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Narrative as co-regulation: A review of embodied narrative in infant development☆

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ABSTRACT

We review evidence of non-verbal, embodied narratives in human infancy to better understand their form and function as generators of common experience, regulation, and learning. We examine their development prior to the onset of language, with a view to improve understanding of narrative as regular motifs or schemas of early experience in both solitary and social engagement. Embodied narratives are composed of regular patterns of interest, arousal, affect, and intention that yield a characteristic four-part structure of (i) introduction, (ii) development, (iii) climax, and (iv) resolution. Made with others these form co-created shared acts of meaning, and are parsed in time with discreet beginnings and endings that allow a regular pattern to frame and give predictive understanding for prospective regulation (especially important within social contexts) that safely returns to baseline again. This characteristic pattern, co-created between infant and adult from the beginning of life, allows the infant to contribute to, and learn, the patterns of its culture. We conclude with a view on commonalities and differences of co-created narrative in non-human primates, and discuss implications of disruption to narrative co-creation for developmental psychopathology.

1. Narrative

Bruner (1986, 1990) identified two modes of cognition. On the one hand, there exists a logico-scientific mode of cognition able to form concepts with knowledge of their lawful properties. This is a timeless, abstract knowledge that enables a technical intelligence with its rich knowledge of facts that can be approached from multiple imagined perspectives to work with the generation of plans for imagined futures, and solutions to present problems. This static, timeless mode of cognition is the focus of educational systems, is cherished by technological societies, and its capability is what we normally identify as intelligence.

However, on the other hand, Bruner identified another form of cognition - narrative. Narrative intelligence places the lawful properties of objects and persons into an animated temporal order, making sense of their events and processes as they relate one to another through lived time. The logico-scientific knowledge of objects and persons become contextualised into this order. Their relations, psychological motives, and the feelings that power their interactions become known and understood within the context of lived, embodied experience. The social value of objects, persons, behaviours, and events become meaningful through one's lived experience, be that in their creation by oneself, observed in others, or recalled in their re-telling.

Narrative informs and structures logico-scientific knowledge because experience generates stories that describes the lawful

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relations between parts, enabling an abstract understanding of those parts. But as lived experience necessarily progresses through time, all logico-scientific intelligence must therefore be expressed back through the animated temporal order of narrative. The two intelligences work hand-in-hand, informing and structuring each other.[1]

In this paper, we explore the origins of narrative intelligence in early infant development and review its major theoretical claim as a fundamental structure of animated events, presenting 'narrative units' of meaning-making. A growing body of work proposes an early narrative intelligence operative in the cycles of activity of young infants, co-created in pre-verbal dialogues of expressive action with attentive adult care-givers, and structured psychologically and temporally by innate psychobiological rhythms, both autonomic and voluntary. We review these claims together with closely related evidence of early adult-infant interaction to explore how narrative might offer improved explanatory resolution to developmental science of intelligence and meaning-making, and provide insight into other experimental frameworks and analysed interactions, such as in neonatal imitation. In doing so, we identify a self- and other-regulating ability of narrative units, and review evidence in the literature of their presence in early human development, with attention from birth to eighteen months of age.

By reviewing and consolidating the literature, we present an account of narrative as an essential structure that governs and gives shape to infant-adult interactions, and their regulations. Finally we draw this together with a comment on disruption to narrative in autism, the place of narrative in primatology, and the potential for narrative explanations for non-human primate intelligence.

2. Narrative as a structure of lived, embodied experience

Human experience appears continuous and regular as a steady 'stream of consciousness' (James, 1890), but it is made up of discreet events that unfold in time, with beginnings, middles and ends. These discreet events are made in active engagement with the world by a physical body expressive of the interests, knowledge, and intentions of the Self-as-Agent (Macmurray, 1957). Generative participation is created by action, itself an energetic and organised activity of the neuromusculature that conveys the feelings of the agent in their vital forms of intent (Stern, 2010). As embodied agents, these participatory experiences become structured by the spatiotemporal properties of the body, and critical to this is its purposeful, future-oriented nature that seeks meaning in interaction with the world (Delafield-Butt & Gangopadhyay, 2013; Reed, 1996). Each action, each self-generated movement of the human body, is necessarily organised prospectively from the beginning of life, with an eye to the future (Delafield-Butt et al., 2018; von Hofsten, 1993, 2007), and primed to affectively evaluate the consequences of one's self-generated actions, or those of an observed other (Bråten, 1998). The finite and future-oriented nature of human motor control asserts a powerful prospective structure to knowledge as anticipatory and structured by the human body, driven by agent's intentions and interest, and excited by the affects that motivates them.

Prospective, narrative organisation, with its origins in human motor control, delivers a necessary unit that opens, then gives closure to activities and engagements to draw experience to a purposeful conclusion, and to make sense of them. In this way, human agency seeks to parcel what seems on the surface to be continuous experience, into the embodied experiences of purposeful events.

2.1. *The serial organisation of action into projects, an embodied foundation of narrative*

> "Not only speech, but all skilled acts seem to involve the same problems of serial ordering, even down to the temporal coordination of muscular contractions in such movement as reaching and grasping. Analysis of the nervous mechanisms underlying order in the more primitive acts may contribute ultimately to the solution even of the physiology of logic." (Lashley, 1951, p. 121).

Human movement generates personal, and shares social, meaning (Sheets-Johnstone, 2011; Stewart, Gapenne, & Di Paolo, 2010). Each action we make, with its future-oriented vision, creates consequential responses from both objects and social others in the environment that can be evaluated and learned (Delafield-Butt, 2020). This generative *action-response* psychology recognises human experience is created by self-generated agent action, whilst its prospective evaluative nature creates a fundamental psycho-motor structure (Delafield-Butt & Gangopadhyay, 2013; Delafield-Butt, 2014). This stands in contrast to a *stimulus-response* psychology predicated on experimental paradigms that treat the mind as passive and reactive. Rather, attention to the prospective nature of human movement presents an agent-centred, ecological view of the mind as giving embodied structure to its content, rather than as receiving a stimulus passively.

Made in engagement with the world, each consequence of sensorimtor action can be learned, then chained to a subsequent action. A 'reach-to-touch' develops into a 'reach-to-grasp'. A 'reach-to-grasp' develops into a 'reach-to-grasp-to-drink' (Pezzulo & Castelfranchi, 2009; von Hofsten, 1993, 2007). Over early infancy, simple actions become chained to present complex, serially organised actions that develop stories with greater spatiotemporal reach to achieve aims and intentions further into the future (Delafield-Butt, 2018).

Where an early 'reach-to-touch' enables acquisition of a goal of about one second into the future, a 'reach-to-grasp-to-place' enables a goal of about three seconds into the future. Several 'reach-to-grasp-to-place' action sequences generates a project many tens of seconds or minutes into the future, from stacking blocks to cooking dinner. In infant development, this is transition from a proximal awareness to one that expands with experience, and the cogntive tools of memory and planning to enable projects with greater and greater distal reach (Pezzulo & Castelfranchi, 2009; Delafield-Butt & Gangopadhyay, 2013; Trevarthen & Delafield-Butt, 2017). These

[1] Think, for example, of the animated inspiration of a good mathematics or physics lecture. It is in the affective telling of the story of technical knowledge that inspires, and is learned.

projects are rooted in movement and are goal orientated, generative, and expressive creations of the infant, but they can also be co-created in dyadic partnership with an attentive other (Fig. 1).

Made in social engagement with an attentive and engaged other, a simple expressive action such as a single gesture of the arm or utterance of the voice can become the first in a sequence of expressions (Delafield-Butt and Trevarthen, 2015). In face-to-face dialogue, these expressions structure the social dynamic and inform the content of social engagement in what Trevarthen identified as 'primary intersubjectivity' - an attention purely to the feelings, interests, arousal, and intentions of the other without additional reference to an external object (Trevarthen, 1979, 2012). Patterned over time, these exchanges between infants and adults last from a few seconds, to fifteen or twenty seconds with consistent engagement, ultimately forming narrative units of meaning-making (Trevarthen & Delafield-Butt, 2013).

Evidence we review below shows that states of increasing arousal and interest in the social other are shared in regular patterns of expressive movement of the body and voice in serial order with shared time. Regulation of the autonomic system on both sides becomes tightly coupled to the social engagement system expressive of affect, arousal and interest (Porges & Furman, 2011). These physiological systems of metabolic and autonomic regulation support the psychological interests and intentions of the infant, structuring their capacity for activity and regulated to serve its needs over time. These coupled psycho-biological processes are at the heart of narrative, and learning the expected regulations of a family and culture (Gratier & Apter-Danon, 2009; Gratier, 2003).

Knowledge of the world is built on this ontogenetically primary and psychophysiologically basic narrative regulation to include attention to objects, symbolic displays by persons, and complex events experienced, then held in memory (Vandekerckhove & Panksepp, 2009). Their experience – parcelled in narrative units – becomes an experience of the regulation of autonomic physiology, and intentional body action, but also of its emerging higher conceptual context and knowledge of the relations between actors and objects. These narrative units become learned in the classical sense, through conceptual organisation, symbolism, and memory. In this way, technical learning is tightly coupled to the more basic understanding of physiological regulation – a feature especially important in early years education and care. Both are organised within the same narrative experiences, which gives them their tight relationship. It is through this narrative organisation we can understand language as tightly coupled to feelings, and its movement in music or poetry (Trevarthen, 1995, 2005). Scottish Englightenment philosopher Thomas Reid highlighted the importance of this affective aspect of language, which he called 'natural signs', as more powerful than the technical meaning of 'artificials signs' of the words placed on top - "Artificial signs signify, but they do not express; they speak to the understanding, as algebraical characters may do, but the passions, the affections, and the will, hear them not: these continue dormant and inactive, till we speak to them in the language of nature, to which they are all attention and obedience." (Reid, 1764, pp. 106–108).

2.2. Narratives of communicative musicality

Narrative patterns in early infant social engagement were first identified in the reciprocity of affects and interests of shared activities in play between adults and infants, with their characteristic rise and fall of arousal and excitement structured by repeated cycles of reciprocal action in what seminal child psychologist Daniel Stern called 'protonarrative envelopes' (Stern, 1985). It is these early narratives, and patterns of intermodal sharing of affective states (Stern et al., 1985), that generate what Trevarthen (1979) similarly identified as 'protoconversations' in the face-to-face vocal expressive sharing of internal states. These experiences later absorb language as well as representations of intentions, objects, events and emotions, creating the conversations of adulthood imbued with meanings in increasingly complex narratives (Delafield-Butt & Trevarthen, 2013).

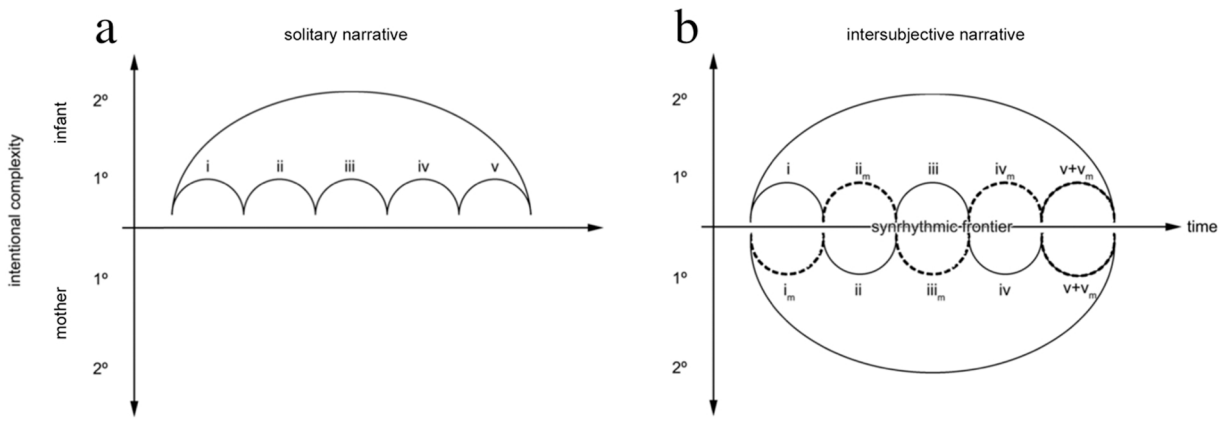

Fig. 1. The motor foundations of narrative across levels of complexity of sensorimotor intentionality: (1°) Individual action units consisting of regular displacement to its goal; (2°) Larger projects of multiple serially organised action units structured by secondary sensorimotor intentionality. (a) The nested hierarchy of solitary purposive movement to complete a task, such as 'to eat', requires the serial organisation of individual purposive actions, such as (i) a reach, (ii) grasp, (iii) transport, (iv) chew, and (v) swallow. (b) Made with an attentive social other, this serial motor organisation can be shared in time where the expressive actions of one actor (i, ii, iii…) are mirrored in the actions of the observer (i_m, ii_m, iii_m…), enabling turn-taking in protoconversational narrative (*c.f.* (Delafield-Butt and Trevarthen, 2015).

Narratives can be seen "inherent in the praxis of social interaction before it achieves linguistic expression" (Bruner, 1990, p. 77). Indeed, embodied, non-verbal narratives can form complete acts of meaning expressed in the affective vitality of movements of the body through gesture and postural shifts, changing facial expressions, and non-verbal vocalisations (Stern, 2010). Even between linguistic adults, expressive movement can convey narrative meaning, with or without language, within a vital musicality or shared timing and quality. Consider the dancer, expressing her story. Words are not necessary to experience a story, nor to re-tell it. Read and Miller (1995) consider narratives to be "universally basic to conversation and meaning making" (p. 143) irrespective of its modality.

Using a sensitive accoustic analysis, Malloch (1999) identified formal features of music within the vocal structure of mother-infant protoconversations. These features included (a) a shared sense of time between partners, and an alignment of expressions within this temporal order, or *rhythm*, (b) a reciprocity of the *quality* of expression of the voice or body, where one's expression informs the quality of expression in the other, and importantly for this paper, (c) a musical *narrative* form created by shared time and recriprocal qualities of expression across a four-part structure of introduction, development, climax, and resolution.

The importance of this discovery is essential. By identifying narrative within the musicality of protoconversation, Malloch and Trevarthen (2009) overturned conventional wisdom that narrative was necessarily predicated on words made with reference to remembered content. Rather, they discovered an ontogenetic primary narrative form that structured sharing experiences of affect, arousal, and interest, conveying and forming the experience of feelings and emotions in mutual, reciprocal interaction patterned regularly in lived, shared time. This fundamental structure of sharing experiences is the earliest expression of a growing narrative intelligence operative in the cycles of activity of young infants, and in the co-created pre-verbal dialogue with attentive adult care givers (Gratier & Trevarthen, 2008; Malloch, 1999; D. Stern, 1985; D.N. Stern, 2010; Trevarthen, 1999).

2.3. Narratives structure vital meaning

Narrative structure underpins our earliest interactions, and remains invariant across the human lifespan, although its musicality can be lost to favour the technical symbolic arrangements of words. Nevertheless, narratives remain universally basic to human meaning-making and are ubiquitous across cultures (Bruner, 1990). They are enriched and elaborated to a high degree of skill to amplify and enhance feelings of affective interest and arousal in all the time-based arts of drama, dance, music, and poetry (Stern, 2010). They structure the arts and entertainment we enjoy daily, or co-create with others. Narratives underpin our knowledge, understanding, and experience of the world at a basic, foundational level. They allow us to create meaning with others, to understand how others behave in a given situation, and even what another individual's underlying thoughts and motivations might be for acting in a certain manner. They give us interpretive insights into another human being, and provide a general structure which we can use to frame our understanding of, and interactions with, other individuals (Gallagher, 2011). Bruner (1990) viewed narrative as an organising life principle of human cognition, pervading our actions and communication, forming a temporal structure of our individual goal-orientated movements and our interactions with friends, parents, colleagues and children.

The complexity of the narratives one creates and encounters vary, but their core features remain invariant. They connect the past and present to an unfolding future, linking our historical experiences with immanent possible future realities (Bruner, 1986). Narratives are experienced and learned, then form a template for understanding future similar events. They are first experienced in the vitality dynamics of action, interaction, and play in infancy, building and fading in a predictably patterned dynamic of phases of arousal and intensity (Delafield-Butt & Trevarthen, 2013, 2015; Delafield-Butt & Stern, 2010). Although the complexity of narratives expands during human development, the narrative form is as present in the interactions of mothers and babies as teachers and students, or the complex technical explanations in a court of law, or a quantum physics laboratory (Bruner, 1990; Delafield-Butt & Adie, 2016; Delafield-Butt & Trevarthen, 2013).

The typical pattern of arousal and intensity develops over four distinct phases: (i) the introduction, (ii) development, (iii) climax, and (iv) resolution (Malloch & Trevarthen, 2009; Malloch, 1999; Trevarthen & Delafield-Butt, 2013; Fig. 2). Each phase has characteristics which define them and give regular structure to joint meaning-making (Delafield-Butt & Trevarthen, 2015). First, the introduction phase generates shared attention between involved parties to established and begin the narrative. Their interaction then builds in the development phase, typically with rhythmic reciprocity between participants that can resemble a musical exchange composed of expressive acts of the body or voice with shared timing. The quality and form of each expression becomes contingent on that of the other, reflecting and adapting its form in creative contribution like two jazz musicians riffing off each other's expressive motif (Gratier & Trevarthen, 2008; Malloch, 1999). The energy and excitement builds, sometimes only subtly and sometimes to a great

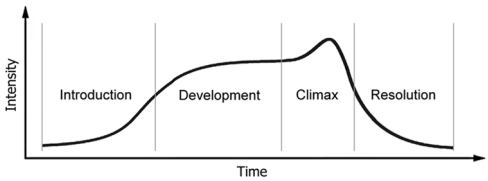

Fig. 2. An intensity (level of inbued energy) contour illustrating the four-part narrative structure as it changes over time: (i) Interest in the narrative begins at a low-intensity in the introduction, which invites participation in shared purposefulness; (ii) the coordination of the actions and interests of real and imagined agents intensifies over the development, as the plan or project is developed; (iii) a peak moment of excitation in mutual intention is reached at the climax; after which (iv) the intensity reduces as the purposes of the participants share a resolution, and those who were closely engaged may separate, extend, or repeat another cycle. Reproduced with permission from Trevarthen and Delafield-Butt (2013).

extent, until a moment of maximal tension is reached, a climax. This is a moment of peak, held energy, which is typically followed by a release in the resolution phase, where the energy can recede to baseline again. At this point, the participants of the interaction may feel free to break from one another, as they process the memory of their shared experience, and reflect on the meaning that was created.

Whilst this structure may accurately describe a single narrative encounter, many of the narratives adults engage and create will be formed of multiple complex cycles, with many derivations of form based on the same principle of its four-part structure.

3. Narrative as learned regulations

The presence of narrative within non-verbal expression allows us to consider their importance prior to the onset of language. From the earliest time in postpartum infant life, individual movement orientated projects can become interwoven with those of a caregiver, creating intersubjective events that contain many of the characteristics of fully formed conversations. The importance of narrative in solo projects and communication also makes it integral to the development of our understanding of the world, understanding of others, and understanding of ourselves (Bruner, 1990; Zahavi, 2007). The patterned nature of arousal and energy, inherent to narrative architecture, gives structure to the process of emotional regulation of all forms of movement and meaning-making in intersubjective states (Damásio, 1999; Trevarthen, 2005). Its predicable, regular patterns enable the coordination of sympathy between individuals in the shared time of vocal and motor expressions of affect, interest, and intention (Delafield-Butt & Trevarthen, 2015).

3.1. Co-regulation of psychobiological states

Co-regulation derived through narrative impacts basic biological and physiological systems. The phases of arousal and intensity in the vitality dynamics of infancy not only form an outward demonstration of a person's inner states, but also allows those internal states of autonomic activity to be influenced by another human being (Porges & Furman, 2011; Stern, 2010). This influence of one individual upon another leads to the explicit co-regulation of physiological states based on autonomic and neurophysiological systems, with the requirement of sensorimotor engagement (Porges, 2011). Indeed, many basic self-regulated biological capacities are supported socially in infancy. Infants prompt support from adults through voluntary communicative signals, which can be very specific and constructive. For example, Vallotton (2009) found infants pro-actively elicit responses from their caregivers during their interactions in nursery, provoking different qualities of care across multiple caregivers to suit their needs. This selective elicitation of social care demonstrates the infant's power of agency, even in social interactions.

Examples of infants actively eliciting support to aid in the regulation of physiological states can be seen through the use of shared body heat with caring adults, or the elicitation of milk from a caregiver (Delafield-Butt, 2018; Tronick, 2005). In these examples, basic needs serve to prompt an engagement with their caregiver, leading the two parties to coordinate their movements in joint projects with shared intention that result in psycho-physical needs being met on both sides – infant and parent. Co-operation allows infants to overcome their individual limitations and at the same time fulfills the needs of the adult to love and nurture, generating satisfaction on both sides of the partnership. The individual acts of behaviour – a vocal cry, facial grimmace, movement of the arms, etc. – are coupled to both immediate physiological needs, warmth and food in these examples, as well as to deeper needs and desires, such as developing the attachments, care, and nurture of companionship (Lewis & Amini, 2001; Trevarthen et al., 2006).

The patterns of behaviour generated and learned in these engagements form remembered patterns of action and interaction, and their consequential effects, that serve as a template with which to plan and organise future action and interaction in a new instance. These learned narrative 'schemas' underpin the successful repetition of projects in future encounters.

3.2. The prospective nature of narrative

Narratives formed in basic movements extend the infant's world through time to structure early self-generated experiences. Purposeful and goal directed acts also follow a basic narrative structure (Delafield-Butt & Trevarthen, 2015) that must "(i) initiate toward that future, (ii) develop in its progression over time and through space with sensory feedback and adaptive anticipatory response charged with memories, and (iii) reach its target before (iv) resolving into a quiet state again" (p. 4). These purposeful and goal directed behaviours are organised in a nested hierarchy of action, where an act, or action chain, is made up of smaller action units, which must be continuously regulated to achieve its desired 'goal' or state (Delafield-Butt & Gangopadhyay, 2013).

The nature of a dyadic regulation allows infants to achieve these future orientated goals more readily than if they act independently (Tronick, 2005). For example, infants who attempt to implement an action chain/project, but fail due to physiological limitations, will enter a state of distress. However, in a system of dyadic regulation, adults are able to sense the purpose of the infant's efforts, and provide additional support that enables them to complete the sequence of actions to achieve that goal. Narrative structuring of solitary actions quickly expands into the social realm of shared projects, where a narrative interplay aids parents and infants in learning the intricacies of one another's patterns and expectations, allowing for the completion of critical endeavours such as feeding. Narratives may also underpin the first dialogues of neonatal imitation and the proto-conversations of early infancy (Nagy & Molnar, 2004; Nagy, 2006).

In these early engagements, bodily movements, vocalisations, and facial expressions operate in a patterned rhythmicity to create a narratively structured state of intersubjectivity. Neonates have a behavioural repertoire of basic abilities which makes them well adapted to become attuned (both temporally and affectively) to another human being, enabling the formation of intersubjective states. These abilities includes a variety of facial expressions of emotions, shaping of the mouth, and lip and tongue movements (Trevarthen, 1979), and are enhanced as infants develop other capacities, such as the capacity to follow another individual's eyes, and perceive their

movements as being meaningful and goal directed. As a package, these behaviours allow infants to engage in primary intersubjective interactions, and become tuned to the vocalisations and gestures of adults (Gopnik & Meltzoff, 1997; Stern, 1971).

For primary intersubjectivity to be created, and therefore co-regulation between adults and infants, affective coordination between the movements and expressions of both parties is required. As children grow and develop, so the narratives they are involved in develop in complexity and modality to structure secondary intersubjective engagements involving shared attention to objects, and become imbued with language that allows for the complex story making characteristic of human culture.

For narrative co-regulation of physiological states or meaning making to take place, participants must be aware of and attentive to each other's expressive vocalisations, movements, and ready to respond sympathetically, in time and in tune with the other. Sustained attention with a sympathetic reciprocity of feeling and expressive action will naturally take on its particular narrative character.

3.3. A narrative hierarchy of embodied regulations

Self- and other-regulations are achieved within the expectations the narrative template provides, enabling autonomic energy systems to be prospectively organised to maintain delivery of vital resources to the neuromusculature during an activity. This is the first, basic level of learning self-regulation, made in primary intersubjective face-to-face engagements. Secondary to this, essential needs or desires can be met, such as heat retention for thermoregulation, food during sucking for sustenance, or curious care and attention for love and companionship. And once these needs and desires are met, then the infant can develop shared attention to objects where learning technical mastery is accomplished in concert with a social other.

4. Development of narrative co-regulation in adult-infant interaction

Despite the importance of narrative as a psychological theory of human meaning-making, a large section of the current literature on co-regulation and adult-infant interaction does not address this underlying narrative aspect. However, recent decades have seen a greater appreciation of the agency and generative role of the infant in interacting with the world and other individuals within it. This is especially true of studies investigating adult-infant synchrony and entrainment, as well as physiological and psychological co-regulation. Understanding the functional and temporal architecture that underlies these core communicative processes can further aid understanding of wider human development, and offer new perspectives on ongoing debates. In this section we explore studies examining adult-infant interaction and co-regulation across early human life (the neonatal period, 4 weeks to 8 months, and 9 months to 15 months) to see how co-regulation is important and present in these early interactions, and how it develops the nature of narrative interactions.

4.1. The neonatal period

New-born infants display sensitivity and awareness of purposeful movements and vocalisations of adults in relation to their own person (Condon & Sander, 1974; Nagy, 2011; van der Meer & van der Weel, 2011). In the hours after birth human infants have been shown to demonstrate an ability to take part in imitative exchanges with adults, conversations rooted in movement (Kugiumutzakis & Trevarthen, 2015; Meltzoff & Moore, 1983, 1989). These imitative exchanges are considered to be a foundation for social communication, and as an example of an infant-generated communicative act seeking responsive company (Meltzoff, 2007; Nagy & Molnar, 2004). They can also be considered a first step in the gradual development through infancy to a more abstract and reflective social intelligence that allows for a theory of mind (Meltzoff, 2007). Indeed, these imitative exchanges represent some of the first examples of a co-operative, co-creation of interest and affect between infants and adults, an initial expression of *primary* intersubjectivity (Trevarthen, 2011). The infant's ability to engage in these social exchanges is built of multiple skills that allow social engagement and joint meaning-making, including the ability to identify their mother's voice and face, and a preference for humanoid faces (Burnham, 1993; Decasper & Fifer, 1980; Valenza et al., 1996; van der Meer & van der Weel, 2011). These contribute to what some consider an innate disposition for intersubjective engagement (Nagy & Molnar, 2004; Stern, 2000; Trevarthen et al., 2006).

Further evidence for an innate readiness or predisposition within neonates towards social interaction has been found through other means. For example, Farroni et al. (2002) demonstrated larger event related potential (ERP) responses when infants (even in the neonatal period) were presented with images of adults with direct as opposed to averted gaze, and Murray et al. (2016) desscribed a social architecture that allowed both adults and infants to respond in a regular and expected manner when interacting in a dyadic engagement. In this study, infants were recorded (in the first nine weeks of life) in interactions with their mothers, and social facial behaviours (e.g. smiling), biological events (e.g. sneezing), non-social mouth movement and expressions of negative affect were coded and mothers monitored for contingent responses. The prominence of contingent maternal responses relative to non-contingent behaviours were examined, and the form of maternal response analysed with respect to their infants' behaviours and ages. The specificity of associations between behaviours in infants and adults were estimated. Their findings demonstrated the infant social expressiveness was structured on specific forms of parental response: a functional, bi-directional social architecture where infant expressivity was contingency of maternal responsiveness, and vice versa.

These early exchanges support the continued development of cooperative engagements, which grow to become more complex and prospective in their nature (Delafield-Butt, 2018; Nagy, 2011). Each act (imitative or otherwise) can be considered part of a larger narrative, which creates meaning over multi-second encounters in a "mutually sustained expectation of a rhythmic project of communication, engaging two persons in a nonverbal 'narrative'" (Kugiumutzakis & Trevarthen, 2015, p. 487).

It is only in the last sixty years, following Meltzoff and Moore's (1977) seminal work, that neonatal imitation has become a focus of

academic attention. From this paper followed a host of studies that supported and clarified the nature of neonatal imitation (e.g., Field et al., 1982; Kugiumutzakis, 1985; Meltzoff & Moore, 1983) as well as others that attempted to replicate, but failed to find supporting evidence (e.g., Fontaine, 1984; Hayes & Watson, 1981; Koepke et al., 1983). Nagy and Molnar (2004), however, went further than to simply replicate the test for neonatal imitation in humans. Their study measured an infant's ability not only to *imitate* a social other, but to *initiate* social interaction. In this study, 45 neonatal infants, aged 2–54 h confirmed imitation of tongue protrusion, but they also found their infants initiated voluntary exchanges with an adult by presenting a spontaneous tongue protrusion of their own. The researchers utilised behavioural and psychophysiological measures to differentiate initiation from imitation. Heart rate determined levels of arousal (increased heart rate was considered reflective of increased levels of arousal) and of orientation, learning and expectance (decreased heart rate was taken to be indicative of these during imitation).

Following several cycles of imitation, it was found that the neonates not only imitated the modelled action, but also initiated an exchange and waited for the adult to respond, demonstrating a motivational desire to take part in the dialogue. Such findings help to illustrate the social motivation that appears to underlie neonatal imitation, as the infants actively sought to continue exchanges with their adult partners. Indeed, during the study it is reported that there were several examples of prolonged exchanges between neonate and experimenter, which were initiated by the participant and developed into what the researchers describe as reciprocal 'conversations' (Nagy, 2006). Nagy has designated these exchanges as experimental examples of the first dialogue (Nagy & Molnar, 2004; Nagy, 2006, 2011). It is these findings, together with the wealth of data on imitation and the social orientation of neonates, that allow us to consider neonatal imitation one of the earliest expressions of primary intersubjectivity in an experimental setting. These early intersubjective exchanges can go on to develop into rich protoconversations involving the serial organisation of expressive actions of the hands, voice, face and body movement later in infancy that structure the pre-verbal narratives of communicative musicality first described by Malloch and Trevarthen (Malloch & Trevarthen, 2009, 1999; Malloch, 1999).

The structure of adult-neonate interactions includes findings that extend beyond neonatal imitation. For example, Condon and Sander (1974) showed infant sensitivity to the motor impulses of adult speech through the use of microkinesics. This method involved a frame-by-frame analysis of the type of movement performed by infants mapped to the acoustic features of the adult's voice. Infants involved in the study were found to move in synchrony to the adult's syllables, words, phrases, and broader rhythm of speech. That is, the changes in the movement of the body parts of the neonates were coordinated with shared sub-second timing to the sound patterns of adult speech. Condon and Sander described this as an interactive dance that preludes the development of speech. Furthermore, they suggested that infants have an ability to discriminate human speech from other sounds and noises, and arrange their motor responses accordingly.

The neonatal period also plays an important role in establishing patterns of co-regulation that have significant impact through development. For example, skin-to-skin contact in premature neonates has been shown to have long term effects on physiologic organisation and behaviour control, whilst physiologic organisation in the neonatal period has also been shown to impact an infant's ability to successfully engage in rhythmic adult-infant dialogues as they grow (Feldman et al., 2014; Feldman, 2006). These findings are supported by evidence suggesting that maternal-neonate separation dramatically increases autonomic activity and greatly decreases quiet sleep duration - quiet sleep being closely related with cortical organisation and neuronal reorganisation processes (Eiselt et al., 2001; Milde et al., 2011; Morgan et al., 2011). Skin-to-skin contact is also important for neonatal temperature regulation, with it having a significant impact on both core and peripheral temperature, not only during the state of skin-to-skin contact but also during subsequence separation (Bystrova et al., 2003; Fransson et al., 2005).

4.2. From 4 weeks to 8 months

Moving beyond the neonatal period, considerable attention has been given to the structure and composition of the interactions and co-regulation that exists between adults and infants. Early studies by the likes of Stern and Beebe highlighted the importance of movement, as well as vocalisation, in understanding the nature of adult-infant interaction. For example, Stern and colleagues (1977) examined the temporal structure of adult-infant interaction and highlighted the importance of a multimodal analytical approach and the need to consider movement as independent units of communication. Beebe and colleagues (1985) also investigated both vocal and kinaesthetic behaviours in the temporal organisation of adult-infant dyadic interactions. Using 15 dyads of mothers and infants (infants aged 4 months), they found that the nature of the temporal patterning varied within each of the behavioural forms investigated. For example, when one member of the dyad increased their levels of vocalisation, this trend was mirrored by their partner. Conversely, with regard to movement, mothers and infants altered their activity level as a function of their partner's level of movement in such a way that as one member of the dyad increased movement activity the other decreased theirs. It is within this ebb and flow of activity that the narrative temporal organisation of an engagement can be found, and it is within this narrative framework that mothers and infants regluate one another's arousal, interest, affect and attention.

However, understanding the temporal nature and organisation of these interactions as synchronous or alternating has been the subject of debate. Condon and Sander (1974) found evidence of a synchronous patterning to the interaction, whereas Beebe and colleagues (1979) found evidence for both simultaneous and alternating patterns in the temporal organisation of vocal and movement behaviour in mother-infant interaction. Meanwhile, Fogel (1977) showed synchronous and alternating temporal patterns could be present at the same time within an interaction. We now understand the synchronous and alternating organisation of expressive movement yields 'shared time' integral to the matching of psychomotor states, and its co-regulatory processes (Malloch & Trevarthen, 2018; Osborne, 2009). In any dyadic interaction between two human beings, expressive movement is integral to dyadic regulation and meaning making (Fogel, 1993). When such interactions are successful and with shared regulation, they become greater than the sum of their parts and there emerges a more complex and coherent understanding of the world (Tronick, 2005).

Underpinning all these engagements is a mutual sensitivity in both adults and infants to the intricacies and details of their social interactions. For example, Grossmann et al. (2008) found that infant brains are highly sensitive to social cues. Across two experiments the researchers investigated the effect of mutual and averted gaze followed by a raised eyebrow, by an animated photorealistic adult face, upon an observing infant's haemodynamic responses and oscillatory brain activity. They found that observing facial communication signals activated regions of infant's temporal and prefrontal cortex that are associated with the same processes in adults. Urakawa et al. (2015) also measured hemodynamic responses, as well as eye movements, whilst infants aged 7 months engaged with a partner during a game of peek-a-boo. Their results found that direct gaze during social play prompted infant attention to be drawn to their adult partner's eyes, and there was a specific activation of the dorsomedial prefrontal cortex during both direct and averted gaze. The impact of gaze on neural activity was also investigated by Leong et al. (2017) during the singing of nursery rhymes. Across two experiments adults recited nursery rhymes, either displayed on a screen (experiment one) or during a live interaction (experiment two), and alternated between direct and indirect gaze (with a control condition in experiment one only in which adults turned their heads as if averting gaze, but remained looking at the infant). Adult and infant neural activity was measured through electroencephalography and the researchers found that adults had a significant causal influence on infant neural activity in both experiments. This influence was stronger during the directed gaze conditions (regardless of head position) than in the indirect gaze condition. In the second experiment of the study, adults were also influenced more by their infant partners through direct gaze than indirect gaze. Additionally, infants were found to vocalise more during the second experiment, and infants who vocalised more had a more pronounced neural influence on their adult partners. These results again highlight the impact of gaze in bidirectional neural connectivity, but also serve as evidence for the role of ostensive signals within intersubjective interactions in creating a mutual temporal alignment, a basis of shared timing.

Such sensitivity to ostensive signal timing is likely underpinnned by shared psychobiological rhythms between adults and infants. Trevarthen identified a common temporal structure in adult and infant limb movements made in communicative gesture, as well as in inter-saccade intervals of eye gaze, despite their differences in size (Trevarthen, 1986). Such common timing principles of the human body, including autonomic and central nervous regulation, enable coupling between individuals along multiple levels of arousal, interest, affect and attention regulation important for human developmental health (Trevarthen et al., 2006).

In addition to sensitivity to social cues, infants are also able to co-ordinate interpersonal timing within a dyadic interaction. That is, they can alter the timing of their own behaviour in line with the timing of another individual with whom they are in engagement. Crown et al. (2002) recorded the interactions of infants (aged 6 weeks) with their mother and a stranger, and then coded for mother/stranger vocal behaviour and infant gaze behaviour. A time series regression was then conducted to ascertain the relationship between infant gaze and adult vocal behaviour. The results showed that infants, even as young as 6 weeks, demonstrated a sensitivity to the temporal structure of dyadic interactions – infants were able to extract the temporal properties of vocalisations from both their mothers and strangers (characterised by the timings of vocalisations and pauses in relation to infant gaze), and express it through gaze behaviour. Additionally, adult vocal behaviour during these interactions was impacted by the temporal organisation of infant gaze behaviour. These results highlight the dialogic nature of the temporal structure of the dyadic interaction.

Key to the maintenance of this temporal structure (and the resulting dyadic co-regulation) is not only infant attunement to the actions and vocalisations of an adult caregiver, but also an adults ability to stimulate infant involvement in interactions. Stern (1974) focused on adult behaviour during dyadic interactions between 24 mother-infant dyads. He found that the actions of adults were organised into discernible units and believed the adult's aim was to maintain a level of arousal in order to promote positive social behaviours. Beebe and Gerstman (1980) also show the importance of considering adult behaviour in adult-infant dialogues in a case study which demonstrates that maternal multimodal acts in the dyadic interaction are communicative in nature. In this study, the relationship between maternal behaviours and infant engagement was measured and a significant relationship found with packages of maternal behaviour (consisting of kinesic hand rhythms and facial display variations) varying systematically with levels of engagement from the participating infant. From these results the researchers inferred the communicative quality of maternal acts and behaviour, which underlies their role in the co-regulatory process.

A final element to consider in relation to co-regulation in this age group concerns the link between pysiological and affective co-regulation. Feldman et al. (2011) measured the cardiac responses of mothers and infants (aged 3 months) during face to face interactions whilst also performing a micro-analysis of vocal synchrony, gaze and affect. In their analysis the researchers found the heart rhythms of both infants and adults were closely coordinated, but also that there was an increase in concordance between the biological rhythms of participants when affective and vocal synchrony existed. Furthermore, Ham and Tronick (2009) found a close link between the physiological and psychological regulations that take place within the adult-infant dyad. Ham and Tronick explored emotional regulation through measuring respiratory sinus arrhythmia and skin conductance concordance whilst participants took part in the still face paradigm. They found that whilst infants were presented with still face, skin conductance concordance in the dyad correlated with infant negative engagement, but following the reestablishment of the interaction it correlated with behavioural synchrony. Maternal respiratory sinus arrhythmia was found to be negatively correlated with infant negative engagement during normal interaction, but was significantly postively correlated to it during the rengagement episode (possibly due to mothers calming themselves to aid soothing their infants). These results not only demonstrate the close link between physiological and psychological regulation within the dyad, but also the impact behaviour can have not only on a dyadic partner but also on oneself.

As infancy proceeds, an important transition from *primary* to *secondary* intersubjectivity develops as infants engage with shared interest to objects and events in their environment (Hubley & Trevarthen, 1979; Trevarthen & Hubley, 1978). Shared narratives transition from exclusive reference to the bodily experiences, affects, interests, and arousal, to include the shared attention to objects and persons in space. An interesting point along this transition is found in tickling play, where attention to a specific, discreet activity of stimulation is made in addition to the primary intersubjective sharing of psychological states, and expectations. In a study by

Ishijima and Negayama (2017), tickling was identified as a precursor to secondary intersubjectivity, with shared attention to body parts, and its peculiar tickling sensations made in anticipatory play. What was striking in their analysis was the narrative form in which tickling play took part, with a clear four-part stucture of introduction, development over repetitive cycles, before the final climax of contact, then resolution to quiet again. Similarly, Rossmanith et al. (2014) analysed book reading as another example of adult-infant triadic shared attention that developed before the onset of full-blown secondary intersubjectivity at 9 months. Again, these adult-infant interactions to a common project were structured "in a highly co-ordinated way, with caregivers carving out interaction units and shaping actions" into what they termed 'action arcs', or non-verbal narrative arcs of shared interest, arousal, and intention. Finally, Reddy et al. (2013) studied the anticipatory nature of infant cooperation in a simple task of being picked up. They found infants as young as 3 months prepared their body posture for the forces involved in being picked up, and this anticipatory awareness of their involvement in a shared project developed with specificity over the next months. In a closely related set of studies comparing Japanese and Scottish narrative projects (see Appendix for definition of terms) of infant pick-up and spoon feeding, at 6 and 9 months, Japanese mothers were found to be more sensitive to the subtle cues of interest in their infants, and responded to follow their infants' initiative, whereas Scottish mothers were more driven and led their infants to follow their adult initiative (Negayama et al., 2015, 2021). But in both countries, the infants learned the narrative sequence of the project, and actively anticipated its steps to co-create joint action in shared time. Altogether, these studies demonstrate a growing awareness of infant involvement in the co-creation of joint projects that extend through time, and an anticipation of how those experiences will be patterned across time. By sharing attention jointly, even young infants demonstated a prospective awareness of the story, and organised their actions in the present moment, contingent on an expected future. Tickling plays on this anticipatory awareness, with exceptionally elatory effects, a feature that can only be created by a trusted, intimate social partner.[2]

4.3. From 9 months to 15 months

As infants grow and develop the nature of their interactions becomes more complex, and the narratives they weave and create with others become more intricate. One example is through the onset of secondary intersubjectivity in which infants and adults share attention to elements of the external world. Striano et al. (2006) investigated the underlying neural activity in joint attention using a live action paradigm which involved an adult gazing at an infant's (aged 9 months) face and then at an object displayed on a screen, or alternatively only gazing at the object presented on the screen. Event related potentials were monitored in infants and found to be greater in amplitude in the joint attention condition. Neural activity during joint attention was also investigated by Hoehl et al. (2014), who examined infant's oscillatory neural activity during a joint attention-based interaction with an adult. The researchers monitored activation of the alpha frequency range and found desynchronisation during a joint attention condition but not in a non-social condition, suggesting that the activation of specific neural pathways is triggered by adult eye contact prior to visual object investigation. Rayson et al. (2019) investigated infant (aged 6.5 and 9.5 months) neural responses (using electroencephalography) in reaction to static images of adults either following infant gaze to a specific object (congruent actor), or looking at an alternative object (incongruent actor). Both infant age groups demonstrated greater neural reactivity to the congruent actor, although this was stronger in infants aged 9.5 months.

Neural activity has also been explored in adult-infant communication across everyday, naturalistic interactions. Piazza et al. (2020) utilised functional near-infrared spectroscopy to monitor neural activity (through changes in bood oxygenation) in both infants (aged 9–15 months) and adults during activities such as playing, singing and reading. The researchers found that adult and infant brains are linked (to differing degrees) during interactions with social cues such as joint attention, smiling, gaze and speech prosody. These findings give an indication into the role of social cues in creating and maintaining intersubjective states, and how the infant brain processes input from adults during interactions, and how adults interpret infant feedback.

Importantly, as discussed, the co-regulation that takes place between adults and infants cannot be limited to social or physiological experiences, but also inherently includes the co-regulation of affective states. Waters et al. (2014) examined how affective states are shared and regulated between mothers and infants (aged 12–14 months). In the study, mothers completed a modified Trier Social Stress Test (Kirschbaum et al., 1993) in which they were asked to give a 5min speech about their strengths and weaknesses to two evaluators before a 5 min question and answer session. Within this task mothers were randomly assigned to one of three conditions. In the first condition mothers received social evaluation with positive feedback from their evaluators, in the second they received social evaluation and negative feedback, and in the third control condition they received no feedback and the evaluators were not present. Cardiovascular measurements were taken of mothers and infants, the positive and negative affect schedule was completed by mothers, and post-stress interviews were conducted during which infant behaviour was coded. The researchers found that infants embodied the mothers stress when they were reunited following completion of the task, and that infants showed greater avoidance of strangers if their mother had experienced social evaluation during their task than infants whose mothers had completed the control condition. Additionally, the dyads showed greater physiological covariation if mothers had experienced social evaluation with negative feedback, as opposed to positive feedback or the control condition. These results highlight how dyadic co-regulation can also create states of negative regulation; i.e. when mothers experience stressful situations, their affective state is transferable to infants, and members of the dyad are capable of destabilising one another.

The loops created by such feedback were explored by Wass et al. (2019). For example, if during an interaction a mother is

[2] Interestingly, tickling is not permitted, or does not work when performed by a stranger. It's intimate nature and counterplay between care and aggression is a potential risk, and so it's co-created experience is exclusive to trusted others (Negayama, 2011, 2022, p.160).

influencing the affective state of her infant, how does this reciprocally influence the mother? To investigate this, Wass and colleagues recorded vocalisations, heart rate, heart rate variability and movement in naturalistic interactions in home settings. They found that in scenarios where the mother's initial arousal level was low but the child's level of arousal was increasing, mothers would correspondingly increase their level of arousal. However, when a high arousal level already existed in mothers, and infant arousal increased, mothers responded by lowering their own arousal level. These results highlight the active role of parents in regulating the arousal state of infants, and how the context of the interaction plays an important role in dictating parental responses. Ultimately, parents connected and disconnected their level of arousal from infants in order to maintain allostasis within the adult-infant dyad (Wass et al., 2019).

Moving beyond the physiological measures utilised by Wass and colleagues, Santamaria et al. (2020) looked at the impact of positive and negative affective states in adults upon neural entrainment. In social interactions with their infants (mean age 10.3 months), mothers were asked to model either positive or negative emotions towards pairs of objects. During the interaction neural activity of both mothers and infants was measured using electroencephalography. The researchers found that during trials in which mothers modelled positive emotion towards an object, both members of the dyad demonstrated stronger integration of neural processes, and mother to infant directional influences were stronger. Such results underline the importance of affective states, not only in social learning, but more broadly in the overall entrainment between adults and infants in dyadic interactions. The researchers suggest that the parent-infant inter-brain network, is in fact, modulated by the affect and tone of a social engagement.

5. Brainstem as a primary regulator of experience

Underpinning co-regulation of autonomic and voluntary behaviour are core brainstem regions responsible for integration of perceptual information and coordination of action (Panksepp, 2005; Porges & Furman, 2011). The brainstem is the primary regulator of the autonomic nervous system with responsibility over sleep, breathing, heart rate, alertness and feeding (Ngeles Fernández-Gil et al., 2010). It also has important functionality with regard to sensory perception, including the uptake of proprioceptive information, touch, hearing and taste all of which are important in the self-regulation of movement for expressive communication (c.f. Dadalko & Travers, 2018), and is critical for action responses in rhythmic social engagement (Delafield-Butt & Trevarthen, 2017; Trevarthen et al., 2011). Further, the brainstem plays a role in some higher cognitive functions including the regulation of social attention, and the modulation of emotions (Geva et al., 2017; pp. 6, 1274; Venkatraman et al., 2017).

The brainstem's role in regulating behaviour and emotion, whilst also being the primary regulator of the autonomic nervous system, has allowed it to evolve into a powerful social engagement system that impacts intonation in our voices, facial expressions, and hand movements (Porges & Furman, 2011). This link between expressive communication and autonomic physiological functions provides human beings the ability to socially share aspects of our wellbeing, vitality, and needs. Such an ability is core to dyadic regulation. Furthermore, it also allows the brainstem to generate the basic impulse for movement, which forms the core of an individual's sense of "self" (Delafield-Butt & Trevarthen, 2013; Panksepp & Northoff, 2009; Panksepp, 1998). The actions that form these basic movements require a knowledge of the external world, rooted in the brainstem's role in sensory perception and visceroception of internal organs. The brainstem serves an integrative and generative regulatory function of the agent (Sherington, 1906). It is through this function that the brainstem creates the foundation of an ontogenetically primary conscious experience and sense of self (Ciaunica et al., 2021).

Dyadic regulation plays a key role in the creation of this first conscious sense of self. The integration of sensory information is influenced through dyadic regulation. It is not a passive process, but is actively generated by the interests and intentions of the infant that becomes regulated through and within joint interaction. Perception of the environment is structured by the self-in-relation to its objects and other persons, which becomes structured in time through social interaction and active, embodied engagement. This activity – self-generated and co-regulated – creates in human experience what Jaak Panksepp (2005) refers to as the Primary 'SELF'.

This brainstem-based consciousness is an adaptable form of mental agency, generating purpose and meaning, as well as anticipating and perceiving the external social world, and its objects (Delafield-Butt & Trevarthen, 2015). It plays a key role in the co-regulations that take place between adults and infants as they actively seek to create and share meaning – meaning that we are coming to recognise as narratively organised action and interaction. Kugiumutzakis and Trevarthen (2015) contextualise a newborn infant's ability to imitate is an example of its desire for narratively structured dialogical interaction, and demonstrates the infant's ability to co-operate in temporal sequencing.

Co-ordination and co-regulation in the temporal organisation and sequencing of dyadic interactions is vital for the successful creation of meaning, as well as the individual achievement of goal-directed actions. Each action unit, let alone action chain, requires a host of muscles within the body to work in near perfect collaborative coordination to initiate and manage the forces involved in the achievement of a goal-directed movement (Bernstein, 1967; von Hofsten, 2007). The ability to co-ordinate and regulate these movements in tandem and synchrony with another is key to wider co-operation in social groups through sympathetic harmonization, and forms a key element of an innate, embodied narrative (see Appendix for definition of terms) organisation of shared psychomotor time in communicative musicality (Malloch & Trevarthen, 2009, 2018; Malloch, 1999; Trevarthen et al., 2011).

The importance of the brainstem discussed here is not intended to undermine the role of the cortex, but rather highlight an often-undervalued aspect of neuroanatomy (Winn, 2012). The complex relationship between the brainstem its wider neuroanatomy underpins the wider role played by this core region (both in terms of location and function) in core aspects of human experience (Buzsáki, 2006; Damásio, 2010; Panksepp & Biven, 2012).

6. Evolution of narratives across the primate order

Shared social projects create narratives between individuals. They make stories that can be held in memory for later recollection and use in planning and decision-making, enabling imagination to extrapolate and chain potential sequences of events into the future. This process informs choice in the present moment, enabling predictions of possible futures, possible outcomes of events based on choices in the present moment. Knowledge of narrative structure allow predictive time travel, and enacting that knowledge yields new instances of its realisation.

Scientific knowledge of the evolution and development of human narrative intelligence has much to gain from comparative study of narrative within non-human primates. As a social order, all primates share projects together, and coordinated interaction between infants and parents remains a necessity for survival, development, and learning, with human child-rearing extending this process significantly and allowing for uniquely human evolution of the development of intelligence (Hrdy, 2009). Yet, despite significant attention across primate species on the origins of language, social cognition, and shared understanding, the concept of narrative – a cornerstone of human meaning-making – has not yet influenced the field of comparative psychology, nor primatology, except in a few, brief cases. At the same time, there is considerable primate research on the nature of shared projects in primate evolution and development. Much of this work has been motivated by a desire to shed light on the evolution of human social development, particularly around the productive and technical capabilities of shared intentionality and sustained coordinated action to solve tasks, and inform language. But fundamental to all of this is how these projects – these stories – are affectively shared in rhythms of the body in primary intersubjectivity, and then later recalled (Tomasello, 2008; Tomasello & Carpenter, 2007; Tomasello et al., 2005; Voinov et al., 2020).

6.1. Imitation in non-human primates

The imitative capacities of neonatal non-human primates, the manner in which rhythms can be shared and understood, and the underlying cognitive capacities give some indication of the capacities of non-human primate infants and juveniles to share and co-ordinate their intentions and actions in social projects (Bard, 2007; Ferrari et al., 2009; Hattori & Tomonaga, 2019; Hattori, Tomonaga, & Matsuzawa, 2013; Martin, Biro, & Matsuzawa, 2017; Matsuzawa, 2007; Myowa-Yamakoshi, Tomonaga, Tanaka, & Matsuzawa, 2004). Additionally, new observation shows a precocious capacity for imaginative, pretend play in chimpanzee juveniles (Matsuzawa, 2020) that suggests creative capacities for exploring and 'mucking about' are intact in juvenile chimps (*c.f.* Reddy, 2008). But more work is required to better understand the composition, character, and species limitations and capacities of embodied narrative meaning-making. As a social order, all primate species share projects together.

6.2. Narrative intelligence hypothesis

The Narrative Intelligence Hypothesis (NIH) provides a potential foundation upon which future comparative work can be conducted. It places the structure of animal projects and interactions within a narrative framework (Dautenhahn, 2001) and outlines an interwoven "relationship between the evolution of narrative and the evolution of social complexity in primate societies" (p. 249), leading to the formation of linguistic communication whilst also acting as a binding agent in the fabric of human social relations. NIH proposes an evolutionary trajectory of intelligence that tracks the growing complexity of narrative transactions.

NIH is in agreement with the narrative projects in human infancy first identified by Stern, Trevarthen, and others. In non-human primates, it is seen in projects of physical contact, such as one-to-one grooming, but it is also evident in non-verbal stories enacted between individuals that begin to allow for communication about social matters. Finally, NIH identifies language-imbued interactions and stories common to human society and culture.

Beyond the impact of narratives on social interactions, NIH proposes they aid in the extension of the temporal horizon, allowing individuals to view time and reality in abstract forms that might not otherwise be possible, and potentially therefore aid in the creation of an autobiographical self (Dautenhahn, 2001; Nelson, 1993). Within these abstract notions of time and self, solo projects and sequences of actions can be built (although within the framework of NIH these represent a form of "pre-narrative" that lacks a social or transactional nature, and so fails to meet the requirement for fully fledged narratives).

An important feature of this view of narrative is they are not the exclusive creation of language, but are also found in the transactions of non-verbal and pre-verbal interactions. This is significant due to the importance of non-verbal and physical interactions in human intersubjectivity, as well as within non-human primate social interactions. For example, Bard et al. (2019) reported in young chimpanzees a flexibility and diversity in their form and use of touch when used communicatively across various types of affiliative contexts, as well as simple dominance/submission scenarios.

NIH proposes that narratives evolved because their structure is particularly suited to communicate about the social world, or for conveying meaningful and socially relevant information including content regarding emotions and intentions (Dautenhahn, 2002). They allow individuals, and the groups they belong to, the ability to deal with increasing complexity in the social field (with increasing complexity and group size also argued as underlying human neocortex size, which helps manage the additional processing associated with human social grouping (Dunbar, 1992, 1993, 1998)). This is not an exclusively human ability, and in animals (such as chimpanzees) can be found in interactions where the content is about the social field. Dautenhahn (2002) predicts "a correlation between the complexity of the narrative format and an increasing complexity of the primate social field" (p. 116), which appears to align with Bruner's notion of the role of narrative in human society (Bruner, 1986, 1990). Important to note, the 'social field' is not limited to group size but could also includes other elements of social complexity, whilst the idea of format relates to the exact structure of the

transaction. The nature of the narrative format in non-human primates requires more detailed investigation, but NIH proposes it follows the four stages described by Bruner and Feldman (1993): (i) a canonical steady state followed by (ii) a precipitating event which then reaches (iii) a restoration, and is finally followed by (iv) a coda, marking the end of the interaction.

6.3. Evidence of narrative as a communicative structure in chimpanzees

The pant hoot is one particular example of narrative structure important in the communicative patterns of chimpanzees. The pant hoot allows direct communication, and offers some flexibility for adapted social co-creation, a phylogenetically early form of vocal narrative co-creation. Pant hooting is common in adult males and serves multiple purposes, most well-known as a long-distance call for the recruitment and maintenance of social relationships (Mitani & Nishida, 1993). Male chimpanzees also pant hoot with nearby individuals in 'choruses' in which two or more chimpanzees will pant hoot together, often in an overlapping fashion. The acoustic features of a typical pant hoot has a temporal pattern that follows the same four-part structure identified in human mother-infant narrative interactions, but these are described under slightly different labels within primatology (Fig. 3). Chimpanzees manipulate the temporal fabric of the pant hoot to allow for social interaction, for example by lengthening the 'build-up' phase to facilitate other chimpanzees in joining a chorus (Fedurek et al., 2013). Recent acoustic analyses further define manipulation of its acoustic qualities to communicate, for example social status and context (Fedurek et al., 2016).

The social function of pant hooting is further exemplified by other underlying features of the behaviour. For example, chorusing is more common among preferred conspecifics than neutral ones, it is a good signal of short-term social bonds, and males who associate more often with one another are more likely to produce similar pant hoot calls (Fedurek et al., 2013; Mitani & Brandt, 1994; Mitani & Gros-Louis, 1998). Although it is not clear if the matching of pant hooting between individuals is linked with shared affective states, in pygmy marmosets it has been shown that individuals modified their calls in terms maximum frequency and frequency range in line with fellow group members, and these increases are likely linked with increased arousal (Elowson & Snowdon, 1994; Mitani & Gros-Louis, 1998; Scherer, 1986). Further investigation is required into the co-regulatory function of alterations in pant hoot calls, but that pant hoot chorusing is narratively structured and serves a social bonding purpose highlights the importance of narrative across species, and gives evidence of its early phylogenetic origins (Mitani & Brandt, 1994).

7. New and developing approaches

Advancements in computational methodologies, machine learning and computer vision movement tracking offer new avenues to explore adult-infant interactions, and infant development more generally. Such approaches can allow for the integration of the multi-modal nature of human interaction, as well as offer new persepectives on older experimental paradigms (Hammal et al., 2015; Vinciarelli et al., 2009). For example, Hammal et al. (2015) automatically tracked and modelled adult and infant head movements during the still face paradigm. The researchers found that mother and infant head movements, and their coordination, varied systematically across the three phases of the paradigm. Head movement has also been automatically tracked with motion capture in infants in dyadic face-to-face engagement (Væver et al., 2015) and in children using computer vision whilst they watched social and non-social stimuli (Martin et al., 2018). Facial expressions (smile strength, eye constriction and mouth opening) have also been modelled using computer vision software in a pilot study involving two adult-infant dyads (Messinger et al., 2009).

Moving beyond the head and face, computational motion tracking of body parts has also been implemented in the study of adult-infant dyadic interaction. For example, to differentiate between situations of emotional neglect and typical development, Leclère et al. (2016) utilised 2D and 3D video sensors to monitor free play sessions between mothers and infants. The researchers also used machine learning techniques to classify dyads on the basis of the captured motion data, successfully classifying 100% of dyads as members of the control group or as dyads with mothers showing neglect.

Machine learning approaches have also been applied to investigate the predictability of mother and infant behaviour during dyadic engagements (Messinger et al., 2010), but despite their growing and varied use in exploring adult-infant interaction, the application of this approach to examine narrative architecture is yet to be implemented. Its ability to integrate multi-modal sources, produce highly accurate markerless motion tracking, and classify data of a temporal nature, make machine learning a significant approach for future research into the role of narrative in dyadic interactions (Leclère et al., 2016; Pouw, Trujillo, & Dixon, 2019; Vinciarelli, Pantic, &

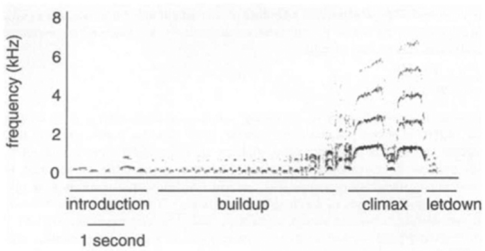

Fig. 3. Audiospectrogram showing the frequency of a typical chimpanzee pant hoot as it varies with time, illustrating its narrative four-part structure of (i) introduction, (ii) development (buildup), (iv) climax, and (iv) resolution (letdown). Reproduced with permission from Mitani and Gros-Louis (1998).

Bourlard, 2009).

8. Conclusions

Despite the long-held belief that narratives rely on a form of abstract, reflective intelligence and language (Hutto, 2007), the pre-linguistic exchanges of infant-adult proto-conversations have been demonstrated to utilise both vocalisations and movement to co-create non-verbal narratives that share affective and social meaning (Delafield-Butt & Trevarthen, 2015, 2009; Malloch & Malloch, 1999). These narratives form a bedrock of adult-infant co-regulation in social engagement that serves to support meaning-making, as well as to co-regulate affective and physiological states. These pre-verbal narratives, and the sensorimotor systems that underlie them, are integrated and organised by a brainstem-mediated primary conscious awareness. It is within this subcortical core self that the origins of narrative co-regulation are to be found, with their psychomotor nature structured by the temporal frame of reference and serial organisation required of coordinated, prospective animal action. Narratively structured co-regulation is rooted in bodily movement: the generative, goal-directed foundation of human consciousness (Merker, 2005).

The infant's role in the creation of narratives and corresponding meaning-making creates a foundation for learning patterns and their temporal organisation, ultimately allowing the learning and development of complex embodied practices with their schemas held in memory (Cobley, 2013; Delafield-Butt & Adie, 2016; Delafield-Butt & Trevarthen, 2015, 2008; Gratier & Negayama et al., 2015). These narratively co-regulated projects, completed in infancy, lay the bedrock for all manner of later learning. The brainstem processes underpinning them regulate the goal-directed movements that represent the initial stage in the conceptual development of patterns of motor behaviours that form the first schemas. Before higher forms of linguistic and conceptual learning can take place, it is necessary that affective and embodied patterns be embedded. As such, where narrative co-regulation is thwarted, the downstream consequences can be profound.

For example, Bruner and Feldman (1993) in their narrative deficit hypothesis argue that autism spectrum disorder (ASD) develops as a result of infant inability to create and participate in joint, non-verbal narrative meaning-making. They propose that ASD symptomatology could be the result of a deficit in narrative communication skills, and an inability to organise and structure one's own experiences into a narrative framework. This deficit also impacts the ability to understand narratives used by others, and engage in co-regulation through a narrative framework. ASD can be linked with intersubjective narratives through a dependency on accurate prospective timing and rhythm, which are integral to the effective integration of motor intentions (Daniel et al., 2022; Daniel, 2019; Delafield-Butt & Zeedyk, Harder et al., 2020). The affective state created as a result of thwarted motor intentions results in distress and isolation leading to emotional and social compensations (Trevarthen & Aitken, 2001; Trevarthen & Delafield-Butt, 2013). This disruption likely has its roots in the brainstem (Dadalko & Travers, 2018), as the successful execution of goal-directed movement requires subsecond accuracy of timing to allow for the coordination of muscle groups shared in preverbal narrative (Delafield-Butt & Trevarthen, 2017), which can lead to disruption in the formation of Panksepp's (2005) core self, and wider ASD symptomology (Delafield-Butt et al., 2022).

Evidence of narrative structuring in the pant hooting of chimpanzees, and the importance of this behaviour in social bonding points to the potential importance of narratives and co-regulation in non-human primates. This is an area of narrative research ripe for further exploration that would help develop our understanding not only of narratives across species, but also their role in our evolution. The continued advancement of machine learning techniques also holds considerable promise in developing our understanding of the role of narrative in co-regulation in both chimpanzees and human beings.

Currently much of our understanding of narratives is limited to human beings, where narratives and the synrhythmic co-regulation they facilitate plays an integral role in the learning and connection that characterises much of early childhood, and indeed later life. For learning and social participation to take place there must be arousal, interest, organisation of action, affect, and the expressive energy of movement, all of which must be regulated for successful and unthwarted co-created meaning. The dyadic nature of intersubjectivity and meaning-making continues to be integral to human experience throughout life, as connection itself "is the regulation and co-creation of the age-possible meanings individuals make of the world and their place in it. The making of meanings is dyadic and continuous" (Tronick, 2005 p21). Were this process not organised and structured in accordance with narrative, human experience would be profoundly altered.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Embodied narrative

Narrative is not exclusively a creation of language, nor is it only expressed through vocalization. Rather, narrative is a framework that structures human activity from its most basic level to its most advanced, both solitary and social. It structures thought and movement, cognition and consciousness. Its structure is developed from the serial organisation of purposeful body movement to give units of self and other regulation with prospective knowledge, the affective, intentional and autonomic systems of which form a deep, invariant embodied structure in which meaning is contextualised.

Co-created narrative

A narrative can be a self-generated in solitary projects, but they can also be created in conjunction with another individual. These social narratives are made with active participation from both sides, and are referred to as co-created narrative.

Narrative projects

Projects refer to the purposeful organisation of actions to achieve a task. Arranged within an envelope with the four-part structure of introduction, development, climax, and resolution, these projects fulfill the criteria of narrative.

Co-created narrative projects

Narrative projects can be created and regulated in partnership with another individual. In such cases the projects are co-created through social engagement and co-operative participation with an attentive and engaged other, from stacking building blocks in the accomplishment of a desire, to the formal discourse of speech in adult-adult dialogue.

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