children (Lach et al., 2009; Azad et al., 2013; Barreto et al., 2019). Research suggests that parental stress is influenced not only by the presence of a disability but also the child's behavioural difficulties, social functioning, adaptive skills, and the availability of family and community support (Operto et al., 2021; Bemister et al., 2015; Azad et al., 2013). Behavioural difficulties have consistently emerged as one of the strongest predictors of parental stress across clinical groups, with associations being particularly pronounced for externalising behaviours (Barroso et al., 2018).

The importance of behavioural difficulties as a driver of parental burden extends across diagnostic categories and developmental stages. Longitudinal research tracking maternal stress from early childhood demonstrates that disability status alone does not explain the trajectory of parental stress (Azad et al., 2013). Mothers of children presenting higher levels of behavioural problems not only reported higher stress levels at the beginning of middle childhood but also showed a significantly slower decline in stress across the school years.

A further dimension of parental challenge that warrants attention is the bidirectional relationship between caregivers' psychological well-being and the quality of the caregiving they can sustain. Parental depression has been shown to reduce positive interactions, decrease consistency, and increase hostile and ineffective parenting practices (Arim et al., 2012). The result is a cycle in which caregiving demands erode parental well-being, which further reduced the quality of the caregiving environment, which may exacerbate the child's behavioural difficulties, which intensify caregiving demands (Azad

et al., 2013). This cycle is one of the most clinically significant features of the parental challenge in the context of ND.

These experiences are not uniformly experienced, and they are not inevitably overwhelming. Positive family functioning, adequate social support, and access to appropriate professional services emerge consistently as protective factors that moderate the impact of caregiving demands on parental well-being (Arim et al., 2012; Bemister et al., 2015). Families with stronger social networks and more positive marital relationships report better psychological outcomes and more positive caregiver-infant interactions. Caregivers who receive support from community professionals show significantly less ineffective parenting (Arim et al., 2012). These findings do not minimise the real weight of parental challenge in this context, they establish that the outcome is not determined by the challenge alone, and that the design and delivery of support for caregivers is as clinically relevant as the interventions directed at the child.

### 2.3 Family-Centred Approaches

Children do not develop in isolation. Every child is embedded from birth within a family, where development unfolds. During the twentieth century, paediatric and early childhood services were organised around a fundamentally different premise, where the child was viewed the patient, the professional the expert and the role of the family was primarily to receive information and comply with recommendations. Parents were treated as a backdrop to clinical treatment, and their knowledge of their own child received little formal recognition (Bamm & Rosenbaum, 2008; Rosenbaum & Novak-Pavlic, 2021).

The shift away from this approach drew on converging intellectual and political forces. An ecological view of child development situated the child within nested layers of

environmental context, family, community, and broader society, each shaping development in ways that clinical encounters alone cannot capture (Bronfenbrenner, 1986). Alongside this theoretical reorientation, advocacy movements began arguing that parents were not passive recipients of professional decisions but indispensable partners in their child's care. Family-centred service (FCS) emerged from this confluence as an alternative philosophy, one that repositioned the professional role from directing to enabling, and from fixing the child's deficits toward strengthening the relational context in which the child develops (Bamm & Rosenbaum, 2008). Today, FCS is widely recognised as best practice in early intervention and paediatric rehabilitation (King et al., 2004; Rosenbaum & Novak-Pavlic, 2021).

The core of FCS is grounded in the idea that a family is the constant in a child's life, whereas professionals, services, and interventions come and go. The CanChild Centre for Childhood Disability Research defines it as a set of values, attitudes, and approaches that recognises each family as unique, positions the family as this constant, and treats parents as the experts on their child's abilities and needs (King et al., 2004). From these principles follow several clinical implications such as genuine partnership with parents in decision-making, honest and accessible information sharing, attention to the strengths and needs of all family members and not only the child, and the individualisation of services to each family's specific circumstances and values (Bamm & Rosenbaum, 2008; King et al., 2004). This strengths-based orientation is further grounded in the World Health Organization's International Classification of Functioning, Disability and Health (ICF, 2001), which formalised the importance of contextual factors in shaping how disability is experienced. Consistent with this perspective, the family is understood as the child's primary developmental environment, and emphasis is placed on functioning and participating rather than on the disability alone (Rosenbaum & Novak-Pavlic, 2021).

The evidence of this approach is substantial. Parents of children with ND who report experiencing more family-centred caregiving also report lower levels of depression and distress, greater satisfaction with services, and a stronger sense of parental competence and self-efficacy (King et al., 2004). Randomised controlled trials demonstrated that family-centred programmes produce better psychological adjustment in children with chronic conditions, reduced parental anxiety, and sustained engagement in home programs (King et al., 2004; Bamm & Rosenbaum, 2008). Importantly, across these studies, parents consistently identify availability, communication, and genuine partnership, rather than the technical content of interventions, as the qualities of services that matter most to them (Bamm & Rosenbaum, 2008).

However, implementing FCS remains challenging. Research consistently identifies a gap between the endorsement of FCS principles and their translation into everyday clinical practice. Professionals trained within biomedical models may struggle to share decision-making authority, institutional structures often prioritise efficiency over partnership, and the time needed to truly understand a family's situation is rarely built into standard clinical workflow (Bamm & Rosenbaum, 2008). Families who do not experience their services family-centred report higher levels of stress and lower well-being, highlighting that the aspiration to centre the family must translate into measurable changes in how professionals and families interact (King et al., 2004). The challenge for intervention research is therefore not only to develop effective programs but to ensure they are delivered in ways that are consistent with these principles, which is particularly demanding when the goal is to support the parent-infant relationship in the context of ND.

Ultimately, family-centred approaches reflect a broader reconceptualization of childhood disability, one that recognises development as embedded within family relationships and

everyday contexts (Bronfenbrenner, 1986; Rosenbaum & Novak-Pavlic, 2021). By supporting parental well-being, strengthening caregiver competence, and fostering collaborative partnerships between families and professionals, FCS seeks to enhance the relational environment within which children develop. From this perspective, supporting caregivers is not separate from supporting children's development, but an essential component of it.

### 2.4 Video-Feedback Interventions and Caregiving Support

Supporting caregivers of children with ND requires interventions that are not only effective but responsive to the relational complexity of caregiving in this context. Video-feedback Intervention (VFI) has emerged as a well-supported approach to this challenge. Broadly defined, VFI is a strengths-based, family-centred technique that uses recordings of naturally occurring parent-child interactions during free play, feeding, bathing or other everyday caregiving moments. These recordings are used as the basis for structured reflection with a trained professional (Fukkink, 2008; Rusconi-Serpa et al., 2009). This intervention invites caregivers to observe themselves from the outside, creating a reflective distance that is rarely available in the immediacy of daily caregiving (Wan et al., 2025). Through this process, caregivers can notice aspects of their own behaviour and their child's responses that usually unfold too quickly, or automatically, to be consciously perceived in real time. The professional guides this observation with attention to what is already working, building upon existing competences rather than focusing on correcting deficits (Rusconi-Serpa et al., 2009).

This strength-based orientation is central to the VFI approach. By positioning the caregiver as an expert on their own child, and by making visible the competencies they already possess, the intervention builds self-confidence alongside sensitivity (Fukkink,

2008). This aligns naturally with the principles of family-centred service, using the parent as an active partner in a collaborative process of observation and reflection. The professional role is to create the conditions in which that reflection becomes safe, carefully selecting video fragments, framing what is seen in supportive language, and guiding the caregiver's attention toward the child's signals and responses in ways that are informative without being evaluative (Rusconi-Serpa et al., 2009; Wan et al., 2025).

Two broad theoretical approaches to VFI are described in literature. Behaviour-oriented programs focus on the observable dimensions of interaction such as sensitivity, contingency and responsiveness, making them concrete and discussable. Psychotherapeutic or representation-oriented programs attend additionally to the mental representations the caregiver holds of themselves, their child, and their relationship, using the footage as a catalyst for accessing and revising the deeper internal patterns that shape caregiving behaviour (Fukkink, 2008; Rusconi-Serpa et al., 2009). In practice, the boundaries between these approaches are permeable, and different programs combine elements of both. Beyond these two broad categories, other models have been developed with specific theoretical foundations, including attachment-based, systemic, and transactional approaches, each with its own entry point into the caregiving relationship (Rusconi-Serpa et al., 2009). What unites this range of approaches is the commitment to the caregiver-child relationship, rather than the child's impairment alone, as the primary site of intervention.

The general evidence base for VFI is robust. A meta-analysis of 29 studies found significant positive effects on parenting behaviour and on parental attitudes, including reductions in parenting stress and increases in self-confidence, as well as effects on child developmental outcomes, with shorter programs consistently emerging as more effective

(Fukkink, 2008). Parental experience of the process has itself been identified as meaningful. A meta-synthesis of qualitative studies found that most parents described the intervention as transformative, with the act of watching themselves interact with their child producing realisations that verbal instructions alone could not replicate (Wan et al., 2025). Parents described unexpected insights about their child's communicative intentionality, a sense of validation in seeing their own competence on screen, and lasting changes in how they attended to and understood their child. This capacity of video to surprise and reorganise how caregivers perceive their child is a distinctive feature of VFI that sets it apart from other parenting support modalities (Wan et al., 2025).

In the context of ND, this mechanism takes on particular significance. As described in the preceding sections, the communicative signals of children with ND are often reduced, atypical, or difficult to read, and caregivers frequently adapt by becoming more directive in ways that inadvertently reduce the child's communicative space (Castagna et al., 2024; Guralnick et al., 2008). The capacity of VFI to slow down interaction and make the child's subtle signals visible directly addresses one of the central relational challenges of this caregiving context.

The evidence from this population is growing and consistently points to improvements not only in parenting behaviour but in the broader relational system. Studies have documented that VFI enhances caregivers' capacity to read and respond, and, in some studies, these changes are accompanied by positive shifts in children's own behaviour, including reduced behavioural problems, improved cognitive outcomes and greater interpersonal functioning (Provenzi et al., 2020b). Effects on parental emotional well-being have been more inconsistent, while some studies found reductions in parenting stress following VFI, others did not, suggesting that behavioural interventions may not

be sufficient to address the deeper and more chronic dimensions of parental distress that characterise caregiving in the context of ND (Provenzi et al., 2020b). Evidence from a randomised controlled trial of VIPP-AUTI, an attachment-based VFI adapted for families of children with ASD, found that parents who receive the interventions showed reduced levels of parental intrusiveness and increased self-efficacy, with effects on the child initiated joint attention emerging at a three-month follow-up (Poslawsky et al., 2014). Recent work has begun to clarify the specific patterns of change that VFI produces, with studies documenting significant improvements in maternal responsiveness, encouragement, and teaching behaviour, and better parenting after the intervention was associated with lower reported parenting stress, suggesting that the mechanism of change may run through enhanced self-efficacy, though this was not directly measured (Montirosso et al., 2025a). A reduction in state anxiety was observed, though trait anxiety and depressive symptoms remained unchanged, pointing to the limits of a behaviourally focused intervention and the need, in some cases, for complementary individual support. Extending these findings to the child, a companion study found that following the intervention children showed significantly increased social engagement during recovery from interactive disruption, an improvement linked to greater maternal sensitivity during the same episode (Montirosso et al., 2025b). Together, these findings suggest that VFI operates as a genuinely dyadic intervention, where the changes in how the caregiver sees and responds to the child create conditions in which the child itself becomes more communicatively active.

Despite these promising findings, many studies in this population have relied on small samples and single-cohort designs, and the high variability across programs makes systematic comparison difficult (Provenzi et al., 2020b). Ongoing randomised controlled trials, including studies examining both behavioural and biobehavioural outcomes and

exploring telecare delivery as a means of expanding access to families in remote areas, represent important steps toward a more rigorous evidence base (Montirosso et al., 2020; Grumi et al., 2023). Taken together, the available evidence supports VFI as a clinically meaningful and practically feasible approach to support caregivers of children with ND, an approach that supports not only the caregiver, but the relationship in which early development unfolds.

# Chapter 3

# Exploring Maternal Unpredictability in the Context of Children with Neurodevelopmental Disabilities

## 3.1 Introduction

Early caregiving constitutes a powerful environmental context shaping infant neurodevelopment. The quality, consistency, and responsiveness of maternal care during the first years of life are foundational to the infant's emerging regulatory capacities, cognitive development, and attachment security (Ainsworth et al., 1978; Feldman, 2007; Sroufe, 2000). A growing body of research has further highlighted that not only the quality but also the temporal organization of caregiving signals matters for development, specifically, whether the sequences of maternal sensory behaviours are structured in ways that are anticipable and learnable for the infant (Baram et al., 2012; Davis et al., 2017).

The temporal organization of maternal sensory signals constitutes a distinct and developmentally significant dimension of early caregiving. Maternal unpredictability, quantified as the entropy rate of sequences of auditory, visual and tactile signals during mother-infant interaction, captures the degree to which one maternal behaviour fails to predict the next (Davis et al., 2017). This dimension is conceptually and empirically independent of maternal sensitivity, since a caregiver may be warm and emotionally responsive while providing sensory signals whose sequence and timing are difficult for the infant to anticipate (Baram et al., 2012; Davis et al., 2017). Evidence from longitudinal studies has shown that higher maternal entropy rate during infancy is associated with poorer cognitive outcomes, reduced effortful control, with effects persisting into middle childhood and above and beyond what maternal sensitivity alone explains (Davis et al., 2017, 2019). Exposure to higher entropy rate has also been associated with alterations in

the maturation of corticolimbic circuits involved in memory and stress regulation (Granger et al., 2021). Longitudinal research further indicated that entropy rate shows moderate individual stability across early childhood, and that it decreases on average as children grow older, suggesting that caregiving interactions become progressively more organised as the dyad develops (Holmberg et al., 2022; Takio et al., 2026).

Despite this growing evidence base, all existing research on maternal entropy rate has been conducted with typically developing populations. The context of ND introduces conditions that may alter the temporal organization of caregiving in ways that have not been examined. Children with ND frequently display less clear, less frequent and less predictable communicative signals than those of typically developing children (Castagna et al., 2024; Provenzi et al., 2021). In response, caregivers often adapt by increasing directiveness and scaffolding during interaction (Castagna et al., 2024; Guralnick et al., 2008), actively reorganising the modalities through which they communicate with their child when conventional interaction channels are less available (Provenzi et al., 2021). Given the evidence from typically developing children on the consequences of maternal unpredictability, understanding how maternal sensory signals are organised in the context of ND becomes particularly relevant. Children with ND already face significant developmental challenges, and the temporal organization of maternal sensory signals may constitute an additional dimension of the early environment worthy of examination.

A further open question concerns the relationship between maternal emotional well-being and entropy rate in this context. In typically developing populations, initial evidence suggested that concurrent maternal depressive and anxiety symptoms may be associated with higher entropy rate during infancy (Davis et al., 2017), though this association has not been consistently replicated across studies or designs (Davis et al., 2019; Holmberg

et al., 2022; Takio et al., 2026). Whether maternal well-being shapes the temporal organization of caregiving signals therefore remains unclear even in typically developing populations. This question takes on relevance in the context of ND, where mothers consistently report elevated levels of anxiety and parenting stress compared to mothers of typically developing children (Lach et al., 2009; Azad et al., 2013). It has not been understood how this heightened emotional burden may be expressed in the temporal organisation of maternal sensory signals, nor whether maternal well-being constitutes a meaningful correlate of entropy rate in this population.

### 3.2 Aims

The present study aimed to provide an examination of maternal unpredictability, operationalised as entropy rate of maternal sensory signals, in the context of ND. Given the absence of prior research examining entropy rate in this population, the study was exploratory in nature. However, drawing on existing evidence from typically developing populations, specific expectations were formulated. The study pursued four aims:

The first aim was to examine whether maternal entropy rate differed between mothers of children with ND and mothers of typically developing children. Given the well-documented differences in communicative signals of children with ND and the caregiving adaptations these elicit (Castagna et al., 2024; Guralnick et al., 2008), it was considered plausible that entropy rate might differ between groups. However, since no directional hypothesis could be derived from the existing literature, no specific direction of effect was predicted.

The second aim was to examine whether infant sex was associated with maternal entropy rate, and whether this association differed between groups. Based on evidence from

typically developing populations showing no significant association between infant sex and entropy rate (Davis et al., 2017; Takio et al., 2026), no significant effect of sex was expected.

The third aim was to examine the association between infant age and maternal entropy rate, and whether this association differed between groups. Based on evidence consistently showing that entropy rate decreases as infants grow older in typically developing populations (Holmberg et al., 2022; Takio et al., 2026), it was expected that infant age would be negatively associated with entropy rate in the control group. It remained an open question whether this trajectory would be observed in the clinical group.

The fourth and final aim was to examine whether maternal entropy rate was associated with maternal well-being, including maternal anxiety, depressive symptoms, and parenting stress, and whether these associations differed between groups. Given that initial evidence has linked concurrent maternal distress to higher entropy rate in typically developing populations (Davis et al., 2017), though not consistently replicated in longitudinal designs (Holmberg et al., 2022; Takio et al., 2026), no strong directional hypothesis was formulated, and this aim remained exploratory.

## 3.3 Methods

### 3.3.1 Participants

A total of 61 mother–child dyads participated in the study. The clinical group included 30 dyads with children presenting developmental vulnerabilities, including psychomotor delay, rare genetic syndromes, emotional regulation difficulties, and risk for autism spectrum disorder (ASD). The control group consisted of 31 dyads with typically

developing children. Families in the clinical group were recruited from the IRCCS Mondino Foundation, whereas families in the control group were recruited through snowball sampling. Children were eligible for inclusion if they were aged between 1 and 36 months, considering corrected age in the case of preterm birth. Mothers were required to be at least 18 years old, fluent in Italian, and cohabiting with the child. Exclusion criteria were the presence of life-threatening medical conditions in the child and any documented psychiatric disorder in either parent. Children in the two groups were matched for age and gender. The study was approved by the Ethics Committee of Pavia, and all participants provided written informed consent.

### 3.3.2 Procedures

The study was conducted remotely. Once informed consent had been obtained from both caregivers, mothers received an email containing their alphanumeric identification code, the link for the Zoom video call, and the link to complete the maternal well-being questionnaires. The timing of the video-recorded mother–child play session was arranged according to participants' availability. Mothers were asked to position their mobile phone or computer in a way that ensured a clear view of both them and their child, and to play and/or interact with their child as they normally would for five minutes.

### 3.3.3. Measures

*Maternal symptoms of anxiety* were assessed using the State subscale of the State-Trait Anxiety Inventory (STAI-Y; Spielberger et al., 1983), a widely used self-report measure that distinguishes between two dimensions of anxiety. State anxiety reflects how a person feels at a particular moment in time, and trait anxiety reflects a relatively stable tendency to experience anxiety across situations. Each subscale contains 20 self-report items rated on a 4-point Likert scale, with scores ranging from 20 to 80. Higher scores indicate greater

anxiety and scores above 40 may indicate a clinical risk for anxiety. Both subscales were administered in the present study, but only state anxiety was considered for analysis.

*Maternal symptoms of depression* were assessed using the Beck Depression Inventory-II (BDI-II; Beck et al., 1988), a 21-item self-report questionnaire widely used to assess depressive symptomatology. Each item is scored between 0 and 3, with total scores ranging from 0 to 63. Higher scores reflect greater symptom severity, and a score above 12 may indicate a clinical risk for depression.

*Parenting stress* was assessed using the Parenting Stress Index–Short Form (PSI-SF; Abidin, 1983). The PSI-SF consists of 36 items rated on a 5-point Likert scale and includes three subscales: Parental Distress (PD), which is related to stress arising from personal factors in the parenting role; Parent–Child Dysfunctional Interaction (CDI), which is related to the parent's perception of the interaction with the child; and Difficult Child (DC), which is related with the child behavioural characteristics. Scores from each subscale can be summed to obtain a Total Parenting Stress score, with higher scores indicating greater stress.

*Maternal unpredictability coding.* Maternal unpredictability was assessed using the Maternal Sensory Signals Coding Manual, from Davis (2017). Using the Observer XT software, mother-child interactions were coded continuously in real time. Two types of codes were applied, events and states. Events capture a discrete behaviour in a single point in time, and states capture continuously mutually exclusive behaviours with duration in time. Three modalities of sensory signals were coded: auditory, tactile and visual. Auditory sensory signals were coded as events with each maternal vocalization, defined as any phrase or sound separated by a pause. Tactile signals were coded as single touch events, defined as each distinct physical contact with the child, and holding states,

coded continuously as holding or not holding the child. Visual signals included object in hand states, coded continuously as whether the mother was or was not holding or touching an object. The child's looking at the mother was coded continuously as a state, distinguishing between looking and not looking at the mother or her activity. From these codes an entropy rate was calculated for each mother. Entropy rate quantifies the degree to which one maternal behaviour fails to predict the next one, with higher values indicating more fragmented and less anticipable sequences of maternal signals. Participants from whom entropy rate could not be estimated were excluded from the analysis.

It should be noted that the pointing code described in the original coding manual was not included in the coding procedure of the present study. The full coding manual is available in Appendix A.

### 3.4 Results

#### 3.4.1 Descriptives

Descriptive statistics for the full sample are represented in Tables 1, 2 and 3.

**Table 1.** Descriptive analysis for infant's age, maternal age and maternal education by group.

| | Group | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| Infant's age (months) | CNTR<br>CLINICAL | 30<br>27 | 13.5<br>13.1 | 7.6<br>7.84 | 4<br>4 | 34<br>34 |
| Mother's age (years) | CNTR<br>CLINICAL | 23<br>22 | 35.1<br>36.2 | 3.81<br>6.32 | 28<br>23 | 44<br>47 |
| Mother's education (years) | CNTR<br>CLINICAL | 26<br>27 | 17.3<br>14.2 | 2.66<br>3.71 | 13<br>8 | 22<br>21 |

**Table 2.** Frequency analysis for infant sex, maternal employment status and infant clinical conditions.

| | Group | | f | % |
|---|---|---|---|---|
| Infant's Sex | CNTR | Male (1) | 14 | 23% |
| | | Female (0) | 17 | 27.9% |
| | CLINICAL | Male | 21 | 34.4% |
| | | Female | 9 | 14.8% |
| Mother Occupational Status | CNTR | Employed | 25 | 47.2% |
| | | Unemployed | 1 | 1.9% |
| | CLINICAL | Employed | 10 | 18.9% |
| | | Unemployed | 17 | 32.1% |
| Clinical Sample | | Psychomotor delay | 22 | 61.11% |
| | | At risk for ASD | 6 | 16.07% |
| | | Emotion regulation difficulties | 5 | 14.52% |
| | | Rare Syndrome | 3 | 8.3% |

Note: Occupational status data were missing for 8 participants.

**Table 3.** Descriptive analysis of entropy rate and maternal well-being between groups.

| | Group | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|---|
| Entropy Rate | CNTR | 31 | 0.843 | 0.187 | 0.392 | 1.18 |
| | CLINICAL | 30 | 0.807 | 0.154 | 0.406 | 1.15 |
| STAI_state | CNTR | 26 | 33.62 | 9.47 | 24 | 60 |
| | CLINICAL | 29 | 33.72 | 6.84 | 20 | 48 |
| BDI | CNTR | 26 | 5.85 | 4.09 | 0 | 13 |
| | CLINICAL | 29 | 7.03 | 4.69 | 0 | 19 |
| PSI_PD | CNTR | 26 | 20.96 | 8.62 | 13 | 51 |
| | CLINICAL | 29 | 22.17 | 7.97 | 12 | 40 |
| PSI_CDI | CNTR | 26 | 17 | 8.69 | 12 | 58 |
| | CLINICAL | 29 | 21.21 | 8.56 | 14 | 56 |
| PSI_DC | CNTR | 26 | 22.69 | 8.96 | 13 | 59 |
| | CLINICAL | 29 | 23.07 | 7.89 | 13 | 57 |

| | | | | | | |
|---|---|---|---|---|---|---|
| PSI_TOT | CNTR | 26 | 60.65 | 24.94 | 39 | 168 |
| | CLINICAL | 29 | 66.45 | 21.79 | 46 | 153 |

### 3.4.2 Group differences in Maternal Unpredictability

An independent samples t-test was conducted to examine whether maternal entropy rate differed between the clinical and control groups. Results showed no significant difference between groups t(59)=0.835, p=0.407, d=0.21, indicating that the presence of a neurodevelopmental condition in the child was not associated with differences in the maternal unpredictability (Figure 1).

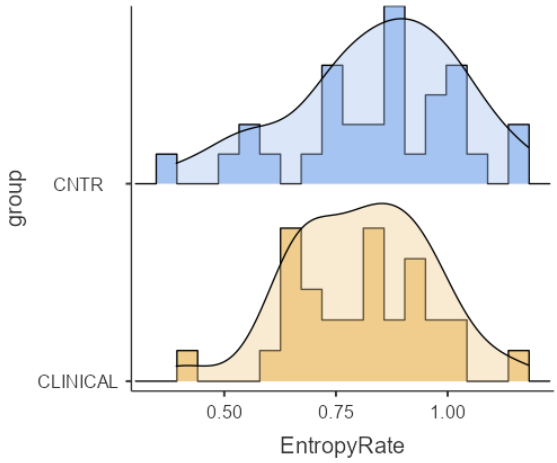


**Figure 1.** Boxplot of maternal entropy rate in the control (CNTR) and clinical group (CLINICAL).

### 3.4.3 Differences in Maternal Unpredictability by Infant Sex

A two-way ANOVA was conducted to examine the effects of group (CNTR vs CLINICAL), infant sex and their interaction on maternal entropy. Results revealed no significant main effect of group, F(1,57)= 1.340, p=0.252, no significant main effect of sex, F(1,57)= 0.916, p=0.342, and no significant group×sex interaction, F(1,57)= 0.713,

p=0.402. These findings suggest that neither the clinical status of the child nor the infant's sex were associated with differences in the temporal organization of maternal sensory signals. The mean entropy rate by group and sex is illustrated in Figure 2.

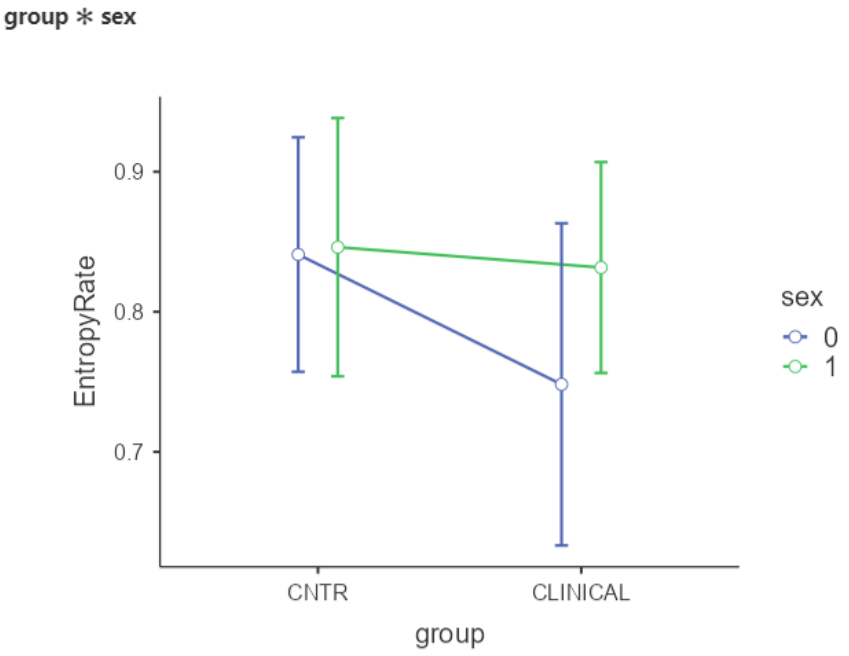


**Figure 2.** Estimated marginal means of maternal entropy rate by group and infant sex. 0=female; 1=male. Error bars represent 95% confidence intervals.

### 3.4.4 Associations between Maternal Unpredictability and Infant Age

A General Linear Model was conducted to examine whether the effect of group, infant age and their interaction predicted maternal entropy rate (N=57). The overall model was statistically significant, $F(3,53)= 5.32$, $p=0.003$, $R^2=0.232$. Results are presented in Table 4 and 5. A significant group×age interaction was found $F(1,53)= 5.256$, $p=0.026$, indicating that the association between infant age and maternal unpredictability differed

between groups. Specifically, infant age significantly predicted entropy rate in the control group but not in the clinical group. The predicted values are illustrated in Figure 3.

**Table 4.** Effects of group and infant age on maternal entropy rate.

| | F | df | p | $\eta^2p$ |
|---|---|---|---|---|
| Group | 0.659 | 1,53 | 0.420 | 0.012 |
| Infant's age | 9.833 | 1,53 | 0.003 | 0.156 |
| Group*Infant's age | 5.256 | 1,53 | 0.026 | 0.090 |

**Table 5.** Simple effects of infant age on maternal entropy rate by group.

| Group | β | SE | t(53) | p | $\eta^2p$ |
|---|---|---|---|---|---|
| CNTR | -0.015 | 0.004 | -3.884 | <0.001 | 0.222 |
| CLINICAL | -0.002 | 0.004 | -0.589 | 0.558 | 0.007 |

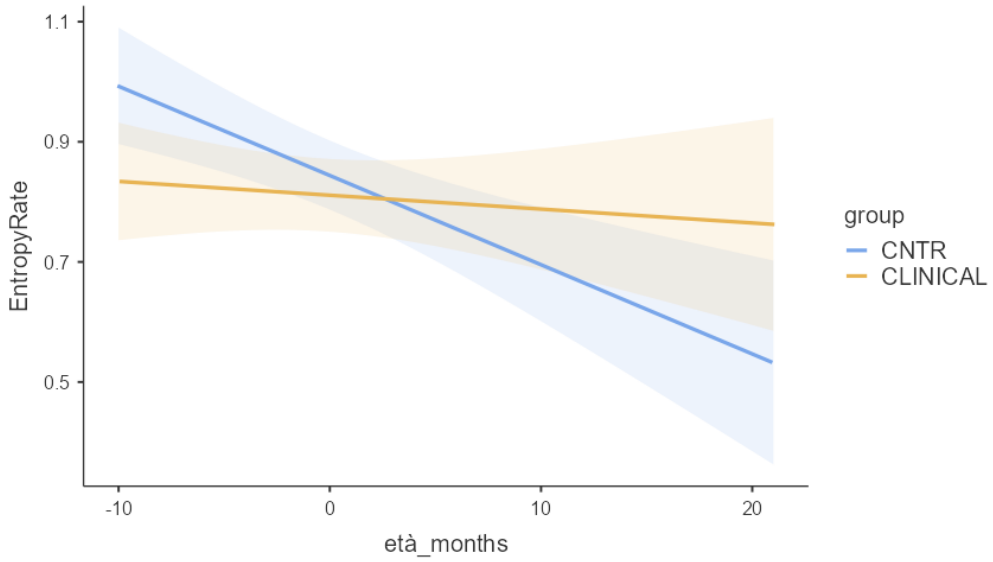


**Figure 3.** Predicted values of maternal entropy rate as a function of infant age by group. Infant age is mean-centered (mean=13.3 months). Shaded areas represent 95% confidence intervals.

### 3.4.5 Associations between Maternal Unpredictability and Maternal Well-being

Independent t-tests were conducted to examine whether the two groups differed in maternal well-being. Results revealed no significant differences between the control and clinical groups in any of the well-being measures, as presented in Table 6.

**Table 6.** Group comparison on maternal well-being.

| Variable | CLINICAL M(SD) | CNTR M(SD) | t | df | p |
|---|---|---|---|---|---|
| STAI_state | 33.72 (6.84) | 33.62 (9.47) | -0.049 | 53 | 0.961 |
| BDI | 7.03 (4.69) | 5.85 (4.09) | -0.996 | 53 | 0.324 |
| PSI_PD | 22.17 (7.97) | 20.96 (8.62) | -0.541 | 53 | 0.591 |
| PSI_CDI | 21.21 (8.56) | 17 (8.69) | -1.807 | 53 | 0.076 |
| PSI_DC | 23.07 (7.89) | 22.69 (8.96) | -0.166 | 53 | 0.869 |
| PSI_TOT | 66.45 (21.79) | 60.65 (24.94) | -0.920 | 53 | 0.362 |

Note: CNTR: n=26; CLINICAL: n=29, due to missing data on well-being measures.

Pearson correlations were computed separately for each group to examine the association between maternal entropy rate and maternal well-being. In the clinical group, entropy rate was significantly and positively associated with state anxiety (r=.451, p=.014), indicating that mothers of children with ND who reported higher anxiety at the time of the interaction tended to show more unpredictable sensory signals. No other significant associations were found in the clinical group. In the control group, no significant correlations were found between entropy rate and the measures of maternal well-being. Results are represented in Table 7.

**Table 7.** Correlations between maternal entropy rate and well-being measures by group.

| | CLINICAL entropy rate (n=29) | CNTR entropy rate (n=26) |
|---|---|---|
| STAI_state | 0.451* | 0.146 |
| BDI | 0.172 | 0.255 |
| PSI_PD | 0.030 | 0.178 |
| PSI_CDI | -0.120 | 0.305 |
| PSI_DC | -0.318 | 0.105 |
| PSI_TOT | -0.151 | 0.205 |

Notes: Values are Pearson r correlations; n varies due to missing data on well-being measures; *p<0.05

### 3.5 Discussion

The first aim of the study was to examine whether maternal entropy rate differed between mothers of children with ND and mothers of typically developing children. Evidence suggests that the presence of ND was not associated with differences in the maternal unpredictability.

This finding is consistent with the conceptualization of entropy rate as a relatively stable characteristic of the maternal caregiving style. Longitudinal research in typically developing children has shown that while entropy rate decreases on average as children grow older, individual differences in maternal unpredictability remain moderately stable across early childhood (Holmberg et al., 2022; Takio et al., 2026). Although these studies did not examine directly the influence of child characteristics on entropy rate, the observed stability across childhood suggests that entropy rate reflects an enduring characteristic of the mother's caregiving style rather than a direct response to the child's behaviour, a pattern broadly consistent with the present finding that entropy rate did not differ between groups.

Regarding the effect of sex and maternal entropy, it was found that neither the infant's sex nor its interaction with clinical status was associated with differences in entropy rate. These findings are consistent with converging evidence from typically developing children, showing no significant association between infant sex and entropy rate (Davis et al., 2017; Takio et al., 2026). Notably, Holmberg et al., (2022) found that mothers were more sensitive to girls than boys, yet no parallel effect was observed for entropy rate, suggesting that sex differences in caregiving may be more specific to measures of sensitivity than to the temporal organization of sensory signals. This study extends this pattern to the context of ND.

A significant group age interaction was found, indicating that the association between infant age and entropy rate differed between control and clinical groups. Specifically, infant age significantly predicted entropy rate in the control group but not in the clinical group.

In the control group, the negative association between infant age and entropy rate extends findings from longitudinal studies in typically developing populations, where entropy rate has been shown to decrease significantly within the first 30 months of life and beyond (Holmberg et al., 2022; Takio et al., 2026). This study observes this pattern in a cross-sectional design, suggesting that this association is robust across different methodological approaches. Two complementary mechanisms have been proposed to explain this pattern. Mothers may acquire better parenting skills and experience as they gain experience with their child, becoming more consistent and predictable in their caregiving behaviour; and the child's own communicative and cognitive development may contribute to more organised and fluent interaction patterns over time (Holmberg et al., 2022). Both processes are likely to operate simultaneously in typically developing dyads.

In contrast, this developmental trajectory was not observed in the clinical group. The absence of significant association between infant age and entropy rate in the clinical group may reflect several complementary processes, though all remain speculative in the absence of direct evidence.

One possibility is that the atypical and less legible communicative signals of children with ND may constrain the bidirectional process through which caregiving interactions typically become more organised over time. In typically developing dyads, the child's growing communicative competence may actively scaffold the organization of maternal

caregiving behaviour. When these signals are reduced or difficult to read, this process may be disrupted or takes longer to emerge.

A further interpretation worth considering is that the stability of entropy rate in the clinical group may reflect a bidirectional process in which neither the child nor the mother undergoes the same developmental shift observed in typically developing dyads. The ongoing challenges of raising a child with ND may require mothers to maintain sustained vigilance and active adaptation, preventing the natural reorganization of caregiving patterns that emerge. Importantly, although the two groups did not differ significantly in overall entropy rate, what distinguished them was the developmental trajectory over time. These findings suggest that the challenge in the context of ND may not be one of the elevated unpredictability per se, but rather a failure to develop, or a slower development of progressively more organised caregiving patterns as the child grows older. These interpretations remain speculative and future longitudinal studies with larger samples are needed to confirm this trajectory and to determine whether the absence of a significant association between age and entropy rate in the clinical group has implications for the developmental outcomes over time.

The associations between maternal entropy and well-being measure yielded a mixed pattern of results. No significant group differences were found in any well-being measure. Although this finding is somewhat unexpected given that mothers of children with ND consistently report elevated levels of anxiety and parenting stress in the existing literature (Lach et al., 2009; Azad et al., 2013), it should be interpreted with caution given the small sample size.

In the clinical group, entropy rate was significantly and positively associated with state anxiety, indicating that mothers of children with ND who reported higher anxiety at the

time of the interaction tended to show more unpredictable sensory signals. No significant associations were found between entropy rate and any other well-being measure in both groups. This suggests that maternal anxiety may have a more direct impact on caregiving organization when the interaction is already more challenging, as in the case of children with ND.

The significant association between concurrent state anxiety and entropy rate in the clinical group is broadly consistent with earlier evidence linking concurrent maternal distress to higher entropy rate (Davis et al., 2017), whereas longitudinal symptom trajectories have not shown consistent associations (Holmberg et al., 2022; Takio et al., 2026). This distinction between concurrent and longitudinal measurement may partly explain the pattern of findings observed in the present study. However, direct comparisons with previous studies are limited by the methodological differences.

The absence of significant associations between entropy rate and depressive symptoms or parenting stress in both groups is consistent with evidence showing that these measures are more consistently associated with maternal sensitivity than with entropy rate. It is also possible that entropy may be more sensitive to acute emotional states experienced during the interaction itself, rather than to general levels of psychological distress. These interpretations remain speculative and should be tested in future studies with larger samples.

This study has limitations that should be acknowledged. First, it is preliminary in nature, comprising a small sample as part of an ongoing research programme. This limits statistical power and all findings should be considered exploratory pending replication in larger samples. Second, the clinical group was heterogenous, comprising children with a range of neurodevelopmental conditions, which may have limited the observation of

condition-specific patterns of maternal unpredictability. Third, the absence of maternal sensitivity measures limits the ability to determine whether the observed associations between entropy rate, infant age and maternal well-being are independent of sensitivity, as has been demonstrated in typically developing populations. Fourth, the cross-sectional design does not allow for examination of longitudinal changes within the individual dyads. Fifth, child developmental outcomes were not assessed, limiting conclusions about the developmental significance of the observed patterns of entropy rate in both populations. A further limitation across studies concerns the lack of consistency in assessing maternal well-being across studies. The use of standardized and comparable measures of maternal well-being across studies would strengthen the comparability of findings and allow for more direct comparisons.

Despite these limitations, this study represents a first step in understanding whether maternal unpredictability operates differently in the context of ND, and whether it may constitute a relevant and independent dimension of caregiving with implications for maternal well-being and child developmental outcomes in this population. Future studies should examine whether entropy rate is associated with child developmental outcomes, and whether interventions targeting the caregiving relationship, such as video-feedback interventions, may benefit from incorporating attention to the temporal organization of maternal sensory signals.

# Conclusion

The present study examined maternal unpredictability in the context of ND, integrating theoretical, empirical and clinical perspectives to address a gap in the existing literature.

The theoretical and clinical foundations reviewed in the first two parts of the thesis established that early caregiving shapes infant neurodevelopment not only through its emotional quality but also through its temporal organisation, and that families of children with ND face unique challenges that make understanding this dimension of caregiving particularly relevant.

Building on this foundation, the empirical study provided a first examination of maternal unpredictability in this population. The findings revealed that maternal entropy rate did not differ significantly between mothers of children with ND and mothers of typically developing children, suggesting that entropy rate may reflect a relatively stable characteristic of the mother's caregiving style, largely independent of the child's clinical status. However, the developmental trajectory of entropy rate across infant age differed significantly between groups. While infant age was a significant negative predictor of entropy rate in the control group, no significant association was observed in the clinical group, raising the possibility that the progressive organisation of caregiving over time may unfold differently in the context of ND. Finally, in the clinical group only, entropy rate was linked to concurrent maternal state anxiety, suggesting that maternal emotional well-being may play a more direct role in shaping caregiving organisation when the interaction is already more demanding.

These findings are preliminary and should be interpreted with caution. Nevertheless, they open new questions about how maternal unpredictability operates in the context of ND,

with potential implications for research and clinical practice. Longitudinal studies with larger and more homogeneous samples, incorporating measures of maternal sensitivity and child developmental outcomes, are needed to explore these results. Attending to the temporal organisation of caregiving, and the emotional well-being of caregivers, may be a relevant dimension in the design of future family-centred interventions.

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# Appendices

## Appendix A- Maternal Sensory Signals Coding Manual

The coding manual used in this study was developed by Davis et al. (2017) and it is available at: https://contecenter.uci.edu/measuring-unpredictable-maternal-sensory-signals/. The following tables summarize de coding scheme from the manual, noting that the pointing code was not included in the present study.

**MATERNAL SENSORY SIGNALS CODING SCHEME**

**PASS 1**

**Sensory category:** Auditory

**Subject:** Mother

| **VOCAL** (Event) |
|---|
| Maternal vocalizations include each distinct utterance or statement (each time there is a break in a sentence, song, phrase, etc., a new vocal should be coded). Laughs and sound effects (e.g., moo) are considered vocalizations.<br><br>*Notes: A new vocalization should be coded for each distinct utterance/statement (i.e. If the mother says "Here is the giraffe. He is red!", code one vocal at the beginning of the first sentence, and a second vocal at the beginning of the second sentence.) Similarly, a new vocalization should be coded for each distinct statement/phrase in a song (i.e. "Mary had a little lamb/ little lamb/ little lamb" would be coded as 3 separate vocalizations).*<br>*Coughs, sneezes, and yawns are not considered vocalizations and should not be coded.* |

**PASS 2**

**Sensory category:** Tactile

**Subject:** Mother

| **TOUCH** (Event) |
|---|
| Tactile contact with the child (other than holding). One touch should be coded for each distinct instance of contact.<br><br>Examples of touch include running fingers through the child's hair, fixing the child's clothes, running a toy car across child's leg, giving the child a kiss, or adjusting child's position.<br><br>*Notes: A new touch should be coded for each distinct instance of contact (i.e. if the mother runs her fingers through the child's hair twice, code one touch at the beginning of the first time she runs her fingers through, and a second touch at the beginning of the second instance).*<br>*Do not code touch if the child touches the mother.* |
| **HOLDING CHILD** (Mutually Exclusive State) |
| Holding the child for a period of time.<br><br>Examples include carrying or picking up the child, securing the child while he/she is sitting on the mother's lap, supporting the child (i.e. supporting the child so that he/she does not fall over when standing), and restraining the child (i.e. holding the child's arm so that he/she cannot reach a toy, or physically stopping child from crawling or walking).<br><br>*Notes: A touch code does not need to be coded when the mother initially touches the child to hold him/her. Touches can be coded while mother is holding child. For example, if the mother is holding child and kisses his/her head, a touch should be coded for the kiss.* |
| **NOT HOLDING CHILD** (Mutually Exclusive State) |
| Not holding the child.<br><br>*Note: This state should be coded if the child is sitting on the mother's lap (i.e., using the mom as a chair and supporting themselves) with out any active contact from the mother (i.e., the mother is not holding/supporting the child, the mother's hands are not around the child to secure him/her).* |
| **CAN'T TELL IF HOLDING CHILD** (Mutually Exclusive State) |
| Mom and child are both out of camera view, or holding cannot be reasonably distinguished due to bad camera angle. |

**PASS 3**
**Sensory Category:** Visual
**Subject:** Mother

| |
|---|
| **POINTING** (Event) |
| Pointing to an object with the intention of directing the child's attention to that object.<br><br>Examples include pointing to a toy, the child's shirt, the child's toes, a window, or the lights.<br><br>*Note: The mother may not be touching an object while she points to it. In this case, "object in hand" would be coded.* |
| **Touching or Holding Object** (Mutually Exclusive State) |
| Touching or holding a toy or other object.<br><br>Examples include shaking a rattle, pressing buttons on toys, touching objects to count, adjusting the boppy, holding a coffee cup, or holding a baby bottle.<br><br>*Note: If the mom is only resting her hand on an object, do not code "object in hand" – instead, code "no object in hand" (e.g., the mother may be resting her hand on the boppy).* |
| **NO OBJECT IN HAND** (Mutually Exclusive State) |
| Not holding or touching an object. (includes passively resting hand on object). |
| **ACTIVITY NOT VISIBLE** (Mutually Exclusive State) |
| Mother is out of the camera view, or her activity is not visible due to bad camera angle. |

**PASS 4**
**Sensory Category:** Visual
**Subject:** Child

| |
|---|
| **LOOKING AT MOTHER** (Mutually Exclusive State) |
| Looking at the mother, the object the mother is holding/playing with, or an activity mother is engaging in. |
| **NOT LOOKING AT MOTHER** (Mutually Exclusive State) |
| Not looking at the mother or her activity. Looking at toys or other objects in the room. |
| **CAN'T TELL CHILD LOOKING** (Mutually Exclusive State) |
| Child is out of the camera view, or looking cannot be reasonably distinguished due to bad camera angle. |