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The Effect of Task and Environment Constraints on Aquatic Locomotor Behavior: Qualitative Data Analysis

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Abstract

Many constraints (environmental, organismic, and task) act on all patterns of motor coordination, although their effects on swimming is less well understood. To this end, we carried out the current study with fifty-six participants, ages ranging from six to twelve years. The experimental tasks were created from the original task in which changes in task speed and environmental context were manipulated. Four aspects in the results were notable: a) a main trend was one of performance with the same developmental status among the tasks; b) when behaviour changed, this occurred due to environmental constraints, leading to more rudimentary patterns of locomotion; c) the developmental status presented initially was associated with greater adaptative capacity in the task combining change in direction and speed; in this case participants with more advanced developmental status presented changes in sequencing as well as parameters; and d) when only speed was increased, changes were restricted to the parameters.

Keywords: swimming, constraints, person-task constraints, person-environmental constraints, aquatic developmental sequences, task, environment

Locomotion is essential for any organism to explore its environmental niche and to find the resources necessary for its maintenance and reproduction. Apart from this biological meaning, motor activity is of great evolutionary interest; from it, one can mark important transitions in the history of the human species (Leakey & Lewin, 1981). Therefore, it is not by chance that mobility has been the subject of many studies on different themes. For example, the fields of biomechanics, motor control, and motor development all have explored a wide range of locomotor topics. In the latter, the fascination that mobility holds for researchers translates into studies on the emergence and acquisition of bipedal gait patterns during early childhood (McGraw, 1935; 1939; 1945; Zelazo, et al,.1972; Zelazo, 1982; Thelen, 1986; Bril & Brenière, 1993; Adolph et al.; 1997; Adolph et al., 2003). In all these studies "locomotion" always referred to movement across a terrestrial surface. The development of aquatic locomotion has received less attention from motor development researchers.

Two classic works mention swimming behavior, both performed in the first half of the 20th century. The first account comes from an experiment conducted by Watson (1919) who evaluated babies in the liquid medium to verify the existence of an innate component for adaptation and mobility. Watson, it is worth remembering, was a pioneer in behaviorism and at that time was interested in identifying which behaviors were innate and which were the subject of environmental conditioning. In his experience, Watson reported that the babies showed aversive behavior to water without any organized or standardized response that denoted an inborn pattern. Watson concluded that swimming was a learned skill and therefore only able to be acquired through experience such as a result of teaching.

The second classic study came as a counterpoint to Watson's study. Myrtle McGraw (1935; 1939; 1945), the researcher then known for investigating the development/maturation of babies, studied their behavior in the liquid (water) medium. McGraw (1939) conducted a series of studies in animals and babies, placing them in the liquid medium and, unlike Watson, found well-organized swimming behavior in animals (small mammals such as mice, non-human primates) and human babies of various ages. McGraw (1939) observed responses in babies with ages ranging from weeks after parturition to more than one year of age. From a cross-sectional study, McGraw (1939) suggested that there was a developmental sequence for swimming with three steps: I. Phase reflexive swimming, from birth until the fourth month of age, which would be characterized by characteristic displacement movements in the liquid medium made by flexion and extension of the limbs in the sagittal plane, with symmetrical movements of arms and legs accompanied by respiratory control. The baby could move in the liquid medium for two to four meters; II. Phase of disorganized movements, after the fourth month until the end of the first year and characterized by gradual loss of the motor coordination shown in the previous stage, with the result that the baby no longer moved by these means; and III. Phase of voluntary swimming, after the first year of life, characterized by the gradual acquisition of displacement behavior in water with asymmetrical movement of the arms and legs being highly dependent on external support. McGraw suggested that this sequence was managed through changes in different levels of the central nervous system motor control in the period from one year after birth.

Why were such different results found between Watson and McGraw? The difference was due to what has been called, after the model by Newell (1986), constraints of the task. Watson introduced the babies into water in the supine position, while McGraw introduced the babies in the prone position. In a more recent study, Newell & van Emmerik (1990) suggested that the well-known motor development sequences, for example, the erect posture, (Shirley, 1933) and manual prehension (Halverson, 1931) could be explained by manipulating task and environmental constraints, which, together with organismic constraints, played a decisive role in the motor response in setting standards. It is worth remembering that the studies that identified these sequences were carried out with biological maturation as the main explanation for the process.

Despite the theoretical and practical implications of McGraw's findings (cf. Xavier Filho, 2006; Xavier Filho & Manoel, 2002), research on aquatic locomotion in the ventral position and its development only reappeared at the end of the 1970s. Erbaugh (1978) studied the aquatic development of children of preschool age and developed a checklist of motor tasks that the child should pass through. In later studies, Erbaugh (1978; 1980; 1986) identified significant differences in the swimming behavior of children of different ages. These changes in behavior were correlated with age although it was possible to see individual differences in observed behavior based on the experience of the subjects.

Reid & Bruya (1984) described the process of entering the water by children and the relationship with the level of aquatic development. The concern of these authors was to characterize the way in which children entered the water, their patterns of progression and movement as well as the starting level of body immersion. Based on their final results, the initial immersion phase of feet first entry into the water was made assisted by the teacher or with the use of appliances (ladders). The jumps and voluntary head-first entrances appeared later when the child displayed a greater dominance of the aquatic environment. This study also indicated that younger children of the sample felt more comfortable for entry after parts of their bodies were immersed in water. The relationship between age and developmental levels was relatively weak.

Two other studies carried out in the 1980s described the aquatic locomotion of babies. In the study by Wielki & Houben (1983) 40 children were observed over a period of four years. The changes described occurred in the movement patterns of the leg kick. The authors described seven ordered patterns of kicking action; the four of them presented between the 3rd and the 10th month were considered reflexive. These patterns have great similarity with those that McGraw (1939) described in the reflexive phase of leg movements; such movements were described as jerky, repetitive, and stereotyped. The other three patterns of action described in the study were cyclic and voluntary alternating movement of the lower limbs characterized by flexion of the legs at the knees, usually performed alternately. They appeared between the 11th and 20th months of age, and the propulsion occurred with the children in the prone position. According to the authors, the most efficient pattern was described as a "pedaling" pattern.

Oka et al. (1984) identified regular changes in muscle organization and age-related patterns of grasping action. This made it possible for researchers to identify that the action of the legs that went beyond the "pedaling" used by 30-month-olds, for a mature gripping pattern used predominantly by children at 72 months.

Langendorfer & Bruya (1995) proposed a developmental assessment instrument, called the Aquatic Readiness Assessment (ARA), for evaluating the development of aquatic locomotion, summarizing the studies on this issue since the 1930s. These authors analyzed nine components identified as developmental sequences that illustrated how stroke action, kick action, and breathing control changed over time.

Finally, Freudenheim, et al. (1996) presented a new way to analyze the development of swimming, demonstrating that there was a close relationship between the hierarchical organization of the task and the phases of motor development (i.e., fundamental movements, combination of fundamental movements, and culturally determined movements which are the origins of advanced strokes such as crawl, backstroke, breaststroke, and classic butterfly/dolphin kicking). Emphasis was given to the acquisition of actions related to the stability of the body in the liquid medium. In the model of these authors, gaining stability is essential for building the actions of stroke and kick. It is interesting to note that in 1939, McGraw had drawn attention to the importance of the orientation of the body in the water in anticipation that body stability was a limiting factor in aquatic locomotion (Manoel, 1995).

A common feature of all the studies reviewed here is that the authors did not consider the possible effects of task constraints and the environment on the configuration of aquatic locomotion patterns and developmental sequences indicated. Considering Newell (1986), Newell & van Emmerik (1990), Langendorfer (2010, 2011, 2015), and Costa et al., (2012), it is necessary to assess whether the swimming behavior patterns acquired after the second year of life, as suggested by McGraw (1935 and 1939), are sensitive to changes to the constraints of the task and the environment.

Based on the study of Herkowitz (1978) on general and specific analysis of the task, the following variables were considered: displacement speed, distance to travel, and direction of travel to analyze the swimming behavior of children. From this analysis, four experimental conditions were defined: Condition 1, swim eight meters straight at a normal, comfortable self-chosen, preferred speed; Condition 2, swim eight meters going around obstacles; Condition 3, swim eight meters in a straight line at full speed; and, finally, Condition 4, swim eight meters swimming around obstacles at full speed.

Thus, the present study aimed to investigate whether the developmental patterns of prone aquatic locomotion may be subject to constraints of the task (i.e., speed) and the environment (i.e., obstacles). To guide the conduct of the study using the c of the Newell (1986) and Newell & van Emmerik (1990) models, the following study questions were elaborated:

First, with the increase in the degree of difficulty of the tasks from Condition 1 to conditions 2, 3, and 4, would the aquatic movement patterns used by individuals tend to regress to more primitive developmental coordination patterns? From the approach of dynamical systems which referred to the notion of constraints, Newell (1986) called for changes in constraints that may lead to the emergence of more advanced standards. This implied that the order, from the simplest to the more complex tasks, did not necessarily imply regressions in behavior.

Second, does the developmental movement status of the swimmer (as identified from Condition 1) alter the degree to which the swimmer modifies the patterns of the task constraints? As mentioned above, changes in the constraints of the task and the environment can lead to the emergence of different patterns. One must consider the intrinsic dynamics of the system (Zanone et al., 1993) as described by the current state of development. Changes in movement patterns would result from changes in convergence constraints of the task along with the development of the individual state.

Finally, what kinds of adjustments are made by each group in each condition, based upon movement patterns expressed in Condition 1? Changes in the task constraints could cause varied behavioral adjustments. Manoel **&** Oliveira (2000) and Xavier Filho (2001) suggested that these adjustments could be grouped into two classes: (a) changes in the sequence of actions that change the displayed level of development and, consequently, the action programs and (b) changes in action parameters such as speed and movement time, which can occur without any change in the level of development or action program; These are therefore considered as parametric adjustments. In this article, we aim to analyze the changes in levels of development and our analysis was therefore qualitative.

Method

Participants

Fifty-six children, twenty-seven girls and twenty-nine boys, aged between six and twelve years, took part in the study. All individuals had attended at least six months of formal programs in swimming schools in the city of Londrina and Apucarana in the northern State of Paraná in Brazil. The selection of the sample was performed for convenience and participation was conditional on the signing of informed consent obtained from those adult caregivers responsible for the children. The research protocol was approved by the Ethics Committee of the Regional University Hospital State University of Londrina.

Materials and Procedures

This is an exploratory study with a quasi-experimental design in which the task conditions (i.e., swimming at a self-determined comfortable pace, swimming at fast speed, and swimming the route with and without obstacles) were constructed to promote variations in the aquatic locomotor patterns of children in the aquatic environment (Thomas and Nelson, 2002). Because all swimmers performed each condition, the study design could be described as within-subjects or repeated measures and was reflected in the statistical analysis.

Each participant was instructed individually on the experimental conditions, and all were able to perform each of the tasks. After making sure that the task was understood, marks were made on the wrists of each participant to facilitate observation during the analysis of the movements in the video. Next, the experimenters asked each swimmer to initiate the attempt; five trials were performed for each condition. The execution time of each attempt was timed; in the C3 condition, the individual was informed of the time to motivate them to swim at maximum speed.

The five attempts of each swimmer within each condition were filmed by two high-definition Panasonic cameras (scope S-VHS Movie Model AG-456 VP with 33-35mm/s record speed). One camera was installed above the water level while the other was placed below the water level to allow viewing of the underwater movement patterns. The total run time was recorded and noted in individual records. Subsequently, the collected images were analyzed frame by frame through the playback equipment (Panasonic VCR Receiver Model AG-1980-P) with the playback speed of 33-35mm/s, 30 frames per second.

Rater Objectivity

The categorization of the developmental level of aquatic locomotion was carried out by three Physical Educators. They were specialists in swimming with over 10 years of experience in swimming schools. The checking protocol proposed by Langendorfer & Bruya (1995) was used and the agreement among raters was higher than 90% while 'the intra-rater consistency was 95%. The percentage of exact agreement (P) refers to the proportion of all assessments made by the three raters that were coincident. This procedure has been used in numerous studies and has been accepted as reliable if intra-observer and inter-observer agreements were 80% or better (Basso, et al, 2005; Roberton, 2013).

Statistical Analysis

For qualitative measures, the aim was to identify significant differences among aquatic developmental levels in the water by swimmers in the experimental conditions. For this purpose, we used the non-parametric Friedman test for repeated measures. Monitoring the location of differences was performed with the non-parametric Wilcoxon test for paired measures. The data were tabulated and analyzed using the statistical package SPSS for Windows version 17.0.

Results

All subjects were able to perform the aquatic locomotor task in the four conditions which meant that there were no participants classified in Level 1 of the Langendorfer & Bruya model (1995). An initial analysis of the behavior of the participants found a wide diversity in aquatic locomotor patterns of participants in Condition 1 associated with the most basic developmental levels because it presented the least difficulty. Thus, we expanded the basic categories of the Langendorfer and Bruya model with the inclusion of two new categories as specified in Table 1.

Table 1
Original and modified Aquatic Readiness Assessment developmental levels for Combined Movement

Aquatic Development Levels for Combined Aquatic Movement	
Langendorfer & Bruya (1995 p. 50-53	Xavier Filho (2001 pg. 35-37).
N1 No locomotor behavior	N1 No locomotor behavior
N2 Dog paddle	N2 Dog paddle
N3 Beginner (early human stroke)	N3 Initial leg arm coordination
N4 Rudimentary crawl or other stroke	N4 Beginner (early human stroke)
N5 Advanced crawl / stroke	N5 Rudimentary crawl or other stroke
	N6 Intermediate crawl / stroke
	N7 Advanced crawl / stroke

In Table 2 we present a review of the development levels of aquatic locomotion.

Table 2
Modified Aquatic Readiness Assessment levels combined movement

Modified Aquatic Developmental Levels Combined Movement (Xavier Filho, 2001)

Aquatic Developmental Levels	**Descriptive Characteristics**
N1 No locomotor behavior	Child is unable to locomote independently in water
N2 Dog paddle	Front stroke characterized by plantar push or rudimentary flutter kick, circle downward arms (underwater recovery), and vertical or inclined body position
N3 Initial leg arm coordination	Standard “Initial Coordination”: Frontal style characterized by alternating upper limb movements with propulsive action ranging from short and fast pulls to long pulls; in both there is an arm stop in front of the body. The breathing pattern ranges from simple breath control, with inspiration stop, to the unsupported front breathing pattern. Leg action may be between the “flutter” kick and the rudimentary crawl pattern. The position of the body in relation to the water level depends on the action of the leg, but the most frequent pattern is the inclined one.

N4 Beginner (early human stroke)	"Human" Pattern Initial: Frontal style characterized by alternating movements of lower limbs with slight natural knee flexion. The action of the arms is done in rectilinear patterns with recovery out of the water; Breathing can be performed with the head turning to both sides, with inspiration occurring on one side and exhalation occurring on the other. On the body position it is slightly inclined in relation to the water. The action of the leg varies from the flickering movement to the action of the rudimentary crawl leg
N5 Rudimentary crawl or other stroke	Front stroke characterized by rudimentary alternating arms with out-of-water recovery with flutter kicking. Breathing patterns may vary
N6 Intermediate crawl / stroke	Intermediate Crawl Pattern: Frontal style characterized by the continuous action of arms with continuous kick without knee flexion, with varied and shifting pattern of breathing, with head high in relation to body position, which makes the swimming position is slightly inclined to the surface of the water. Another feature of the pattern is the discontinuous action of the arms stopping in front of the body to facilitate breathing
N7 Advanced crawl / stroke	Front stroke with defined arm, leg, and breathing patterns, usually with level or horizontal body position

Regarding the level of development to verify relationships with age, the participants with a more advanced state of aquatic development were those with a higher mean age (Table 3). The same relationship was also present in the amount of experience in swimming programs. In general, the higher the average experience, the more advanced the level of development.

Table 3
Number of participants by level of development with average age and experience

Level of development	*N*	*Age (Years/months)*	*Experience (months)*
N2	3	7,3	12
N3	9	7,7	10
N4	11	7,7	12,5
N5	7	7,3	17
N6	13	7,8	17
N7	13	8,8	22.5

To analyze the continuities and changes in levels of development between the conditions, a series of Friedman non-parametric simple analyses of variance were performed demonstrating statistically significant differences between the levels of development in the water and the experimental conditions (X^2 = 48.048 $p < 0.000$). The Wilcoxon test detected that the location of these differences occurred between conditions C1 to C2 ($Z = -3,989$ $p < 0.001$), C1 to C3 ($Z = -2.288$ $p < 0.02$), and C1 to C4 ($Z = -3.236$ $p < 0.001$).

In the transition from C1 to C2, there was permanence of all participants at Level 2. Although there were some changes in participants from other levels, the only significant alteration was by participants categorized as Level 7; in this case, 50% of the participants moved to a more rudimentary level (Table 3). As the trend of change was, in most cases, descending, one can conclude that the need to overcome obstacles created a condition with a higher degree of difficulty (Table 4).

Table 4
Changes in aquatic development level from C1 to C2 (%).

C1-C2	Remain	Change	Progressive change	Regressive change
N2	100,00	-	-	-
N3	44,44	55,56	20,00	35,56
N4	70,00	30,00		30,00
N5	62,50	37,50		37,50
N6	69,23	30,77		30,77
N7*	50,00	50,00		50,00

* significant p <0.02

In the C3 condition, the task requirement (constraint) of travel speed was increased to a maximum level. To respond to this demand, the majority of participants changed developmental level. The direction of change was generally to a more advanced level (Table 5). The Friedman simple analysis of variance indicated significant differences between the levels (X^2 = 13.694 p <0.02). The non-parametric Wilcoxon test identified the location of these differences at level 3 (Z = - 2.121 p <0.03).

Table 5
Changes in aquatic developmental levels from C1 to C3 (%).

C1-C3	Remain	Change	Progressive change	Regressive change
N2	33,33	66,67	66,67	-
N3*	44,44	55,56	55,56	
N4	80,00	20,00	20,00	-
N5	50,00	50,00	25,00	25,00
N6	76,92	23,08	4,33	18,74
N7	100,00	-	-	-

* significant p <0.03

The transition from C1 to C4 can be considered to have added the greatest difficulties for all participants. In fact, among those who changed their developmental level, approximately 35.8% presented a more rudimentary pattern (Table 6). Friedman's simple analysis of variance detected significant differences (X^2 = 50.672, p <0.0001); the location of these changes occurred at N7, where the non-parametric test for unpaired measures Wilcoxon showed significant differences (Z = -2.449, p <0.01). In fact, the test results indicated that remaining at the same level across conditions was significantly different for those swimmers using N7.

Table 6
Changes in aquatic developmental level from C1 to C4 (%).

C1-C4	Remain	Change	Progressive change	Regressive change
N2	100,00	-	-	-
N3	33,33	66,67	33,34	33,33
N4	80,00	20,00	-	20,00
N5	50,00	50,00	-	50,00
N6	76,92	23,08	-	23,08
N7 *	100,00	-	-	-

* significant p <0.01

Discussion

Referring to the first question of the study, we found that changes in actions did not occur linearly. The need to vary the direction of travel (Condition 2 – a person-environment constraint) led to regressions to more rudimentary developmental levels. The demand for faster displacement speed (Condition 3 – a person-task constraint) led to progressing to higher developmental levels (i.e., the participants presented more advanced patterns of behavior). Speed is known as a control parameter (and person-task constraint) for terrestrial locomotion patterns. For example, the demand for increased speed leads to important transitions in the coordination of human and animal locomotion patterns (Kelso, 1984; Shapiro et al., 1981; Thelen & Ulrich, 1991). The fact that we observed a tendency to shift developmental level in this study allowed us to affirm that speed acts as a control parameter in the coordination of swimming behavior similar to how it acts in terrestrial locomotion.

Corroborating the results of this study were data on the organization of the crawl stroke swimmers with different skill levels obtained in studies such as those conducted by Lerda and Cardelli (2003), Potdevin et al. (2006) and Seifert et al. (2007) which supported the statements presented herein, reporting that there was a close relationship between skill level and level of coordination of the stroke action, and that with increased swimming speed there was a change in the patterns of stroke coordination.

The implications of these results were both theoretical and practical. From a theoretical point of view, it would be interesting to study individuals with water displacement patterns seen as rudimentary and create tasks with different speeds to observe the extent to which this experience can contribute to progressive or regressive developmental changes. The practical implications follow the same line. Experimentation with different speeds might help the learner to discover more efficient and effective displacement patterns.

This discovery was used in the sense given by some authors who considered practice as creating a space for exploration and selection of action patterns (Turvey, 1977; Saltzman, 1979; Newell, 1986; Barela, 2006; Adolph & Berger 2006; Langendorfer 2011).

Variations in the displacement direction as a result of obstacles (i.e., person-task-environment constraint) had the effect of regressing to less advanced patterns. The search for these patterns can mean selecting a mode of action more stable in the face of the challenges posed by environmental conditions. It is also possible that the participants sought a more appropriate pattern for changing direction to avoid obstacles. This would involve changing the position of the head and therefore the position of the body by placing it in a more vertical position to facilitate the display of obstacles. These changes usually involved patterns classified as more rudimentary. In studies conducted by Langendorfer (1987a, 1987b, 1990) and Manoel & Oliveira (2000), this regressive change toward more primitive patterns was observed with the focus on the target compared to the focus on the distance or speed. In these studies, the authors concluded that individuals sought a more suitable pattern for the task, which coincided with a more rudimentary level along the developmental continuum. Additional studies including manipulating similar constraints are required to clarify the decision on which of the alternatives is chosen.

It should be noted that changes in the action sequence did not occur in every condition, and the N2 and N7 levels tended to present more non-changing behavior, which leads to the discussion of the second question. The individual's state of development is not totally malleable to changes in the constraints of the task or the environment. Manoel & Connolly (1997; 1998) showed that handgrip patterns in a manipulative task depended not only on variations in person-task constraints but also on the action sequencing requirements. It required that we understand that the action program established from child intention also acted as a constraint. In this study, the participants in the N2 and N7 groups did not always change their patterns of action. Two explanations can be given for this. The first refers to the characteristics of the adopted category system in both cases where there was no possibility of moving to lower levels than N2 (considering that the N1 implied non-action) and more advanced levels than N7. The other explanation refers to the underlying organizational state at every level. In the case of N2, individuals have few possibilities for variation in patterns, so challenges resulted in within-coordination pattern variations, denoting the degree of stability of this state of development. The same applied to individuals at N7 except that at N7 only regression was possible instead of progression.

The C4 condition constrained the action pattern of all participants the most, as shown by the percentage of regressive changes toward more rudimentary developmental levels; nevertheless, the N7 individuals remained at the same level. This may have indicated that the most advanced stages of development were characterized by greater internal variability to the action program, allowing the individual to adjust to the growing demands of the task and the environment in which it occurs (Manoel & Connolly, 1995). It is possible intermediate levels change more often to transitional stages, with the possibility of exploring new ways of sequencing the action or returning to more stable modes of action that characterize more rudimentary patterns.

Finally, it was necessary to consider the third study question on the nature of the adjustments made by the participants. The analysis in this research was qualitative and thus more attention was given to developmental levels presented in each condition. The C2 and C3 conditions were marked by qualitative changes in the developmental levels of the sequence for the majority of participants in all groups. In condition C4, this was for the groups N3, N4, N5, and N6, but not N2 or N7. During this condition, these two groups may have made parametric adjustments instead of coordinative pattern changes. As recommended by Newell (1986) and Langendorfer (2011), changes in the constraints of the task and the environment did lead to qualitative changes with the transition from one pattern of action to another.

Study Limitations

The results should be considered with caution, since in some situations it was not possible to identify the location of the statistically significant changes. It would be interesting to replicate this study, expanding the sample in each group corresponding to the levels of development. This recommendation is necessary to decrease the likelihood that the absence of statistically significant results was due to the small sample size.

In addition, it would be interesting to outline longitudinal studies in which changes in the constraints of the task and the environment are made systematically to verify their potential developmental effect. Along the same lines, power analysis could be carried out to investigate whether the degree of experience in the aquatic environment is an important factor in the process.

Conclusion

This study aimed to evaluate the conditions under which swimming behavior patterns assessed developmentally and qualitatively became susceptible to variations in the task and the environment. The notion that person-task and person-environmental constraints functioned as non-specific agents to engender changes between developmental swimming behavior patterns, which traditionally have been regarded as resulting from maturational development, were used as theoretical support for the impact of the constraints.

The results indicated that the developmental sequence assessment model proposed by Langendorfer & Bruya (1995) was susceptible to changes due to person-task and person-environment constraints. We observed that the handling constraints of the task (i.e., demand for increasing travel speed) generally resulted in progressive change in developmental level in many participants. Another constraint, the person-environment constraint of providing obstacles to travel around led to the regression in patterns at more rudimentary levels of development (Xavier Filho, 2001).

Finally, it should be noted that the ability to swim offers unexplored territory for research on the complexity of motor actions and their developmental process. Manipulating constraints can trigger changes in the way the elements interact in a given motor action system, which may cause a new coordinative pattern in that system. Swimming represents one of these systems since it features coordinating patterns that involve a high degree of organization among its elements (i.e., arm stroke, leg kick, and breath control). To be performed in the aquatic environment, the task requires different postural orientation than on land since the head needs to move to maintain an adequate oxygen supply. If postural orientation is already an important aspect for locomotion and manipulation skills, in swimming behavior it takes on major proportions because the person in that environment is experiencing completely new orientation relationships. McGraw (1939) gave prominence to this aspect. This author was pioneering in providing glimpses of the potential that the study of swimming offers from both theoretical and practical points of view. Until now, subsequent work has only humbly followed the way she pointed us over eighty years ago.

References

Adolph, K. E. (1997). Learning in the development of infant locomotion. *Monographs of the Society for Research in Child Development, 62(3),* 1-158.

Adolph, K. E., & Berger, S. E. (2006). *Motor Development Handbook of Child Psychology*, John Wiley & Sons, Inc.

Adolph, K. E., Vereijken, B., & Shrout, P. E. (2003). What changes in infant walking and why. *Child Development*, *74*(2), 475-497.

Barela, J. A. (2006). Exploração e seleção definem o curso de desenvolvimento motor. *Revista Brasileira de Educação Física e Esporte*, *20*(5), 111-113.

Basso, L., Marques, I., & Manoel, E. J. (2005). Collective behavior of components in overarm throwing. *Journal of Human Movement Studies, 48*, 1–14.

Bril, B., & Brenière, Y. (1993). Posture and independent locomotion in early childhood: Learning to walk or learning dynamic postural control. In G. J. P. Savelsbergh (Ed.) *The Development of Coordination in Infancy* (pp 337–358), Elsevier Science.

Costa A. M., Marinho, D. A., Rocha H., Silva, A. J., Barbosa, T. M., & Ferreira, S. S. (2012). Deep and shallow water effects on developing preschoolers' aquatic skills. *Journal of Human Kinetics*, *32*, 211-219.

Erbaugh, S. J. (1978). Assessment of swimming performance of preschool children. *Perceptual and Motor Skills, 47*, 1179-1182.

Erbaugh, S. J (1980). The development of swimming skills of preschool children. *In: C. Halliwell, C. et al.* (Eds). *Psychology of Motor Behavior and Sport* (pp.324-35), Human Kinetics.

Erbaugh, S. J. (1986). Effects of aquatic training on swimming skill development of preschool children. *Perceptual and Motor Skills, 62*, 439-446.

Freudenheim, A. M., Gama, R. I., & Moisés, M. P. (1996). La habilidad nadar (re) visión. *Revista Ciencias de la Actividad Física*, *4*(7-8), 139-155.

Halverson, H. M. (1931). An experimental study of prehension in infants by means of systematic cinema records. *Genetics Psychology Monographs, 10*, 107-206.

Herkowitz, J. (1978). Developmental task analysis: The design of movement experiences and evaluation of motor development status. In M.J. Ridenour (Ed.) *Motor Development* (pp.139-64)**.** Princeton Book.

Kelso, J. A. S. (1984). Phase Transitions and Critical Behavior in Human Bimanual Coordination. *American Journal of Physiology*, *15*, R1000–R1004.

Langendorfer, S. J. (1987a). Prelongitudinal screening of overarm striking development performed under two environmental conditions. In J. E.: Clark, & J.H. Humphrey (Eds.), *Advances in Motor Development Research-1* (pp 17-47), AMS Press.

Langendorfer, S. J. (1987b). Children's movement in water: A developmental and environmental perspective. *Children's Environments Quarterly*, *4*(2), 25-32.

Langendorfer, S. J. (1990). Contemporary trends in infant preschool aquatics into the 1990's and beyond. *Journal of Physical Education, Recreation, and Dance*, *61*(5), 36-39.

Langendorfer, S. J. (2010). Applying a developmental perspective to aquatics and swimming. In P.L. Kjendlie, R. K. Stallman, & J. Cabri (Eds.). *Proceedings of the XIth International Symposium for Biomechanics and Medicine in Swimming*: Norwegian School of Sport Sciences, 16th -19th June 2010.

Langendorfer, S. J. (2011). Considering drowning, drowning prevention, and learning to swim, *International Journal of Aquatic Research and Education*, *5*(3), Art. 2. https://doi.org/10.25035/ijare.05.03.02

Langendorfer, S. J. (2015). Changing learn-to-Swim and drowning prevention using aquatic readiness and water competence. *International Journal of Aquatic Research and Education*, *9*(1), Art. 3. https://doi.org/10.25035/ijare.09.01.02

Langendorfer, S.J., & Bruya, L.D. (1995). *Aquatic Readiness: Developing Water Competence in Young Children*. Human Kinetics. ISBN: 0-87322-663-1

Leakey, R., & Lewin, R. (1981). *A Evolução da Humanidade.* Martins Fontes.

Lerda, R., & Cardelli, C. (2003). Breathing and propelling in *crawl* as a function of skill and swim velocity. *International Journal of Sports Medicine, 24*, 75-80.

Manoel, E. J., & Oliveira, J.A. (2000). Motor developmental status and task constraint in overarm throwing *Journal of Human Movement Studies***,** *39*, 358-378.

Manoel, E. J. (1995). Análise desenvolvimentista da tarefa motora: Uma direção para a integração das pesquisas básica e aplicada em desenvolvimento motor. *Boletim do Laboratório de Comportamento Motor*, *2*(3), pp. 2-4.

Manoel, E. J. (1998). The development of manual dexterity in young children. In: K. J. Connolly. (Org.) *The Psychobiology of the Hand*, *147*, 177-198): MacKeith Press and Cambridge University Press.

Manoel, E. J., & Connolly, K. J. (1997). Variability and stability in the development of skilled actions. In K. J. Connolly & H. Forssberg (Eds.), *Neurophysiology and Neuropsychology of Motor Development*. (1st ed., pp. 286-318). MacKeith Press & Cambridge University Press.

McGraw, M. B. (1935). *Growth: A Study of Johnny and Jimmy.* Appleton-Century.

McGraw, M. B. (1939). Swimming behavior of the human infant. *Journal of Pediatrics, 15*, 485-490.

McGraw, M. B. (1945). *The Neuromuscular Maturation of the Human Infant*: Hafner.

Newell, K., & van Emmerick, R. E. (1990). Are Gesell's developmental principles general principles for acquisition of coordination? In: J.E. Clark, & J.H. Humphrey (Eds.), *Advances in Motor Development Research-3* (pp 85-135), AMS Press.

Newell, K. M. (1986). Constraints on the development of coordination. In M. G. Wade, & H. T. A. Whiting (Eds.), *Motor Development in Children: Aspects of Coordination and Control* (pp. 341-360). Martinus Nijhoff. https://doi.org/10.1007/978-94-009-4460-2_19

Oka, H., Okamoto, T., Yoshizawa, M., Tokuyama, H., & Kumamoto, M. (1983). Electromyography and cinematography study of the flutter kick in infants. In J. Terudo, & E.W. Bedrinfield, (Eds.), *International Behavior Sport Sciences*, *8*, (p. 167-172): University Park Press.

Potdevin. F., Bril, B., Sidney, M., & Pelayo, P. (2006). Stroke frequency and arm coordination in front *crawl* swimming. *International Journal of Sports Medicine*, *27* (3), 193-198.

Reid, A., & Bruya, L.D. (1984). *Assessment of developmental motor patterns in preschool aquatics*. Paper presented in the Biennial Conference of the Council for National Cooperation in Aquatics, Fort Worth, TX.

Roberton, M. A. (2013) Testing the validity of the Halverson developmental sequences for skipping. *Research Quarterly for Exercise and Sport*, *84*(2), 198-205. https://doi.org/10.1080/02701367.2013.784726

Saltzman, E. (1979). Levels of sensorimotor representation. *Journal of Math Psychology*, *20*, 91-163.

Seifert, L., Chollet, D., & Rouard, A. (2007). Swimming constraints and arm coordination. *Human Movement Science*, *26*(1), 68-96.

Shapiro, D.C., Zernicke, R.T., Gregor, R. J., & Diestel, I.D. (1981). Evidence of generalized programs using gait analysis patterns. *Journal of Motor Behavior*. *13*, 33-47.

Shirley, M. M. (1933). *The First Two Years: A Study of Twenty-Five Babies. Vol.1. Posture and Locomotor Development*: University of Minnesota Press.

Thelen, E. (1986). Development of coordinated movement: Implications for early human development. In M.G. Wade & H. T. A. Whiting (Eds.), *Motor Development in Children: Aspects of Coordination and Control*. (pp. 107-24). Martinus Nijhoff.

Thelen, E., & Ulrich, B, D. **(**1991). Hidden skills: A dynamic systems analysis of treadmill stepping during the first year. *Monographs of Society for Research in Child* (Serial n.223),l *56*, p.1-35.

Thomas, J. R., &; Nelson, J R. (2002). *Métodos de Pesquisa em Atividade Física* (3rd ed.). Artmed.

Turvey, M. T. (1977). Preliminaries to a theory of action with reference to vision. In R. Shaw & R. J. Bransford, (Eds.) *Perceiving, acting, and knowing: Towards an Ecological Psychology*. Erlbaum.

Watson, J. (1919). *Psychology from Standpoint of Behaviorist*. Philadelphia: J.B. Lippincott.

Wielki, C. & Houben, M. (1983). Descriptions of leg movements of infants in an aquatic environment. In *Biomechanics and Medicine in Swimming* (pp. 66-71), *14*, University Park of Maryland.

Xavier Filho, E., & Manoel, E. J. (2002). Desenvolvimento do comportamento motor aquático: implicações para a pedagogia da natação. *Revista Brasileira de Ciência e Movimento*. Brasília, *10*(2), 85-94.

Xavier Filho, E. (2001). *O efeito das restrições da tarefa e do ambiente no comportamento de locomoção no meio aquático*. Dissertação (Mestrado). São Paulo: Escola de Educação Física e Esporte (EEFE)d,a Universidade de São Paulo.

Xavier Filho, E. (2006). *A aquisição da locomoção aquática em bebês no primeiro ano de vida*. (121 f). Tese (Doutorado em Educação Física). Escola de Educação Física e Esporte (EEFE), Universidade de São Paulo. http://www.teses.usp.br/teses/disponiveis/39/39132/tde-03122007-105655/

Zanone, P. G., Kelso, J. A. S., & Jekka, J. (1993). Concepts and methods for a dynamical approach to behavioural coordination and change. In G.J.P. Savelsbergh (Ed.) *The Development of Coordination in Infancy*. North Holland Publishing Company.

Zelazo, P. R. (1982). The year-old infant: A period of major cognitive change. In T. Bever (Ed.), *Regressions in Development: Basic Phenomena and Theoretical Alternatives* (pp.47-79). Laurence Erlbaum Associates Inc.

Zelazo, P. R., Zelazo, N. A.; & Kolb, S. E. (1972). Walking in the newborn. *Science*, *176*, 314-315.

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