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Status of the human newborn

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Introduction

The newborn period, extends through the first two to four weeks after a full-term birth (37-40 weeks gestational age: e.g., Nagy, Pal & Orvos, 2014). To understand properly the status of the human newborn and the demands of adjusting to the extra-uterine environment, we need to consider a behavioral repertoire that embraces findings on sensory, motor and communicative abilities, abilities that are tempered by the modulating effects of behavioral state. Understanding will also be promoted through the medium of cross-species comparisons and in particular those involving non-human primates across a variety of rearing conditions.

Here, we focus on comparisons between human and chimpanzee (*Pan troglodytes*) newborns as means of highlighting commonalities and differences across these closely-related species sharing 23 million years of evolutionary history and becoming separate species 5-7 million years ago (Bard & Leavens, 2014). In doing so, we draw on findings derived from studies using the Neonatal Behavioral Assessment Scale (NBAS: Brazelton & Nugent, 1995). One advantage of the NBAS is that it assesses the infant within the social context of a supportive examiner, with procedures that are designed to produce optimal infant performance while also challenging the arousal and coping capacities of the newborn. Another is that it has been used in studies with both human and chimpanzee newborns, with the latter involving comparisons between infants raised in different social contexts. All told, these studies have revealed few differences between the two species, but marked influences of rearing conditions, demonstrating that both species adapt developmentally during the first 30 days of life (Bard *et al.*, 2011).

Across biomedical institutions housing chimpanzees in the 1980s and 1990s, infants were born to chimpanzee mothers, who did not have sufficient maternal competence to raise them successfully. Therefore, newborn chimpanzees were raised in nursery settings by human caregivers. Caregiving practices of these nurseries differed (in terms of caregiver-

infant ratio, type and amount of care, etc.), which impacted developmental outcomes (Bard *et al*., 2011; Bard, 2012). The diversity of neonatal experiences across settings resulted in significant within species differences. In contrast to erroneous conclusions about species differences derived from studies using a single group of chimpanzees, those studies that use multiple groups allows for more accurate conclusions about species differences (Bard & Leavens, 2014).

To begin, we consider evidence concerning newborn responsiveness to visual and auditory stimuli, followed by a review of motor abilities. We note that, in some respects, the distinction between sensory/perceptual ability and motor/action abilities is an artificial one. The importance of accounting for state regulation is addressed next before moving on to the issue of neonatal imitation and communicative competencies more generally in the closing sections.

Sensory abilities of the newborn

Alertness and visual orientation

As noted elsewhere in this volume, third trimester fetuses can perceive both visual and auditory stimuli external to the womb. At birth, however, the newborn begins a journey where vision typically becomes the dominant perceptual modality. Minutes after birth, some newborns are in an alert state, and are finely attuned to looking at, and responding to communicative bids from parents (Kugiumutzakis, Kokknaki, Makrodimitrak, & Vitalaki, 2005; Nagy *et al*., 2014).   Newborn periods of alertness, at 2 days-of-age, are of moderate duration (5-15 seconds), but may be delayed or variable (e.g., Bard *et al*., 2011). When alert, newborn humans can follow visual stimuli, with smooth saccades, across a 30-degree horizontal arc. To obtain optimal infant performance, the NBAS examiner moves an object slowly, with occasional pauses to regain infant focus. At this age, visual pursuit does not

improve if the stimulus also emits sound, but an animate stimulus (human face and voice) captures more attention than inanimate stimuli (red ball and red rattle). Moreover, newborns are better at following animate stimuli (Bard *et al*., 2011). By 2-4 days-of-age, newborns discriminate their mothers' faces from those of strangers (Field, 2007).

By 30 days-of-age, periods of alertness have improved in duration (15 to 30 seconds). Newborn visual orientation abilities have also significantly improved, and they can follow a red ball through 60 degrees of horizontal movement, and also begin to follow short vertical movements. At this age, they do not show an improvement in tracking if the visual stimulus also emits sound, nor with regard to differences in orientation between animate and inanimate stimuli.

Using the NBAS, Bard and colleagues (2011) found that newborn chimpanzees, at 2 days-of-age, have frequent (more than 2) and sustained (15 seconds) periods of alertness, which is significantly longer than 2-day-old humans. By 30 days, however, humans have improved in alertness and there are no species differences in alertness, or in visual or auditory orientation. Overall, in terms of orientation assessed during the NBAS, the chimpanzee newborns were not different from their human counterparts (Bard *et al*., 2011).

Visual acuity

Visual acuity is an aspect that appears to be different in chimpanzee compared to human newborns. During the NBAS, the examiner holds orientation items at a distance that results in optimal performance. For human newborns, it is typically about 30-38cm (the typical distance from the eyes when an adult holds a newspaper), but for the chimpanzee newborns, this was often up to 60-76cm. During formal visual acuity testing, young chimpanzees performed equally well when stimuli were held at both 38 and 76 cm, although they did not differ significantly in their acuity compared to human newborns. Furthermore, the visual

acuity of both humans and chimpanzees is significantly less mature than that of rhesus monkeys (Bard, 2012; Bard *et al.*, 2011).

Other sensory modalities

Newborns can discriminate colors, if these are very bright (green, blue, yellow, and red), and shapes if the edges are depicted with bold contrasts (triangles, circles, crosses, and squares; Field, 2007). They can also distinguish different tastes and odors, and may show emotional facial expressions of gaping, frowning, or nose wrinkling (components of a 'disgust' expression) to bitter and sour tastes and smells of butyric acid, versus lip smacking, sucking, or rhythmic tongue protrusions to sweet tastes and smells of milk (components of a 'happy' expression).

Touch is an important modality that we know relatively little about in newborns (Field, 2007). Fetuses, even as young as 21 weeks of gestational age, respond to touches to the abdomen (Marx & Nagy, 2015). Touch can convey and modulate emotion, especially distress, such as during the still-face paradigm (Nagy, 2008). There are large cultural differences in the amount of touch experienced by newborns, with newborns in some cultures having as much cradling contact as do newborn chimpanzees (i.e., physical contact during 100% of their sleeping and waking time), and many, especially in Western urban settings experiencing considerably less (Bard, 2012). Interestingly, there is an inverse relation between the amount of cradling contact and mutual gaze, such that 2 and 3 month-old humans and chimpanzees who experience up to 100% cradling contact have relatively low levels of mutual gaze, and vice versa (e.g., Bard, 2012).

Motor abilities of the newborn

Newborn reflexes

Many of the same reflexes can be elicited in newborn humans and chimpanzees (Bard, Hopkins, & Fort, 1990;Table 1; Figs. 1-3). It is interesting to note that rooting is elicited differently between the two species, and results in contrasting outcomes: for human newborns, a stroke in the corner of the mouth elicits a head turn in that direction with an open mouth; for chimpanzee newborns, touching the lips elicits an open mouth and a head bob. This difference makes sense when one observes nursing under natural conditions: in humans, the baby is usually held horizontally in the mother's arms, whereas in chimpanzees, the baby is usually vertical, with his/her body against mother's ventrum.

It is informative to know that although these closely related species share many of the same reflexes, there are some cases, such as rooting and stepping, when they are differently expressed. Together, these findings demonstrate a common strategy for conducting neurological examination, tailored to cater for species-characteristic forms of elicitation.

Table 1 about here

Figure 1 about here

Figure 2 about here

Figure 3a, b, & c about there

Evidence from the motor cluster of the Neonatal Behavioral Assessment Scale

Surprisingly, based on comparative evaluations with the NBAS, there are few differences between newborn chimpanzees and humans in motor performance (Bard *et al*., 2011). Newborn chimpanzees and humans exhibit equivalent motor maturity, with smooth movements of the arms (consisting of arcs of 60 degrees at 2 days and 90 degrees at 30 days), in equivalent ability to hold the head up (i.e., between 2s and 10s) during the pull-to-sit manoeuvre, with equivalent reactions to 'cloth-on-face' (i.e., neck stretch with one undirected swipe in the upper quadrant), and with moderate amounts of both spontaneous activity and elicited activity (i.e., in response to the examiner's handling). There was one motor item in

which species differences were identified, however, and that was in muscle tone (e.g., resistance to examiner's handling), with the chimpanzees judged to have significantly more muscle tone than human newborns.

There are significant differences in the motor abilities of newborn chimpanzees based on their rearing environment (Bard *et al.*, 2011). For example, at 2 days-of-age, newborn chimpanzees raised in the nursery at Southwest Foundation for Biomedical Research, San Antonio, Texas, were able to right their head for only 2 seconds during the pull-to-sit maneuver (the same level as a group of humans). Neck control was significantly better, however, in mother-raised chimpanzees from the Institute of Primate Studies, Norman Oklahoma, and in those raised in the nursery of the Yerkes Primate Research Center, Emory University, who showed no head lag and held their head upright for 10 seconds. By 30 days-of- age, the pull-to-sit performance of all groups improved, but the human group was not distinct from the mother-raised chimpanzee group. At 30 days of age, the neck control of both of these mother-raised groups (humans and chimpanzees) was not as mature as that of the nursery-raised chimpanzee groups (Bard *et al*., 2011).

Experimentally-based evidence

Most research portrays motor behavior as relatively fixed (i.e., hard-wired). Chimpanzee group comparisons, however, highlight the responsivity of the developing motor system to the early environments. Some research on neonatal motor responses, moreover, suggests them to be intentional, purposeful, and socially responsive (e.g., Nagy *et al*., 2014). For example, when small forces are applied to their arms, newborns attempt to oppose the force impeding their ability to keep their arm up and moving normally (van der Meer, van der Weel & Lee, 1995). To effectively counteract the forces, however, the newborns need to see their own arm, either directly or via a video monitor. Furthermore, the fine finger movements of human newborns are affected by the social environment. For example, newborns show more

finger movements in the presence of their mother, than when only an object was present. Newborns also showed purposeful movements (extending the arm and opening the hand) when looking at an object within reach, but not when looking away from the object. Thus, these experiments provide evidence that newborns actively monitor and control their own movements, and that they are socially influenced (Nagy, 2008; Nagy *et al.*, 2014).

Behavioral states of arousal and arousal regulation in the newborn

Arousal

Arousal and its regulation are important aspects of newborn behavior that are assessed in the NBAS. The NBAS is organized to assess newborns behavior in all states, from sleep through moderate distress. Fussiness and crying are treated as two distinct conditions that are associated with mild and moderate/severe distress, respectively. The NBAS examiner easily measures how quickly the newborn becomes upset enough to cry, the level of distressed arousal, how often the infant is distressed, and how often the infant cycles between the different behavioral states (e.g., from sleeping states to crying).

Human newborns typically cried when first handled by the examiner, that is, in the first 5-10 minutes of the NBAS test. This quick transition to crying was also found in mother-raised chimpanzees, but nursery-raised chimpanzees cried only toward the end of the procedure (Bard *et al.*, 2011). Human newborns and mother-raised chimpanzees cried at least twice during the NBAS, easily returning to a calm state, whereas nursery-raised chimpanzees were significantly less distressed, and either did not cry, or cried only very briefly. Furthermore, there was no species differences in how often newborns became upset: mother-raised chimpanzees fussed to five items at 2 days and almost seven items at 30 days-of-age, whereas the nursery-raised chimpanzee groups and the human newborns tended to fuss to four, or fewer, items. Newborn humans and chimpanzees showed around eight

changes of state during the 20-25 minute NBAS administration (Bard *et al.*, 2011). Overall, human and chimpanzee newborns show similar patterns of arousal and arousal regulation, which is highlighted only when the diversity of chimpanzee outcomes (as a function of rearing environments) are included (Bard & Leavens, 2014).

In addition to descriptions of arousal states during NBAS testing, we also described arousal of chimpanzee newborns during observations with their mothers. We found that fussiness is more common, and crying is less common in nursery-raised chimpanzees compared to mother-raised chimpanzees. It is important to note that colic (defined as inconsolable crying, continuing for hours every day) was not observed in any nursery-raised or mother-raised chimpanzee, but that it is in human newborns raised in urban settings. Colic in human newborns is notably less commonly reported in rural settings (e.g., Soltis, 2004).

Arousal regulation

The second cluster of NBAS items relating to arousal is called State Regulation (Brazelton & Nugent, 1995). Newborn humans and nursery-raised chimpanzees are able to quiet themselves, such that, when upset, they used self-calming behaviors to return to a quiet and alert state for at least 15s during NBAS testing (Bard *et al*., 2011). In contrast, mother-raised chimpanzees were significantly less able to self-quiet, returning to a quiet state only briefly (for one or two 5s periods). One of these self-calming behaviors is sucking on the thumb, wrist, or fingers when distressed. During the NBAS testing, human newborns were able to insert (briefly, once or twice) a finger, thumb, or wrist into their mouths in an attempt to suck. Mother-reared chimpanzees, as a group, were significantly less capable than the human newborns and the nursery-reared chimpanzees in hand-to-mouth self-comforting at 2- and 30-days-of-age. It is likely that chimpanzees raised with their biological mothers rarely need to regulate their own arousal, and thus do not exercise various self-calming abilities, whereas nursery-reared chimpanzees are often without a caregiver, and regularly need and exercise

self-comforting behaviors.   Mother-raised newborn chimpanzees and humans responded to cuddling with relaxation and molding into the examiner's arms, whereas nursery-reared chimpanzees additionally responded with nestling and clinging (Bard *et al*., 2011).

For chimpanzees, it is clear that both their arousal and their ability to regulate arousal are highly influenced by their early rearing environments. It may well be that the constant cradling contact experienced by mother-raised chimpanzee newborns makes them both more aroused in the absence of cradling (as during the NBAS testing) and less capable of self-regulation in the newborn period (since their mothers are constantly available). The nursery-raised chimpanzees, in contrast, must rely on their own resources to regulate their distress, but also become less aroused within the first days after birth. These comparisons of mother-raised and nursery-raised chimpanzee groups, therefore, highlights the impact of the early social environment on newborns' arousal levels and on their abilities to regulate their arousal.

In human newborns, the impact of social stimuli on arousal regulation is illustrated in an interesting set of studies on the soothing properties of sucrose (Zeifman, Delaney, & Blass, 1996). In the week or so after birth, sucrose delivered to a crying human newborn results in sustained calming. However, by 4-weeks of age, this calming influence was found only when sucrose was paired with mutual gaze with an adult. Thus, within the neonatal period, social stimuli become integrated with other extrinsic stimuli for arousal regulation. Cross-cultural comparisons suggest similar processes occur in human newborns with regard to the types of social stimuli that regulate arousal. More complex arousal regulation (e.g., involving attention orientation, comfort objects) develops later in infancy in both humans and chimpanzees (reviewed in Bard, 2012).

Imitation competence of the newborn

Imitation, especially of unseen actions, has been heralded as a marker of emerging cognition. For decades, it was thought that imitation of facial actions, for example, developed only in older 1-year-olds, but we now know that neonates can copy the movements, expressions and gestures of social partners. Specifically, neonates reliably imitate lip protrusion, tongue protrusion, mouth opening, sequential finger movements, and even vocal stimuli (Field, 2007; Kugiumutzakis *et al.*, 2005; Nagy & Molnar, 2004). Neonates imitate even complex fine motor finger movements, such as raising the index finger, raising two and three fingers in selective imitation (Nagy *et al.*, 2014). The ability to imitate does not require full-term maturity as not only term, but also preterm neonates imitate (Field, 2007).

Chimpanzee newborns imitate mouth opening, tongue protrusion, and a sequence of three mouth actions, with some being able additionally to imitate the sound of tongue clicks (Bard, 2007). Moreover, both neonatal humans and chimpanzees utilize imitative exchanges with the intention to communicate. Chimpanzee imitate better in a communicative setting compared to a highly structured setting (Bard, 2007). In human newborns, physiological indices (i.e., heart rate) differentiate between the 'responding' (heart acceleration) and the 'provoking' or 'initiating' (heart deceleration) of imitative movements, thus providing strong evidence for intentional turn-taking in the social communication of newborn infants in their first days of life (Nagy & Molnár, 2004).

Recently, Nagy *et al*. (2014) reviewed the literature, and found an intriguing pattern relating infant age with success in imitation experiments. Studies with newborns in their first week of life have been predominantly successful in finding evidence for imitation, whereas those conducted when infants are 2-4 weeks of age have found less success. There appears to be a sensitive period when neonates are particularly prone to selectively copy and reproduce actions modelled to them (Nagy, 2011). The unique characteristics of responses in the early neonatal period might be parallel to the filial imprinting processes (Nagy *et al*., 2014). Thus,

newborn humans and chimpanzees are capable of engaging in communicative exchanges with their caregivers, as seen in neonatal imitation, and such exchanges provide a strong foundation of the emergence of early bonding. Such bonding, under normal conditions, leads to the later development of attachment systems (Nagy, *et al.*, 2014).

Social communicative abilities of newborns

The interest in the psychologically active and pro-active young infant rose with the development of the microanalytical observation techniques by anthropologists, pediatricians, neurobiologists, and psychologists (e.g., Bullowa, 1979). Given the methodological difficulties in investigating and interpreting young infants' behavioral responses, physiological indicators such as the heart rate changes were used in understanding how newborns are able to learn, to appraise and anticipate the upcoming stimuli, indexed by heart rate deceleration or cardiac orientation (e.g., Nagy & Molnar, 2004).

Evaluating neonates' social understanding and responsivity is methodologically challenging. An innovative paradigm, designed to address this challenge, the 'still-face paradigm' was developed to test young infants' understanding of social interaction. Although there is a wealth of data on the social competence of these older-aged infants, those with regard to newborns are scarce. Do newborns, with virtually no extrauterine experience in social communication, understand the situation? Nagy (2008) found the still-face effect in newborns (3 to 96 hours old), by employing longer experimental phases than other researchers. Newborns decreased their gaze toward the experimenter and increased their distress (crying) during the still-face condition. Some of these changes even lasted into the re-engagement phase, a phenomenon that is known as a 'carry over' effect in older infants. Thus, there is evidence that neonates, with minimal postnatal experience in reciprocal social engagement, already understand social communication, and find its disruption distressful.

Face perception

Newborn infants prefer certain visual stimuli with social significance, such as characteristics of faces. For example, they prefer looking at upright compared to inverted faces. From 45 hours of age, neonates prefer their own mothers' face over a stranger's. Newborns also prefer a gaze that is looking at them, opposed to averted gaze (Rigato *et al*., 2011). When the facial and gaze cues are co-manipulated, it was found that these socially relevant cues influence the efficiency of neonatal learning. Newborns quickly learnt the identity of a new face when the eye gaze was direct, but not when the face was presented with averted gaze. This finding is consistent with results established for older infants, and has been predicted by the notion of 'innate' intersubjectivity and second-person social-cognitive models (Nagy, 2008, 2011).

Emotional expressivity

Newborn humans and chimpanzees are also capable of complex patterns of emotional expressivity. As early as 36 hours after birth, babies reliably copy the full facial gestalt of happiness, sadness and surprise (Field, 2007). Newborn humans also show disgust and smile to bitter and sweet tastes, respectively. Even anencephalic and hydrocephalic newborns and infants show these expressions. As such expressions evolved, in part, to communicate internal states and prospective actions, it is plausible to assume that they sub-serve survival and bonding from the moment of birth. Newborn chimpanzees exhibit joy with sounds (greetings and laughter) and facial expressions (smiles /playfaces), exhibit anger with threat vocalizations and bulged lip faces, exhibit distress with pout faces, whimpers, fussy faces, crying, and scream faces, exhibit fear with alarm calls, and interest with 'bright' faces and effort grunts (Bard, 2012). The cranial nerves responsible for innervating the facial muscles develop from the 10th gestational week, and facial expressions of smile, frown and cry-face have been observed reliably by 24 weeks of gestation (Reissland, Francis, Mason, & Lincoln,

2011). Therefore, it is not surprising that neonates around the time of birth have the ability to respond to social stimulation even with complex facial and vocal emotional expressions

Neonatal awareness of biological motion

The early sensitivity to stimuli with social significance extend to biological motion, gross movements, such as walking, movements that are not yet in the motor repertoire of the newborn. Other species also attend preferentially to biological motion, such as newborn domestic chicks, great apes , and dolphins (Rugani, Salva, Regolin, & Vallortigara, 2015). Human adults need only 100 ms to recognize a point-like walker . Two-day old human newborns also show this spontaneous preference for biological motion likely as part of an evolutionarily ancient non-species-specific system that predisposes the organism to recognize, attend to, or even follow other individuals right after birth (Rugani et al., 2015).

Although evaluating social and communicative responsiveness in neonates remains technically challenging, evidence points unequivocally to the fact that newborns prefer stimuli with potential social significance, such as voices, smells, and faces. If given a chance, newborns actively control and interact with their environment to experience socially relevant stimuli and events. For example, they quickly learn to change the intensity of their sucking when a pacifier is connected to a tape playing the mother's voice. Whether it is slowing or increasing their sucking rate that sets off the playing of the mother's voice, newborns always learn the rule and employ the sucking rate that results in playing their mothers' voices.

Conclusions

Over a range of functions assessed by a widely-used standardized examination of newborn behavior, there were no marked differences between human newborns and their chimpanzee counterparts. We know much more about the developing social proclivities of humans compared to chimpanzees, however, but for those skills that have been tested, e.g., neonatal imitation, we find strong parallels in outcomes across species. More noticeable are within

species differences, evident when variations in the rearing experiences of chimpanzee newborns are considered, e.g., when the chimpanzee mother plays a crucial role. We also highlighted recent and older findings that clearly support the claims about the socially-directed nature of much of newborn behavior, an understandable characteristic when one considers the necessity of newborns being able to contribute to the process of developmental adaptations, such as bonding with carers immediately after birth, a process that is set in motion during the second trimester of pregnancy. There is a need to track the longer-term consequences of caregiving experiences on a variety of developmental outcomes, with careful extrapolations to human development. Here as well there are fruitful lines of longitudinal research to be pursued in cross-species comparisons involving the great ape and human newborns (e.g., the development of imitation beyond the neonatal period).

See also:

Ethological theories; Cross-species comparisons; Developmental testing; Direct observational methods; Prenatal sensory development; Prenatal motor development; Childbirth; Attention; Audition; Biological motion perception; Face perception and recognition; Imitation; Multisensory perception; Olfaction and gustation; Vision; Social development; Emotional development; Temperament; Perception and action; Locomotion; Prehension; Brain and behavioral development; Excessive crying and colic; Ethology; Primatology; Development of consciousness; Evidence of evolution in human development.

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