STEPPING, PLACING, AND HEAD TURNING BIASES IN NEWBORN INFANTS: A NEURODEVELOPMENTAL PERSPECTIVE

Erik Domellöf
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Department of Psychology
Umeå University
SE-901 87 Umeå, Sweden

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Abstract


In the present thesis the stepping, placing and head turning responses in healthy human fullterm newborns are investigated. The main focus is put on a study of these newborn responses in relation to functional asymmetries, while at the same time exploring and discussing different factors that possibly can affect the outcome of such studies. Study I aims to examine one such factor in relation to underlying mechanisms controlling leg movements in focusing on the effects of glucose on newborn stepping and placing responses. The results revealed that glucose, as well as an inactive state, resulted in less pronounced stepping responses and difficulties in eliciting them. There was also a tendency towards a similar finding for placing in that both glucose and an inactive state were associated with a less vigorous placing response, although this could not be proved significant. However, there was no effect of glucose on expressions of laterality in either of the responses studied. A theoretical debate in progress concerns whether different newborn functional asymmetries can be said representing a single neural system for lateralization or multiple sub-systems rooted in different neural mechanisms (Grattan, De Vos, Levy, & McClintock, 1992). In order to look closer at this issue in relation to newborn head- and leg preferences, Study II was designed to investigate the presence of side biases in newborn stepping and placing responses (lower-body), together with head turning preference (upper-body), and whether observed lateral biases of the upper- and lower body are congruent with each other. No evident lateral bias could be found for either response in terms of the first foot moved or direction of head turning. Furthermore, asymmetries in head turning did not correspond to asymmetries in leg movements, in support for multiple sub-systems rather than a single lateralized system. However, a lateral bias was found for onset latency in relation to the first foot moved in both stepping and placing. The findings are discussed in relation to underlying neural mechanisms for lateral biases in leg movements and the important role of a thorough methodology in investigating newborn responses.

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Stepping, placing, and head turning biases in newborn infants: A neurodevelopmental perspective

Erik Domellöf

INTRODUCTION

Lateral preference, in particular the inclination of most people to preferably use one hand over the other in manual activities, is a predominantly human phenomenon that has continued to intrigue us through history. About 70-90% of humans, depending on cultural background and preference assessment criteria, show a right-handed preference (Porac & Coren, 1981). Narrowing it down to the Western countries, this figure increases to 85-95% (Brackenbridge, 1981). Furthermore, even though right-handedness is the most consequently laterally biased behavior, a majority of human populations also tend to prefer the right foot, right eye and right ear (Porac & Coren, 1981). However, it is still an open question why humans seem to be characterized by right-sidedness as the norm and how this develops.

Humans start showing lateral preferences already during early infancy. In the past, it was generally assumed that the brain of the human newborn was both structurally and functionally symmetrical. Later functional asymmetries were looked upon as an age-dependent phenomenon, emerging as a consequence of hemispheric dominance for language abilities (Hopkins & Rönnqvist, 1998). However, modern research has provided evidence for motor asymmetries as early as in the healthy first- (Hepper, McCartney, & Shannon, 1998; McCartney & Hepper, 1999), second- (Hepper, Shahidullah, & White, 1990) and third trimester foetus (Ververs, de Vries, van Geijn, & Hopkins, 1994), as well as in the newborn in the first few hours after birth (Hopkins, Lems, Janssen, & Butterworth, 1987), challenging the old assumptions. Thus, it is now well known that the movement repertoire of the healthy fullterm human newborn is characterized by a number of functional asymmetries. It has further been progressively recognized that in the exploration of the nature and developmental characteristics of the earliest lateralized behaviors lies important clues to the puzzling issue of human laterality.

Investigating the development of functional laterality in the motor performances of human newborn infants involves looking at the emergence of a preference for one side or the other and whether this can be determined as a stable phenomenon or not. As right hand preference is one of the most dominant and reliable human lateralized behaviors, observing newborn functional asymmetries in relation to development of handedness has naturally gained most research interest. There are also many different models concerning the origins of handedness and how early neuroanatomical asymmetries are involved in this development (see Hopkins & Rönnqvist, 1998, for a review). However, the development of foot preference behavior has not been investigated to the same extent. Thus, one of the aims of the present thesis is to explore if there exists a neonatal foot preference, as expressed by newborn stepping- and placing responses. For instance, do newborn infants show a consistent lateral preference in terms of e.g. the first foot moved? Another question relates to what underlying neural mechanisms that seems to govern early functional asymmetries. An ongoing theoretical debate concerns whether newborn functional asymmetries are controlled by a single laterized system or multiple sub-systems (Grattan, De Vos, Levy, & McClintock, 1992). One way of exploring this is to see whether a relation exists between asymmetries of the upper- and lower-body or not. However, when setting out to explore...
newborn motor behavior, e.g. in relation to functional asymmetries, it is vital to consider the methodology used. In order to get reliable results, there are factors affecting the performance of the newborn that needs to be controlled for. For instance, behavioral state has been proved having an effect on the quality of newborn responses (c.f. Rönnqvist, 1995). Another factor that potentially could affect the newborn nervous system in relation to motor responses is the application of sweet-tasting substances such as glucose. Glucose is commonly used as a “pain-killer” in neonatal management (e.g., when taking a blood sample). However, little is known of the link between such orogustatory stimulation and newborn motor behavior. Sweet-tasting substances have been related to the function of newborn upper-body movement in e.g. promoting increased mouthing and hand-to-mouth contacting (Barr, Pantel, Young, Wright, Hendricks, & Gravel, 1999). Although, the effects of saccharides on newborn leg movements have never before been investigated. Thus, in the first part of this thesis (Study I), the effects of glucose on newborn stepping and placing responses are investigated as a preliminary to shed some light over this particular issue. Having considered this potential confounding factor, the second and main part of the present thesis (Study II) address the question if functional asymmetries in newborn leg responses (lower-body) and head turning (upper-body) share the same lateral biases.

The importance of studying infant functional asymmetries is perhaps best understood when considering the relationship between development of functional laterality and developmental delays in young infants and children born at-risk for deviant developmental outcomes (e.g., prematurely born infants). Many studies have demonstrated that left-handedness is clearly overrepresented in groups with severe and generalized cognitive deficits, and that there is an association between left-handedness (as well as ambiguous handedness) and different developmental disorders (e.g., Bishop, 1990). Exploring the nature of early lateral biases and, further on, the link between these biases (or deviations from such biases) to later forms of side preferences could thus be of great clinical relevance in e.g. refining the methods of early discovering of cerebral palsy and other neurological disorders as expressed by side-related deviations. Increased understanding of the effects of sweet-tasting substances such as glucose on newborn motor behavior also has a potential clinical value as this type of knowledge is of therapeutic importance in the care and management of infants in the immediate postnatal period.

BACKGROUND

Motor control

There are several different theories of motor control aiming to explain the complex issue of movement and its relation to the nervous system (and beyond). Some of them stem from over 100 years ago and some are more contemporary, but they all contain elements worth considering when discussing issues involving the generation and control of movement and its development.

Reflex/Hierarchical-oriented theories

In the early 1900s, the famous British neurophysiologist Sir Charles S Sherrington founded the classic reflex chaining theory. Sherrington, often cited in the neuroscience textbooks for
his description of “the final common path” (i.e., the final expression of a motor behavior is completed by way of the motor neurons of the spinal cord and the muscles), proposed that movements are triggered by stimuli and based on reflex elements linked together in a chain of activations. Although appealing in its assumptions, Sherrington’s reflex theory of motor control contains several limitations. For instance, the model fails to explain both spontaneous and voluntary movements, movements without sensory input and novel movements (Shumway-Cook & Woollacott, 2001).

The hierarchical theory of motor control, initiated by Hughlings Jackson in the early 1900s, suggests that the nervous system is characterized by a strict top-down hierarchical organization. In this model, the brain controls motor function at different levels (higher, middle and lower levels of control, roughly corresponding to the association areas, motor cortex and the spinal cord). Thus, a reflex in this theoretical framework is a primitive lower-level reaction under cortical control, as opposed to Sherrington’s view of the reflex as the fundamental unit of action (Shumway-Cook & Woollacott, 2001).

Advanced scientific observations of infants in relation to motor development evolved strongly as a research area in the 1930s and 1940s. Pioneer scientists such as Arnold L. Gesell and Myrtle B. McGraw initiated the field of thoroughly studying and documenting early motor responses, as well as implemented the use of new and sophisticated techniques and methods to do it, with a lasting impact on current research on infant motor development (Thelen & Adolph, 1992; Bergenn, Dalton, & Lipsitt, 1992). For instance, McGraw conducted elegant studies on infant neuromuscular development in e.g. analyzing the achievement of erect locomotion from stepping response to mature gait (McGraw, 1940). This type of research added evidence to a reflex/hierarchical theory of motor control as correlations could be drawn between stages of motor development and increased maturation of the central nervous system (CNS), with increased higher-level control over lower-level reflexes as a result (e.g. as demonstrated by the successive disappearance of various postnatal “primitive reflexes”). However, more updated modern hierarchical theories suggest a more flexible hierarchical organization in motor control. Depending on task, any level can exert control over another (top-down or bottom-up), with reflexes as one of many processes involved. Thus, lower-level behaviors may not be as immature or primitive as previously thought (Shumway-Cook & Woollacott, 2001).

One example of a more modern approach to the reflex/hierarchical theories is the so-called motor programming theory. In this theoretical framework the focus is put on the concept of a central motor pattern (i.e., a patterned motor response generated in the absence of an afferent input). For example, based on experimental findings such as preserved locomotion ability in spinal cats, the hypothesis of a central pattern generator (CPG) in the spinal cord, autonomously generating locomotion (although with sensory input recognized as having important modulatory effects), was formed (c.f. Forssberg & Grillner, 1973; Grillner & Wallen, 1985). The CPG has also been suggested as the neural network behind the production of stepping movements in the human infant (Forssberg, 1985). Even though fundamental neural structures producing complex coordinated behavior in the absence of feedback have been proven evident by numerous experiments, the concept of the CPG as central control of motor action such as locomotion (hardwired inside the organism and more or less independent of other contexts) has been criticized (see below).

**Systems-oriented theories**

Parallel in time to Gesell and McGraw, the Russian neurophysiologist Nicolai Bernstein outlined a theory portraying the body as a mechanical system with mass and joints and
subjected to both external and internal forces. Thus, Bernstein’s system theory takes into account that movements are dependent of situational and environmental factors (e.g., gravity) as well as the neural control of movements. As a result of this constantly changing contextual influence, the same motor command can produce diverse movements as well as different commands produce the same movement. Furthermore, Bernstein did not regard neural motor control as a strict top-down program. Instead he claimed that movement control is distributed and a function of a number of interacting systems working together at different levels within the body mechanical system. Complicating movement coordination and control even more, Bernstein introduced the concept of degrees of freedom (e.g., all body joints can flex, extend or even rotate, causing many independent states for central control to consider in planning and carrying out a movement). Even though Bernstein acknowledged a hierarchical control system, with higher and lower levels, a central executive could never manage to control movement down to each and every muscle by itself. The solution must be that movement control is a shared process and Bernstein suggested that “synergies”, i.e. groups of muscle action units collaborating in effectuating actions of the muscles, existed to help reduce the degrees of freedom and thus simplify for the executive level (Shumway-Cook & Woollacott, 2001; Schmidt & Lee, 1999).

Bernstein’s system theory offers a broader perspective than the other pioneer theories on motor control and has had an important impact on modern thinking in relation to movement coordination and control and its development. An example of a modern theoretical approach inspired by Bernstein’s system theory is the dynamical systems model. In line with Bernstein, dynamical systems theorists discard the thought of actions as hard-wired. Actions are viewed as self-organized, resulting from multiple collaborating subsystems, and patterns of movement vary dynamically with the bodily system and context or task (Ulrich, 1989). For instance, Thelen and collaborators have in a series of experiments investigated early motor development from a dynamical systems perspective (e.g., Thelen, Ridley-Johnson, & Griffin, 1982; Thelen & Fisher, 1983; Thelen, Fisher, & Ridley-Johnson, 1984). In contrast to motor control theories with a more structural approach (i.e., focusing on the underlying programs for behaviors), Thelen et al. employ a functional perspective where the actual performance, including changes in physiological and emotional state of the performer as well as the context of the action, plays a vital part. During development, children’s motor performances get increasingly better, not simply because of neural maturation (as believed by McGraw, see above) but rather as a result of context-tuned control structures progressively becoming integrated with the inborn movement system and thus optimized for action (Thelen, 1985; Thelen, Kelso, & Fogel, 1987). The motor neurophysiologist hypothesis of a CPG controlling locomotion is also discordant with this dynamical systems model. The critique raised by Thelen in relation to the CPG concept is that it effectively overlooks the complexity of postural control and the role of sensory information (Thelen & Smith, 1998). For example, in the dynamical systems perspective an early response such as stepping is not hard-wired to the CNS or the result of a spinal pattern generator gradually coming under cortical control, but an active functional behavior displaying dynamic changes and sensitivity to states of wakefulness. Furthermore, as shown by Thelen and coworkers (1982; 1984) the stepping response does not “disappear” as previously believed, but gets affected by changes in physical growth, body composition and environmental factors. They showed that by facilitating the biodynamical demands the response could actually be restored in infants older than 2-3 months (approximately the age when the response seemingly disappears). Thus, it was concluded that growth-related changes in body segment biodynamic properties can be as important as neural maturation.

Today, the dynamical systems approach to motor control has become widely accepted, at least in a developmental perspective. Brain maturation and concepts such as the CPG are
still regarded as important factors, but integrated in the more holistic framework of the dynamical systems model. For example, Vaal, van Soest, & Hopkins (1995) present an interesting model for the early development of locomotion. In this model, interactions and modulatory feedback loops between different subsystems, including higher centers, a CPG, the musculo-skeletal system and the environment, represent the control and coordination of locomotory movements. During development, changes occur in the dynamical processes at three time-scales; state dynamics (the direct system behavior in real time), parameter dynamics (modulation of the weight of neuronal connections in environmental or task constraint adjustment) and graph dynamics (influential processes in relation to the “system architecture”, e.g. establishment or destruction of connections). Subsequently, changes arise in all levels of the interactional subsystem model (e.g., in the integration of visual, vestibular and proprioceptive information at the higher level and in the growth and differentiation of muscles at the lower level) that will affect the control and coordination of locomotion.

Finally, one further concept that is progressively evolving out of the dynamical systems approach should be mentioned, entitled catastrophe theory. Applying the concepts and methods of dynamical systems, catastrophe theory (in relation to e.g. motor development) aims to explain if changes in development constitute nonlinear, discontinuous phase transitions (viz., corresponding to “catastrophes”). For instance, Wimmers, Savelsbergh, van der Kamp, & Hartelman (1998) replicated the finding of an increase in reaching without grasping to reaching including grasping in 3- to 5-months old infants and could further model this finding within the context of catastrophe theory. They found that this particular development could very well emerge from a discontinuous phase transition, indicating an underlying developmental process of structural modification (as opposed to e.g. McGraw’s view of new behaviors as strictly corresponding to the emergence of new underlying fixed structures).

**Neural setting**

It is well known that the body of the human being is represented at the primary motor and somatosensory cortex by different areas for different parts (e.g., leg and head). These areas also vary in size depending on the amount of precise motor control required for a particular body part (e.g., a large area for lips and tongue in relation to vocalization movements, as compared to a relatively small area for the trunk). The fully developed motor system is best regarded as a network, an ordered system combining hierarchical and parallel models including many shared interconnections. In this network, the cortex is the major route through which other structures can reach the spinal cord. The control of movement involves subcortical structures such as the basal ganglia, the thalamus, the red nucleus and the cerebellum, and the widely distributed sensory input has a monitoring function of the sensory consequences of movement.

The distal musculature is cortically controlled through the lateral system of the spinal cord. Corticofugal fibers are sent from the cortex to brainstem motor nuclei (corticobulbar fibers) and to the dorsolateral interneurons and motor neurons of the spinal cord (corticospinal fibers). Axons from the cortex can project directly, via the lateral corticospinal tract (pyramidal tract), to the interneurons in the lateral part of the intermediate zone and the lateral motor neurons. The lateral corticospinal tract descends on one side of the brain stem, crosses the midline at the medulla and ends on the opposite side of the spinal cord. Projections through the lateral corticospinal tract control distal muscles of importance for precise movements, e.g., movement of the hand. The corticofugal fibers of the ventromedial system terminate bilaterally on medially located inter- and motor
neurons. Projections through the ventral corticospinal tract control proximal movements such as movement of the trunk. The brainstem also makes direct connections to the spinal cord. The rubrospinal tract within the lateral system is involved with limb movement and the reticulospinal-, tectospinal- and vestibulospinal tracts within the ventromedial system with whole-body movement. The structures in the brainstem also receive projections from the sensory systems of the spinal cord and are involved in both producing movements, as well as regulating motor function and sensory input. The thalamus relays information to the cortex, both sensory input to the primary sensory areas and motor behavior information to the motor areas, and is thus central in both sensation and motor control. Thalamus is also involved in two respective loops through the basal ganglia (involved in motor programs and complex motor sequences) and the cerebellum (involved in coordination and motor learning), transmitting information from these structures to the motor cortex (Kandel, Schwartz, & Jessell, 1991; Kolb & Wishaw, 1996).

The final expression of the motor behavior is done by way of the motor neurons of the spinal cord and the muscles. The dendrites of a motoneuron extend over most spinal grey matter, receiving both excitatory and inhibitory inputs (mainly from local interneurons). The motor neurons integrate segmental (reflex), proprio- and supraspinal inputs and project impulses to the muscles to activate or deactivate. At the muscle level, multiple control is needed for postural stability and proximo-distal interactions, as well as co-contraction and fractionation (two basic patterns of muscle usage).

Comparing the nervous system of the human newborn with its fully developed future character, the former could be regarded as more primitive than the latter. This is particularly true for the cortical level. Thus, the CNS is still very much “under construction” at birth and years of maturation remains to be done in close interaction with experiences made in the environment outside the uterus. However, the CNS starts develop already with the formation of the neural tube, approximately 3-4 weeks following conception, and important foundations for the later highly advanced nervous system are progressively built already during the subsequent prenatal period. Of particular interest in relation to the motor system is the neuromuscular development of the fetus. De Vries, Visser, & Prechtl (1984) have by means of ultrasound scanning managed to map the movements of human fetuses at different ages and linked these to changes in the developing neuromuscular system. The first writhing movements of the embryo can be observed at 8 weeks of age, coinciding with the emergence of the spinal cord with motor neurons about to innervate the developing motor system. Increased spontaneous movements at 10 weeks, followed by observations of isolated movements, as well as more general movements of a global character at 11 weeks, appear parallel to the establishment of interconnections between the primary afferent nerves and interneurones of the spinal cord followed by a burst in the number of motor neuron synapses. By 13-15 weeks there is a marked increase in neurons connected to the major body segments and the myelination of nerve fibers also begins. At the same time a range of different, clearly defined movement patterns are observable in the fetus. Taken together this lends to the suggestion that coinciding changes in fetal behavior and CNS formation seem to exist and even that the early movements of the embryo assists the CNS differentiation with important feedback processes. From these and similar studies it is also apparent that early movements most likely are governed by spinal and lower brainstem systems. However, inhibition of activity can also be observed already during later stages of prenatal development and is thought involving higher systems.

Developmental progress generally follows a cephalo-caudal and proximo-distal pattern. For instance, control of the upper-body develops before lower-body and the centre of the body is controlled before more remote parts during motor skill development. Kuypers and colleagues have in a series of studies on the neural structures in rhesus monkeys advanced the knowledge of the motor pathways controlling movement (e.g., Brinkman & Kuypers,
In their work they have concluded that three main pathways, corresponding to the tracts described above, are involved in different types of action. Summarizing these pathways, we have (1) the ventromedial brainstem pathways, that are fibers sent from the motor cortex to both sides of the body, involved in the control of whole-body movement, posture and integrated body-limb movement (e.g., walking), (2) the lateral brainstem pathways, that are cells projecting to the contralateral limbs for individual movements (e.g., kicking with your leg), and (3) the cortico-motor neuronal pathways, containing neurons directly projecting from specific cortical areas (representing the fingers mainly) to the spinal cord and motor neurons serving movements of the digits. The direct corticospinal connections develop gradually over the first 6 months postnatally in rhesus monkeys (Kuypers, 1962). The roles of the corticospinal and corticobulbar tracts (CST, CBT) in the function of the human newborn nervous system are still not fully understood (see Sarnat, 2003, for a review). The fundamentals for these pathways, i.e. when axonal growth cones terminate at their designated destination in the spinal cord and brainstem respectively, are completed around midgestation. However, they are still immature in terms of myelination and axonal sprouting at the time of birth. Even though these features have started develop already prenatally, the CST and CBT are not considered entirely neuroanatomically developed until 2 years of age, following a cephalo-caudal maturational progress. Nonetheless, there are several indications that the CST and CBT are important functional pathways in the neonate by means of inhibition of stretch reflexes at spinal levels, influence on muscle tone and posture, antagonism of the effects of the ventromedial brainstem pathways (i.e., proximal extension and distal flexion), reinforcement of tactile reflexes, early mediating of individual finger movements, and relaying epileptic activity from the cerebral cortex (Sarnat, 2003). Thus, already from the very beginning of life there seem to be at least some functional higher level influence on neonatal behavior. Another indication in support of this is the suggestion that behavioral state, a product of supraspinal regulating centers, can assert a direct influence on the alpha motor neurons in e.g. a less active state of wakefulness inhibiting muscle activity (Casaer, 1979).

Thus, to conclude, in comparison to the knowledge of the adult motor system there is still a lot to learn about the neonatal nervous system in relation to motor control. However, as new techniques for studying newborn infants is developed as well as more angles of approaches are tested, the possibilities of understanding more about fundamental neural mechanisms from the beginning of life are progressively increasing.

Saccharides and newborn motor behavior

One aspect of the newborn nervous system in relation to motor responses can be studied by investigating the link between orogustatory stimulation and newborn motor behavior. A consistent finding is that saccharides have a calming influence and facilitate pain reduction in newborn infants. For example, Blass and Smith (1992) demonstrated that both fructose and sucrose reduced spontaneous crying in 1-to-3 day-old newborns, even at small doses with low concentrations (e.g., 0.2ml/0.34M sucrose). In a subsequent study, involving both fullterm newborns and those born prematurely, they reported that glucose had a calming effect comparable to sucrose, a finding supporting the claim that the taste of sugar evokes changes in central opioid mechanisms during early development (Smith & Blass, 1996). The antinociceptive effects of sweet-tasting substances have also been revealed by studies using the heel stick procedure in screening for the disease phenylketonuria (PKU) as the painful stimulus. For instance, it has been shown that sucrose, especially when accompanied by sucking, not only seem to reduce crying and heart-rate responses to this pain-inducing event, but also the amount of facial grimacing (Blass & Watt, 1999).
In two previous studies the specificity of the effects of saccharides on the movements of newborns has been the focus of interest. According to one, both mouthing and hand-mouth contacting in newborns increased following the oral administration of sucrose relative to that of water (Barr et al., 1999). In another study, the same substance promoted an increase in rhythmical sucking on the fingers for both fullterm and chronically stressed postmature infants, with the former manifesting more mouth openings and arm movements than the latter (Hayes, Smith, Herrick, Roberts, & Swanson, 1997). However, to date there has been no study concerning the effects of one or other saccharide on the movements of the lower limbs made by newborn infants. In Study I a first insight into this particular relation is given. The association between saccharides and newborn motor behavior is in principal unknown territory. Yet it poses an interesting and potentially important area to learn more about in being one entrance to an increased understanding regarding the pathways of the developing nervous system, with prospective consequences for improvements in neonatal care.

Infant motor asymmetries

The origins of studying expressions of laterality in infant motor development can, in resemblance to motor control theory, also be traced back to the first half of the 20th century. For instance, Arnold Gesell, known for his detailed observations of infants and children in order to establish developmental norms, also documented expressions of laterality in young infants (c.f. Gesell, 1940). However, it is not until the last decades that early motor asymmetries have been established as a unique phenomenon and a research area in its own right (Hopkins & Rönnqvist, 1998).

Observations of behavioral lateralization have been done already during the prenatal development from 10 weeks gestational age and onwards (Hepper et al., 1998). For instance, McCartney & Hepper (1999) found significantly more right-arm movements than left-arm movements in a longitudinal study of healthy human fetuses from 12-27 weeks’ gestation. This type of finding in early gestation suggests that lateralized motor behavior are under spinal or muscular control rather than cortical, as well as rather being foregoing later structural brain asymmetries than a consequence of the same (McCartney & Hepper, 1999). Studies of motor lateral asymmetries in newborns cover a wide range of movements. Many of the early expressions of asymmetry studied have also been suggested as developmental precursors of later lateralized functions, especially movements of the upper-body in relation to handedness (e.g., Turkewitz, 1977; Michel & Harkins, 1986). Thus, the trend has turned from regarding lateralized motor behavior as a consequence of cerebral specialization for cognitive functions (language mainly) to rather put the focus at the role of early motor asymmetries in the development of functional cerebral specialization in general (Michel, 1998).

Head turning

In 1947, Gesell and Ames reported the observation of human newborns’ preferential assumption of a right-sided head position when lying supine and with the head released from the body midline, and also related this to the development of right-handedness (Gesell & Ames, 1947). This early finding has continued to attract attention in modern time. The main reason for the common interest in head positioning in newborns is that the propensity for most fullterm newborns to turn their head to the right stands out as the most consistently observed neonatal functional asymmetry (Rönnqvist & Hopkins, 1998;
Where studies of other expressions of motor asymmetries in newborns fail to find consequent lateral biases, the dominant right-sided posture of the head, both in terms of assumption and maintenance, has been repeatedly documented (e.g., Turkewitz, 1977; Hopkins et al., 1987; Liederman, 1987; Grattan et al., 1992; Rönnqvist & Hopkins, 1998; 2000). Some studies have failed to replicate this finding (e.g., Saling, 1979; Trehub, Corter, & Shosenberg, 1983) but, as showed by Rönnqvist and Hopkins (1998), assessment procedure and type of scoring method used can possibly explain for findings of biased direction or not.

The head-orientation preference of newborn infants is commonly regarded as included in the general preferential limb-flexed postural organization within the first 10 postpartum days (Casacr, 1979; Michel, 1983; Jouen, 1992). Neonatal limb flexion has been attributed to supraspinal influence (Peiper, 1963), although perhaps more likely is that it is a result of neuromotor tonus stemming from segmented reflexes partly conditioned by prenatal posture (Michel, 1983). Preferential head orientation has also been theorized resulting from either supraspinal mechanisms (viz., asymmetrically lateralized activation of neuromotor mechanisms at different levels of the brain) or intrauterine position (Michel, 1983). However, as head turning movements from a midline position have been observed already in fetuses (Versers et al., 1994), this would support a view of head orientation preference as neurally governed rather than being the result of intrauterine environment (Michel, 1983). Other explanations include hereditary factors (Liederman & Kinsbourne, 1980) and epigenetic mechanisms (Liederman, 1983; Butterworth & Hopkins, 1993), but there is today a general agreement that newborn head-orientation preference reflects asymmetries in the neonatal nervous system (Rönnqvist & Hopkins, 1998).

In defining head turning, the differentiation between assumption (i.e., turning the head after midline release) and maintenance (i.e., keeping the head in the preferred posture) of head position, as described by Turkewitz (1977), is important to consider as there is a discussion whether they may constitute two separate functional asymmetries with different underlying neural mechanisms or not (Rönnqvist & Hopkins, 1998). Rönnqvist and Hopkins (1998; 2000) have in a series of methodologically advanced studies (i.e., controlling for biomechanical constraints, using both global and specific scoring as well as kinematic measurements) of healthy newborn head position preference, both for assumption and maintenance, managed to find support for a neural origin, probably involving ipsilateral innervation and the muscles of the neck (posterior and sternocleidomastoid). They also found that lateral biases of newborn head positioning was strongly associated with behavioral state in that lateralized preference appear mediated by the state of the newborn (Rönnqvist & Hopkins, 1998; 2000). Behavioral state, or “levels of arousal”, is generally a very important factor to monitor in studies of neonatal movement (Rönnqvist, 1993). Depending on the state of the newborn (ranging from State 1, quiet sleep without REM activity, to State 5, aroused and crying, according to Prechtl’s definition, see Prechtl, 1982), the motor responses vary in e.g. degree and intensity. Behavioral states thus appear to represent qualitatively different conditions of newborn CNS activity, shown for instance in relation to the Moro response (Rönnqvist, 1995). Furthermore, newborn postural behavior and position in space have also been related to state (Casacr, O’Brien, & Prechtl, 1973), also interesting in relation to head positioning (see discussion Rönnqvist & Hopkins, 2000).

Neonatal right-sided head orientation preference has been suggested as related to later right handedness, where the former is thought facilitating the latter (e.g., Michel, 1981; Michel & Harkins, 1986). The rationale behind this association lies in the different visual experiences and neuromotor activity of the respective hand following head orientation possibly having a lasting effect on the cortical mechanisms underlying later hand use.
For example, if the head is oriented preferably to the right in a newborn, she also looks at the right hand and activates the right hand more compared to the left. This, in turn, could result in a better visuomotor coordination and consequent preference in favor of the right hand in e.g. later reaching for objects. However, it should be pointed out that this theory, although both elegantly put forth and interesting, has been challenged and the relation between head orientation and hand-use preference is probably more complex than this. For instance, as there is a sex difference in the strength of lateralized hand-use (viz., females having a stronger right-sided preference than males), newborn girls should consequently display a stronger head orientation preference to the right than boys. Although, the majority of studies of neonatal head orientation preference fails to find such differences (Rönnqvist & Hopkins, 1998).

Stepping and placing responses

In studies of newborn infants’ motor asymmetries in leg movements, stepping and placing are two commonly employed responses. The stepping response is elicited by holding the infant upright under the armpits, lowering her towards a flat surface until the soles of both feet touches the surface and tilting her slightly forwards. The infant will then respond with making alternating steplike movements, characterized by a rapid flexion and a prolonged extension of the leg. Even though it may look like the infant is “walking”, the newborn stepping response is not the same as adult gait (in terms of joint movements and muscle activity, see Forssberg 1985). The placing response is elicited by holding the infant the same way as for stepping but then lifting her so that the dorsum of the feet touches a vertical edge (e.g., the edge of a table). The response of the infant will be a flexion of one leg, moving it forward and finally placing it on the surface. Thus, this response is also similar to a walking step.

The neural substrates behind stepping and placing responses are not fully understood. Although, it is thought that there are different pathways underlying the two respective responses. Stepping has been suggested occurring through stimulating afferent nerves situated at spinal levels S1 and S2 (by way of the footsole among other things) and by efferent discharges from lumbar-sacral segments (Taft & Cohen, 1967). Placing, in contrast, is triggered by stimulation of the dorsum of the foot and has been claimed to derive from supraspinal mechanisms - initially via midbrain structures and then later in development through cortical mediation (Zapella, 1966). However, as placing can be elicited in hydroencephalic infants and newborns with a lesion of the spinal cord, it is more likely that this response also is primarily rooted at a spinal level (Forssberg, 1981).

Although many studies have addressed the issue of neonatal upper-body functional asymmetries as potential precursors for later handedness, only a small number of studies have focused on the predictability of functional asymmetries in stepping and/or placing responses in relation to “footedness”. As a right-sided foot preference is an evident lateralized behavior in humans, as well as being strongly correlated with right handedness (Porac & Coren 1981), further investigation of this relation is justified. The studies that have been made of expressions of asymmetry in stepping and placing responses to date show a lack of consistent evidence for a lateral bias. Two studies have noted a right foot preference for stepping (Peters & Petrie, 1979; Melekian, 1981). Two other studies did not find any lateral bias for stepping (Thelen et al., 1982; Kamptner, Cornwell, Fitzgerald, & Harris, 1985) and one reported no lateral bias for placing (Korczyń, Sage, & Karplus, 1978). Furthermore, in three other studies where both stepping and placing responses in the same newborns were observed, the same discordant pattern appears. A right foot preference for stepping but no preference for placing was found in one (Grattan et al.,
1992), no preferred foot for stepping but a right-foot bias for placing in the second (Cioni & Pellegrinetti, 1982), and a left foot preference for stepping together with a right foot preference for placing in the third (Trehub et al., 1983).

The inconsistency of lateral biases in lower limb responses between these previous studies may partly be explained by differences in methodology and measurement. For instance, the behavioral state of the newborns and the manner by which the responses were elicited differ between the studies (or were not controlled for). In Study II of this thesis, stepping and placing responses of newborn infants are investigated with an effort to refine both the methodology and measurement used. Furthermore, only one previous study has compared lower- and upper-body functional asymmetries (Grattan et al., 1992). Thus, Study II also includes analysis of stepping and placing responses in relation to head turning.

**EMPIRICAL STUDIES**

Even though much have been done in investigating early expressions of laterality in newborn infants’ motor responses, it is still a comparatively young research area and there are a lot of question marks remaining to be straighten out. In the two studies presented in this thesis we wanted to explore the nervous system function in healthy fullterm newborns with regard to motor behavior, concentrating on effects of glucose on lower-body responses (Study I) and asymmetries in the lower-body in relation to head turning (Study II), while at the same time including a focus on effects of methodological factors in this type of research.

**Study I**

As the effects of sweet-tasting substances on newborn upper-body movements have been studied before, introducing a possible link between orogustatory stimulation and sensorimotor systems controlling newborn movements, we also wanted to investigate whether any effects could be found for lower-body movements. Furthermore, as saccharides such as glucose is a part of the handling procedure of newborns (in e.g., screening for PKU), findings of glucose effects on movements could be important to bring forward for methodological considerations when studying newborn motor behavior. Thus, our main objective with Study I was to investigate if the quality with which stepping and placing are expressed differ between fullterm infants who have and have not been fed glucose prior to testing. As glucose also have been suggested as a calming agent for crying newborns, it should have an effect on behavioral state organization during wakefulness. Relevant in this respect is the finding that the intake of a carbohydrate feed with lactose (a milk sugar yielding glucose on hydrolysis) by newborns results in a change from an ‘aroused’ to a ‘non-aroused’ index of state (Oberlander, Barr, Young, & Brian, 1992). If sugar-based solutions on newborn responses are state dependent, qualitatively different responses (e.g., in terms of vigor) may be elicited in glucose-fed infants depending on whether or not they are crying. Alternatively, two crying infants may differ in glucose-fed infants depending on whether or not they are crying. Thus, we also wanted to address the questions if stepping and placing responses differ qualitatively depending on whether the newborn is in an active or a relatively inactive state during testing and, if so, the effects of glucose are mediated by this state. Finally, as Study I also functions as a control in the methodological considerations when studying newborn motor responses in relation to functional asymmetries, we also carried out an analysis of the effect of glucose on the infants’ leg preferences during stepping and placing (not presented in the printed article).
The participants of Study I consisted of a sub-group of the newborns in the second study incorporated in Study II (see below). The context, i.e. location and procedures for eliciting the stepping and placing responses, were also the same as in this study. The design of Study I was a between-group design comparing 12 newborns receiving a small dose of glucose prior to testing of either stepping or placing responses with a control group containing 12 newborns, matched for sex, birthweight and postpartum age, performing the same responses without receiving any glucose. Although non-parametric statistics would perhaps had been the most obvious method for the type of data used, one vital aspect of Study I regards potential interaction between effects of state and glucose. As this is something that non-parametric statistics do not cater for, we choose to use 2 (glucose: yes, no) by 2 (state: active, inactive) ANOVAs as statistical approach. For the analysis of glucose in relation to preferred leg for stepping and placing respectively, a $t$ test for independent samples was used.

Results

The results of Study I indicate (1) that intraoral glucose administration results in a less vigorous stepping response in healthy fullterm newborns in comparison to newborns not receiving glucose, and (2) this effect seems to be independent of the infant’s state of activeness during response elicitation, although state has a separate effect on the quality of the stepping response characterized by an inactive state resulting in a marked reduction in the briskness of the response (see Figure 1).

![Figure 1](image-url)

*Figure 1*. Mean quality rating of the stepping response as a function of glucose and state. Rating scale: 2 = evident response, 1 = weak response and 0 = no response. Standard errors are indicated by vertical bars. Figure reproduced from European Journal of Pediatrics 162 (7-8), p. 546, Springer-Verlag.
Although not significant, a similar result was also obtained for the placing response (viz., the placing response tending to be less pronounced in the group of newborns subjected to glucose administration and when the infant was in an inactive state).

One infant was excluded from the analysis of glucose administration in relation to leg preference during stepping as a leg preference could not be stated for this particular infant due to a lack of a sufficient amount of trials. However, the analysis of the remaining newborns revealed no significant effect for neither stepping (t [9] = .83, p = .43) nor placing (t [10] = -1.20, p = .26).

Discussion

The lack of an interaction between the effects of glucose and state does not lend support to the suggestion that glucose effects are mediated by the newborn being in one state or another with regard to neonatal responses. At least, this possibility does not seem to hold for leg movements during wakefulness. If this is the case, then the influence of endogenous opioids released by the taste of sugars on such responses could be sustained across qualitatively different waking states. Irrespective of such states, intraorally administered sweet-tasting substances could engage newborn movements in contrasting ways depending on whether they are elicited or form part of the spontaneous repertoire. This sort of differential effect is posited on the basis of glucose 'dampening' the expression of the stepping response as we found compared to the facilitation of spontaneous and related manual movements by sucrose as reported previously (e.g., Barr et al., 1999; Rochat, Blass, & Hoffmeyer, 1988). Such speculation is hampered by a lack of insight into the neuropharmacological mechanisms that determine how saccharides can modulate the output of the developing motor system and whether such modulation affects the neural systems controlling the upper and lower limbs in newborns differently. One possibility is that sugars such as glucose exert an enervating influence on alpha-gamma coactivation - an essential component in the generation of active muscle power (Murphy & Martin, 1993) - via the imposition of a presynaptic inhibitory influence on muscle spindles.

The reason for stepping being more susceptible to glucose effects than placing possibly can be explained by differences in sensory pathways and underlying neural mechanisms of the two responses. In placing, the response is triggered by stimulation of the dorsum of the foot whereas stepping is augmented by the activation of sensory afferents of the footsole, among other things. Furthermore, as the generation of stepping has been associated with spinal mechanisms (e.g., Peiper, 1963) while placing has been claimed to derive from supraspinal mechanisms (e.g., Zappella, 1966), it might be that glucose and associated saccharides selectively diminish the responsiveness of spinal mechanisms concerned with the generation of stepping movements.

In addition, an interpretation of the finding of no glucose effects on expressions of laterality could be that there are separate neural mechanisms for the leg responses per se and expressions of functional asymmetries in them. As the participants of Study I are included in Study II this result was also important for increasing the validity of the results in the latter study.

Study II

As described above, a large number of studies have confirmed the finding of a right-sided preference for head positioning in human newborns but much fewer studies have been
devoted to investigating functional asymmetries in the lower limbs and also with a lack of consistent findings. Thus, little is known of whether expressions of neonatal functional asymmetries share the same lateral biases across different parts of the body. As far as we know, only one study has previously addressed this question. Grattan and collaborators (1992) studied the directional biases in upper- and lower-body movements in a sample of 36 full term newborns, not finding a clear-cut association for any of the expressed asymmetries. Accordingly, they concluded that evident functional asymmetries in the upper- and lower-body of the newborn are governed by different neural subsystems rather than a single system for lateralization. Furthermore, Grattan et al. did not find a concordance between lateral biases in stepping and placing (in terms of the first foot moved), in line with previous research in relation to asymmetries in these particular responses (see above). Thus, it may be that the underlying neural mechanisms for stepping and placing are different as well.

In order to further investigate these issues, Study II is dedicated to neonatal functional movement asymmetries in the upper body (head turning preference) and lower body (first foot moved in stepping and placing) in terms of concordance. Furthermore, as one plausible explanation for the lack of consistency in studies of newborn functional asymmetries (head positioning possibly excepted) is differences in methodologies used, an emphasis is put on the need to consider factors that may have a bearing on whether definite functional asymmetries are found. To date, this type of refinement has not figured to an adequate extent in the relevant studies. One such factor is considered in Study I (see above). In Study II we included an enhanced control of variables that could possibly affect expressions of laterality in the responses studied. Apart from carefully reassuring that the stepping, placing and head turning were elicited in an unbiased manner, we also controlled for the infants behavioral state and leg mass. Furthermore, latency time for newborn stepping and placing responses was introduced as an alternative measurement variable to frequency. This type of measurement has figured in one previous study (Grattan et al., 1992), though the scoring method they used was rather rudimentary compared to the one used in Study II (viz., frame-by-frame video analysis).

The participants of Study II consisted of 43 healthy fullterm newborns (20 females and 23 males), of 37-42 weeks gestational age and tested at the postpartum age of 48-96 hours. The testing for head turning, stepping and placing (three subsequent trials for each response) took place in a warm, quiet and dimly-lit room. Additional care was taken to optimize clear-cut observations by using e.g. a surrounding screen blocking unwanted sources of lateral stimulation, a non-slip cloth for the stepping surface, a specially-made placing bar and head turning screen. Furthermore, in order to control for behavioral state and leg mass being associated with expressed asymmetries, we also monitored the infants’ state during testing and conducted anthropometric measurements for calculation of the volume of the respective leg of each newborn. Elicitation of the responses were done according to the standard procedure for each response (as described above), with care taken to avoid confounding of expressed asymmetries (e.g., no diapers, postural support during head turning, both feet touching surface or bar at the same time).

During each testing session, preference in first foot moved and head turning direction was noted. All sessions were video recorded, allowing later verification of these “on-line” notations as well as coding for behavioral state and latency times of the stepping and placing responses. Chi-square analysis was used for preferences in head turning, stepping and placing frequencies and their interrelations. Two way ANOVAs and t tests were employed for the parameters tested in relation to foot preference. For the analysis of behavioral state, state was used as a between-subject factor (with repeated measures for side) as recordings of each newborn in both an active (state 4-5 according to Prechtl, 1982) and
an inactive state (state 3, according to Prechtl, 1982) for all responses could not be obtained.

Results

A majority of the newborns in Study II showed a rightward bias for head turning (60.5% right, 39.5% left), though this difference did not reach significance (see Table 1). The newborns also showed a slight right-sided preference for stepping and a minor left preference for placing (Table 1). However, none of these biases proved to be significant. Furthermore, the newborns displayed wide intra- and inter-individual variability in relation to preferred direction and first foot moved during head turning, stepping and placing. Thus, no significant associations could be found between any of the three respective responses studied.

Table 1
Group data for side preference (stepping, placing and head turns) and onset latency (stepping and placing). Abbreviations: N = number, s = seconds, R = right, L = left, No = excluded infants, SD = standard deviation

<table>
<thead>
<tr>
<th>Variable</th>
<th>Preference (N)</th>
<th>Latency (s)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>L</td>
<td>No</td>
</tr>
<tr>
<td>Stepping</td>
<td>23</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Placing</td>
<td>19</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Head turn</td>
<td>26</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Stepping R</td>
<td>1.85 (1.38)</td>
<td>0.66 - 3.95</td>
</tr>
<tr>
<td></td>
<td>Stepping L</td>
<td>1.18 (1.32)*</td>
<td>0.14 - 3.58</td>
</tr>
<tr>
<td></td>
<td>Placing R</td>
<td>1.04 (1.32)</td>
<td>0.04 - 2.69</td>
</tr>
<tr>
<td></td>
<td>Placing L</td>
<td>0.45 (0.62)*</td>
<td>0.04 - 1.47</td>
</tr>
</tbody>
</table>

* = p < .05.

However, as also shown in Table 1, significant effects could be found in relation to latency times of the onset foot during stepping and placing. These effects are characterized by a shorter onset latency for the response trials when infants started with the left foot. As judged by a significant correlation between the onset latencies for stepping and placing, this pattern is also occurring similarly within newborns. Furthermore, in an overall comparison onset latency for placing are significantly shorter than for stepping (Table 1).

Behavioral state did not account for any effect on side preferences in terms of head turning direction or first foot moved during stepping and placing. However, a significant main effect of state on latency time for stepping was found (in that an active state was related to a shorter onset latency), though a similar significant state effect could not be found for placing onset latency.
No effects of differences in volume between the right and the left leg on preferred foot or latency time for either stepping or placing could be found.

Discussion

Although not significant, the relation between expressed right-left biases in head position assumption in our study approximates a 2:1 ratio that has been found in similar studies (Rönnqvist, Hopkins, van Emmerik, & de Groot, 1998; Rönnqvist & Hopkins, 2000). The present finding of no consistent bias for either stepping or placing in terms of first foot moved is not in line with previous studies as all of these have reported a lateral bias for at least one of the two responses. This might be a reflection of the differences in methodologies used and that a more conservative methodology may result in difficulties in observing lateral biases in terms of frequency. However, the lack of concordances found is in line with previous studies and also in support of Grattan and collaborators’ (1992) theory that the control of asymmetries in movements of different body parts is mediated by multiple subsystems rather than a single lateralized system.

Perhaps the most intriguing finding of Study II is the bias in latency times between left and right foot during stepping and placing. A corresponding finding in the upper-body of the newborn has been made in terms of a shorter onset latency of right arm extension during evoked Moro response (Rönnqvist, 1995). This arm latency bias has further been linked to a right-sided head preference (Rönnqvist et al., 1998). Put together these respective findings offer an interesting relation to the asymmetric tonic neck response (ATNR) and thus suggest an early crossed lateralized upper-lower body extension-flexion synergism in the newborn. Relating the finding of a shorter latency time for the leading left foot to the present knowledge of the functional pathways in the neonate (as described above) also allows an interpretation in terms of possible different stages of myelination of the pathways to the left and right leg to be made. The majority of axons of the CST are primarily involved in inhibition of the motor neurons of the spinal cord. Thus, a sign of developmental progress is when e.g. the stretch reflex gets gradually more inhibited as a consequence of increased myelination and sprouting of terminal axonal ramifications (Sarnat, 2003). In a study focusing on infant hand preference in relation to unilateral and bilateral reaching, this feature has been discussed in terms of one side being inhibited in order to facilitate activation of the other, indicating a more advanced stage of one side compared to the other (Hopkins & Rönnqvist, 2002). According to the findings of Study II, this might also be reflected in lower limb movements in terms of an inhibited right limb facilitating the short latency of the left limb (i.e., a more advanced developmental stage of the right leg).

Finally, the findings of differences in state effects and latency times between stepping and placing are also interesting in relation to the discussion of neural pathways mediating the respective responses. Behavioral state having and effect on stepping latency but not placing latency suggests an influence of supraspinal levels on the stepping response, in contrast to the view on stepping as being exclusively spinally mediated. Quite the reverse, placing, suggested deriving from supraspinal mechanisms, had a significantly shorter onset latency than stepping and was unaffected by behavioral state, indicating a predominant spinal mediation. However, it should be noted that the differences in latency time also could be explained by dissimilarities in the receptors involved (foot sole stimulation for stepping elicitation vs. dorsum of foot for placing) and greater mechanical delay time for stepping compared to placing.
CONCLUSIONS

The aim of this thesis was two-fold. Firstly to investigate if glucose has effects on newborn stepping and placing responses, as well as expressions of laterality in these responses, and secondly to explore if functional asymmetries in the newborn upper- and lower-body seem to stem from the same neural system or from different sub-systems.

In Study I, glucose as well as an inactive state could be associated with less pronounced stepping and eliciting difficulties of the same response. A similar, though not significant, pattern could also be found for placing. Despite the relatively small number of infants participating in Study I, as well as the lack of baseline measures prior to glucose administration enabling within-subject comparisons, the main findings stand out as both novel and interesting in relation to glucose effects on newborn leg movements. Hopefully the study will encourage continued and more thorough exploration of glucose effects on newborn motor activity, adding to the understanding of the developing sensorimotor systems. Furthermore, the results also point to the fact that it may be important to control for administration of glucose or other sweet-tasting substances when studying newborn motor behavior. Not including this methodological consideration could lead to inappropriate judgments about the functional integrity of the newborns’ nervous systems. Within the framework of this thesis, a particular methodological concern was whether glucose had an effect on expressions of laterality in stepping and placing responses or not. However, as judged by the results of Study I, functional asymmetries in the studied responses remained unaffected by glucose.

In Study II, no evident overall head positioning bias could be found. However, a 60% bias to the right, corresponding to findings of previous studies of laterality in newborn head positioning (Rönnqvist et al., 1998; Rönnqvist & Hopkins, 2000), was observed. Moreover, no lateral biases in relation to the first foot moved in newborn stepping and placing responses could be found, and there was no concordance between displayed asymmetries in stepping, placing and head turning. However, a lateral bias in terms of shorter onset latency of the left foot in elicitation of both the stepping and placing response, possibly reflecting differences in stages of myelination of the pathways to the left and right leg, was found. Leg mass was found not related to either asymmetries in leg responses or onset latency. As judged by these findings, expressions of lateral biases in newborn upper- and lower-body functional asymmetries are difficult to find in terms of scoring frequency of head positioning and first foot moved, but rather can be found in more subtle parameters such as onset latency. Furthermore, the findings lend support to upper- and lower-body motor asymmetries being controlled by multiple neural subsystems, in line with Grattan et al. (1992).

Thus, in order to obtain as straightforward results as possible, a coherent methodology and the use of more refined measurements might be worthwhile to strive for in future studies of newborn functional asymmetries. Our ongoing research involves analysis of kinematic parameters in relation to newborn stepping and placing responses, likely to add to the knowledge of lateral biases in leg movements. Apart from the theoretical interest in learning more of the developing sensory and motor pathways in relation to newborn functional asymmetries in the lower-body, this type of knowledge may also be of clinical use. In this latter perspective, a brain lesion such as periventricular leukomalacia (PVL) could be mentioned in particular. PVL is a cerebral white matter damage considered to be a strong predictor of cerebral palsy (CP), especially spastic diplegia. One hypothesis about how PVL relates to spastic diplegia is that the lesion, usually bilateral, damages the medial fibres, thus affecting the pathways from the motor cortex to the lower extremities (Hopkins, 2002). A better understanding of lower body functional asymmetries and their
neural origins in the healthy newborn could prove to be of great clinical value in the early diagnosis and treatment of this developmental disorder.

REFERENCES


