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Adapted Physical Activity in Promoting Infant Motor Development

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Abstract—The acquisition of motor skills involves the infant's exploration of many possible body segment configurations in its environment and, then, the selection of those that are the most useful. This view of development implies that sensory information, the result of an action performed, is used to achieve or maintain the subsequent performance. When this flow of sensory information is changed, motor skill acquisition is limited, and the course of motor development is disrupted. Given that infants and children with disabilities show delays in motor milestone acquisition, it could be suggested that such delays are related to perception-action changes. Therefore, adapted physical activity would be important in minimizing such deficits by presenting special opportunities in which perception-action cycles are promoted and reinforced.

Key Words: Development, motor development, Down syndrome.

Motor development in infants and children is characterized by two aspects, order and regularity. These two features were crucial in providing the pioneers of this field with a means of suggesting that motor development had to be determined by intrinsic factors: that is, maturation (Gesell, 1933). In this view, acquisition and improvement in motor skills were due to genetic processes present in all humans.

No doubt that these early efforts were important to the start and definition of many studies conducted during the last century. Indeed, the pioneer workers did their jobs so well that for quite some time motor development studies were oriented by such principles; and even today many still are.

As a consequence, the motor development field underwent a moribund period (Clark & Whitall, 1989), in which it seemed that everything had been uncovered. Maturation was the explanation for most motor development questions and queries.

However, this approach began to come under scrutiny when Bernstein (1967) and Gibson (1979) questioned many of the maturation principles, leading to other views of motor development. The early work done by Thelen (Thelen, 1986, 1989b) was crucial in providing a better, more organized understanding of motor development—one that was based upon dynamical principles (Thelen, 1995, 2000; Thelen & Smith, 1994).

Motor development: a dynamical view

Motor development is characterized by changes that evolve over the lifespan. Despite showing regularity and order, these changes, might be understood as a *dynamical* process. In this case, developmental changes need to be understood as *successive stable and unstable states and phase shifts that move the system from one attractive state to another* (Thelen, 1989a, 1989b).

Although such a dynamical view of motor development is provocative, it needs to explain two main questions that have been present since the early work in the field: a) where does movement come from?; and b) what produces change in development? I would like to argue that the answers to these questions might be sought through a dynamical view of motor development. However, we need to dispose of many of our previous concepts and be willing to accept a rather radical way of looking at these phenomena.

Birthday kit

Due to the evolutionary process, nature provides us at birth with a basic motor repertoire which allows us to initiate our behaviors. Actually, even before being born, babies can already perform several movements, despite all of the constraints related to the environment in which they are located, the womb. After being born, motor manifestations are intensified and many other motor actions become possible. However, these movements have been characterized as involuntary, spontaneous, and reflexive (Clark, 1994), and many have not paid much attention to their importance.

I would like to suggest that these movements are the foundations for our motor repertoire, which will be built over the lifespan. These early motor actions are quite different from reflexes and can be modulated quickly after their first occurrences. These spontaneous, or reflexive, movements might be initiated by environmental stimuli; however, the responses are not stereotypical, and, in many cases, infants control them voluntarily.

The primary function of these early motor manifestations is related to survival of the infant (Clark, 1994). A good example of this function is the sucking reflex that makes it possible for infants to suck just after being born. However, after the first sucking experiences, infants are able to control this action quite well, changing the strength and frequency of the movement.

Besides this initial survival role, these reflexive movements also have another important function in the infant's early development: they provide the possibility for infants to start a dialog with the environment (Clark, 1994). Reflexive and spontaneous movements lead the infants to produce their first motor manifestations and to acquire the sensory consequences due to these movements. Therefore, infants are able to start to learn what they can perform in this new world, and also what the sensory consequences of their actions are. In doing so, they start to map the relationship between action and perception and start to learn not only about what they can do, but what they can do within this new environment and its many constraints such as gravitational force, contact with surfaces, object properties, etc. Based upon these sensory consequences, some performed actions are repeated, while others are avoided and new ones are discovered. As a consequence of this dialog between the infant and her or his surrounding environment—one that is based upon repetitive cycles of action and perception—the motor repertoire of each infant starts to be built.

Assuming that reflexive and spontaneous movements are changed and modified based upon sensory and motor experiences, the answer to one of the basic questions in motor development might be that the motor repertoire originates from the basic motor patterns that we are born with. That is, the central nervous system provides a set of possible motor patterns, a "birthday kit," which is mastered along with the environmental conditions surrounding infants after they are born. Therefore, our motor repertoire is built in such a way that it is delimited by the organism as well by environmental constraints, and, therefore, adapts to local conditions. Further motor acquisitions would follow the same principles along the lifespan.

Development: multi-causal and exploration-selection principle

One assumption of the dynamical view of motor development is that motor behavior and, specifically, developmental changes are due to several factors (Thelen, 1986), denominated constraints (Newell, 1986). This multi-causal view of motor development is based upon the idea that humans are complex systems, composed of and influenced by many factors (Barela, 2001; Thelen, 1986): relating to the organism (emotional, psychological, motivational, etc.), to the environment, and to the task.

This explanation can then provide an answer to the other basic question regarding motor development: that is, what does promote changes? The answer is: changes in the constraints that come from the organism, from the environment, or from the task (Clark, 1994)? Therefore, genetic hereditary—specifically, the gene—is not the predictor for the acquisition of new motor skills, as the maturational view suggests. Maturation of the nervous system, in this case, is viewed as one factor (constraint), a very important one. However, it is not the only one in the acquisition of motor skills for our repertoire.

When applying this multi-causal view of motor development, we still need to understand how the many elements of the system integrate and contribute, each to the other, so that new motor skills emerge. Thelen (1995) suggested that two principles underlie this process: *exploration* and *selection*.

The principle of exploration involves the discovery of both *the how* and *the what* a specific motor task requires in order to be performed. In this case, the configuration of the body segments in their environmental context needs to be identified. For instance, during the acquisition of independent walking, an infant needs to figure out the body orientation necessary to maintain its trunk vertically aligned and balanced over an unstable basis of support. The problem that the infant must solve is how to perform something that it has never performed before. In this case, the infant will *explore* many possibilities of muscle activation and body positioning, and then *select* one (or ones) that best satisfy the requirements for maintaining an upright position while stepping. Therefore, this is a problem to explore: How does the organism in the environment (the infant) select the best task solution to achieve its behavioral goal (independent walking)?

In the case of acquisition of independent walking, the infant's first attempts are characterized by many difficulties, inconsistencies, falls, and the absence of the refined control of movements. However, after just a few frustrated trials—but crucial ones, infants master the coordination and control of their many body segments, and start to perform the task of walking. Additionally, with the practice of this new skill, it becomes consistent, stable, and can be performed with proficiency. Therefore, the acquisition of a new motor skill might be understood as a two-stage process: the acquisition of the new body configuration required by the task, and the refinement of the movements of the newly-acquired actions (Thelen, 1995).

A very important aspect that involves these exploration and selection principles, and, therefore, the acquisition and refinement of the newly-acquired motor skills, is that they are based upon repetitions of the task, which will provide correspondent cycles of perception-action. The infant explores a specific configuration of muscle activation and the result of this tentative effort will then be acquired through the sensory consequences of the action. The knowledge of whether or not the goal was achieved—the efficiency of the action, is available to the infant through his or her perception: through the relationship between action and the sensory consequences of this action. Figure 1 depicts a representation of interaction between the organism, the environment, and the task constraints while a motor skill is performed, and their relationship to perception-action.

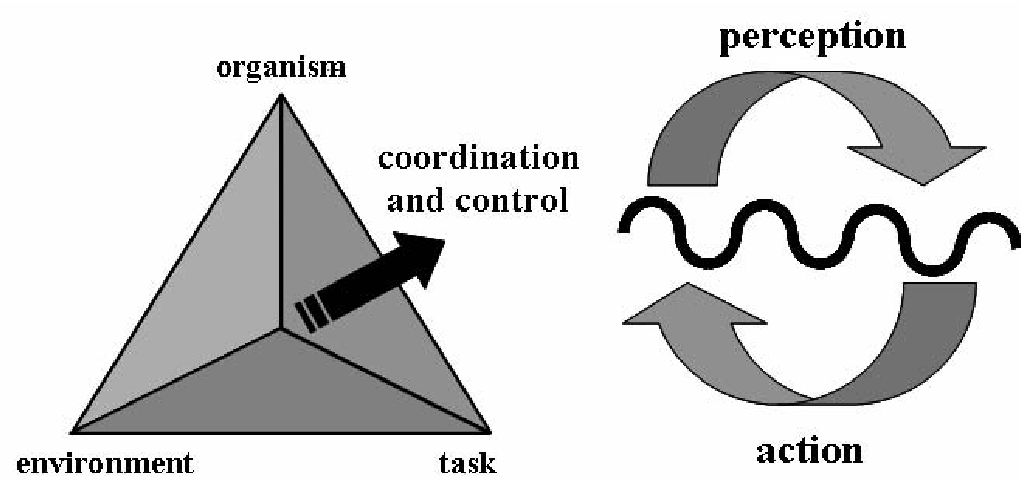

Figure 1. Schematic representation of the three sources of constraints that are involved in the emergence of a motor action (adapted from Newell, 1986) and the perception-action cycle, the result of relationships and interactions among all constraints.

Motor development epigenetic

If, indeed, several factors contribute to the course and rate of development, and if this process occurs as the result of infants' and children's explorations of the environment in which they are inserted, then this implies that all of the movements in our repertoire are learned. Of course, the exceptions are those movements that we are born with and constitute our "birthday kit." Therefore, it seems, we need to re-classify the phylogenic and ontogenetic motor skills. In this case, I would classify as phylogenic those belonging to our "birthday kit," and all the others as ontogenetic, because they are acquired by infants and children through their interactions with the environment.

A second implication of such a view of motor development is that motor skills in the repertoire are learned by *active* persons (infant, child, adult, and older adult). In other words, the individual is the one that governs the course and the rate of his or her development. Again, the acquisition and refinement of a motor skill involve exploration and selection of a specific body configuration out of many other possibilities. Therefore, changes depend on how the person is willing to progress on his or her own course. As previously mentioned, motivation is the propulsion, and the task is the reason for changes toward the acquisition and refinement of motor skills (Thelen, 1995; 2000). Let us picture an infant standing upright and holding onto a coffee table. She is not yet walking independently, but is willing to cross the dining room to get a toy. The motivation to get the toy is what makes this infant to want to perform his or her first steps in order to cross the dining room. The task of crossing the dinning room, which involves a specific organization of body segments and many other controlling requirements—walking independently, is the reason that these new body configurations and controlling mechanisms are acquired.

With regard to this intricate relationship between the developing infant (as with any other person) and the environment in which she or he is surrounded, coherent and useful *sensory information* constitutes the fuel that pushes developmental changes as infants learn how to use their bodies in this physical and social world in which they belong (Thelen, 1995; 2000). Therefore, the dynamic process of exploration and selection is based upon the ability of the developing infant to promote behaviors that will provide her or him with a wide variety of perceptual and motor experiences. Thus, this infant will acquire those actions that will lead her or him to build up her or his motor repertoire in order to show functional behavior within the environment (Barela, 2001).

Motor development: dynamic view in special populations

Remarkably, infants and children with disabilities show a delayed acquisition of motor skills when compared to their neurologically normal (NN) peers, even though usually the same developmental sequence is observed. For example, Down syndrome (DS) infants master independent sitting around the ninth month, whereas NN peers sit independently around the seventh month of age. Regarding independent walking, DS children acquire it around the seventeenth month, and NN peers around the twelfth month of age (Schwartzman, 1999). Yet, in children with cerebral palsy, depending on the commitment of the child, the acquisition of independent walking occurs only around the twenty-fourth month of age (Sherrill, 1998).

According to the maturational view of motor development, such delays in the acquisition of motor milestones should be attributed to changes in the nervous system, prohibiting the production and controlling of appropriate muscle activity necessary for movement execution. Although one can not deny the important role that the nervous system plays in the developmental course and its consequences when the nervous system is changed due to a trauma, paralysis, or anomaly, it is necessary to better understand how such insult to the central nervous system affects the developmental process regarding special populations.

In this case, I would like to suggest that the principles underlying the development of infants and children with special needs are the same as those that underlie the development of NN infants and children. Recently, using a program based upon motorized treadmill, Ulrich, Ulrich, Angulo-Kinzler, and Yun (2001) showed that appropriate intervention anticipates independent walking acquisition in DS children. Specifically, those children enrolled in the motorized treadmill training started to walk independently three-and-a-half months before those children who were not enrolled in such an intervention. Based upon these results, the supremacy of any component such as nervous system maturation and, also, the role of experience (intervention) in the developmental course of infants and children with special needs must be reviewed.

Infants and children with special needs definitely have different organismic constraints that lead to a different relationship among all other constraints (environmental and task) in order for a specific movement to be produced. As a result, the perception-action cycle is also compromised and, therefore, the developing infant would experience differences in the process of exploring her or his potential for motor action in the environment, and would have different sensory information. Actually, this lack of "dialogue" with the environment is compromised when *any* system in the infant is insulted (nervous, motor, perceptive, etc.), and the impact of this insult in the developmental course and rate depends on the degree of such an insult.

Infants with some insults also might start out with a different basic-level "birthday kit" than NN infants. Therefore, the resources that they have available from the beginning might be different. Again, in this case, the dialogue between the infant and the environment, crucial to learning about what she or he can do and the consequences of these actions, would be compromised. Finally, the dynamical view implies active participation by the developing infant (motivation, experiencing different situations, etc.) and, consequently, mental retardation would compromise even more an already reduced ability for the exploration of the surrounding world.

Considering that infants and children with disabilities might have difficulties interacting with the environment, the role of adapted physical activity is critical in *promoting* and *expanding* their possibilities and varieties of motor and sensory experiences. Therefore, adapted physical activity must promote conditions for infants and children with disabilities so that they may develop and demonstrate functional behaviors relative to their environments. In this case, adapted physical activity could have, among other roles, that of promoting opportunities for infants with disabilities to produce motor actions and gain the sensorial consequences that they would not have by themselves.

Perception-action in DS children

We have used the moving room paradigm to examine how sensory information is related to motor action in DS children (Polastri, 2002; Polastri & Barela, 2002; 2005). In this situation, the walls and the ceiling of a room are moved back and forward, which produces corresponding body oscillations (Lee & Lishman, 1975). As with NN infants (Barela, Godoi, Freitas Junior, & Polastri, 2000), DS children with different sitting experience (novice and experienced) coupled to the visual information provided by movement of the room, and displayed corresponding trunk sway when seated inside of the room.

Although visual manipulation induced trunk sway in all DS infants, the strength of sensory and motor coupling was experience-dependent. Infants that had more sitting experience coupled more strongly to the visual information than did the less experienced ones (Polastri & Barela, 2005). Therefore, experience in performing a specific motor skill involves different coupling strengths between sensory information and motor activity in DS infants.

Polastri and Barela (2005) observed that, in general, DS infants not only can couple to sensory information, but also that this coupling was similar to that which was observed in a NN population (Barela, Godoi, Freitas Junior, & Polastri, 2000). However, the coupling between sensory information and body sway in DS infants is dependent to the degree that these infants have experienced performing a specific task. Therefore, practice seems to be a determinant factor for the acquisition and refinement of a coherent and stable relationship between sensory information and motor action in DS individuals.

We also examined the effects of systematic and specific experience in the motor sensory coupling in infants with DS. The DS infants were brought to the laboratory for seven consecutive days and were submitted, each day, to a 10-minute session of the moving room. The results indicated that even after their prolonged exposure to the moving room, the movement of the room continued to induce trunk sway. Similar results were observed for NN seven-month-old infants who were exposed to the same experimental protocol (Barela, Júnior, Godoi, & Polastri, 2001). More important, however, was that the practice effects were also experience-dependent for sensory motor coupling in DS infants. The coupling between visual information and trunk sway decreased for DS infants with more experience in sitting, whereas it increased for less experienced infants. The results observed for the more experienced DS infants were similar to those observed for NN seven-month-old infants (Barela, Júnior, Godoi, & Polastri, 2001), whose experience in sitting was a duration of about one-and-a-half months.

The decrease in strength of the coupling between visual information and trunk sway after a period of exposure to this situation might be due to the fact that the moving room produces an illusory situation, which conflicts with the information that comes from other systems (vestibular and somatosensory) that the infants seem to be able to resolve. The visual information provided erroneous information about body sway that, with prolonged exposure, experienced DS sitters were capable of resolving, decreasing the visual information's influence on trunk sway. This was possible because coherent mapping between sensory information and body sway had already occurred in these infants.

On the other hand, novice DS sitters still explored their actions in the newly acquired position and had a less stable relationship between visual information and trunk sway. When exposed to the moving room even after some time, these infants were not capable of resolving the conflicting sensory cues and properly discriminating between the details of the situation. Yet, because the coupling between visual information and body sway was weak, exposure to the moving room produced a strengthening of this coupling.

Taking these combined results into consideration, two aspects are notable. First, experience plays an important role in developing the coupling between sensory information and motor activity in individuals with DS. Moreover, experience, especially that provided by adapted physical activity, constitutes a unique opportunity to promote sensory-motor mapping through the identification of coherent coupling between relevant sensory information and motor activity, and, consequently, the acquisition of new motor skills. Second, experience is also crucial for the refining of already acquired motor skills. In this case, experience strengthens the sensory-motor coupling, making it more stable.

If the coupling between sensory information and motor action in DS infants and children is similar to that of NN youngsters, what, then, is the cause of their developmental delays? One possible reason could be that infants and children with DS have difficulties in exploring their motor capabilities, and, therefore, they acquire fewer sensory consequences that are related to their movements. In such a case, infants and children with DS would require a longer time to map the sensory-motor relationships.

In general, individuals in special populations have reduced motor repertoires that can be characterized as stereotypical and with rigidity of movements (Schwartzman, 1999; Sherrill, 1998). These characteristics can prevent infants and children from fully interacting with the environment, and, therefore, they might explore less and learn less about their motor and sensorial possibilities. Their opportunities for experiencing repetitive cycles of perception-action could be, depending on the case, severely compromised. Moreover, remember that the developmental course is a result of active interaction between the infant with its environment, and, in this case, if the infant is less active, the development would also be delayed.

With this view, intervention assumes a decisive role in promoting new motor and sensory experiences, and becomes a crucial instrument in order to minimize and compensate for such difficulties. Intervention would fill the gap due to the absence of the infant's own explorations of her or his movements. Intervention would aim to promote opportunities for the practice of movements and skills that should be incorporated into the infant's motor and sensory repertoire, through repetitive cycles of perception-action. Infants and children with special needs have to be exposed to a rich environment, with opportunities for motor and sensory activities in which they can explore new motor and sensory possibilities through a variety of different tasks. However, because they have difficulties in exploring this environment, the role that parents, teachers, instructors, and other professionals have, in addition to providing them with such an environment, is also to help them explore and interact with it as much as possible. This can be done by encouraging, motivating, and showing them the importance of doing some activity.

Also, another important role is providing resources that will change and minimize some of the environmental and task constraints that prevent infants and children with disabilities from performing and acquiring specific skills. Our main role is to help them move and discern what information from this movement is most useful for the next performance. In other words, our task is to let them figure out for themselves how to achieve coherent and stable coupling between sensory information and motor activity.

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