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DYNAMIC COUPLING: INTRINSIC AND EXTRINSIC INFLUENCES ON REACHING AND GRASPING IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

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RESUMO

O presente estudo teve por objetivo comparar a influência de restrições da tarefa e organísmicas na realização de tarefas de alcançar e apreender em indivíduos com hemiplegia derivada de paralisia cerebral, durante execuções com uma mão e com ambas as mãos. Para tanto, três estudos diferentes foram realizados: 1) envolvendo a realização de tarefas de alcançar e tocar; e alcançar e apreender; 2) envolvendo a realização de tarefas de alcançar e tocar; e alcançar e apreender com estresse de tempo; 3) envolvendo a realização de tarefa de alcançar e apreender, com a manipulação do ângulo da mesa, no qual se encontrava o objeto. Essencialmente, o conjunto de dados aponta para um acoplamento na ação do lado comprometido com o outro, durante o movimento bimanual. A influência das restrições introduzidas na tarefa foi diferente entre os sujeitos. Os resultados do estudo foram discutidos sob a ótica da abordagem dos sistemas dinâmicos, a qual atribui grande ênfase no papel das restrições do organismo, do ambiente e da tarefa no comportamento.

UNITERMOS: Paralisia cerebral; Controle motor, Preensão manual.

The work I am presenting comprises about two thirds of a project we have been engaged in over the last five years. A total of 11 experiments have been conducted and I will be showing results from 8 of them. All of the experimenters have been involved children with hemiplegic cerebral palsy in a situation where they are required to reach and grasp or touch an object under various experimental conditions. In addition, all of the children are required to reach and grasp or touch first with hand, then with the other, and finally with both hands together. A major feature of the experiments is the comparison of the unimanual action with the action of the same hand during the bimanual condition. For example if the trajectory of the hemiplegic hand is high during the unimanual condition, and the non hemiplegic hand is low, what happens during the bimanual condition? Does the hemiplegic hand stay the same, move to the trajectory of the non hemiplegic hand or indeed does it influence the non hemiplegic side? Similar questions can be asked about the timing of the movement and posture of the hand during the movement. Data has been collected in two days. First, a 3 dimensional kinematic system was employed to collect data such as velocity profiles, mean/peak velocities, correlations within and between hands, and distance/time graphs. Secondly, a normal video camera was employed to provide information on trajectory of the reach, posture of the hand, associated movements and corrections made during the reach. Before embarking on a description of the experiments I first would like to provide a brief outline of some recent theorising in the field of motor development which has made some impact into the field of disability and has provide us with the theoretical underpinnings for our work.

Explanations of children's motor development have taken a major step forward

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through the application of ideas of what has become to be called dynamic systems, which as the name implies involves the final product or whole being he active cooperation of many parts, and contains multiple subsystems all contributing in a unique manner. A number of labels have been attached to these ideas each representing the disciple of origin and ranging from mathematics and physics, through chemistry and biology to human development. Terms have emerged such as complexity theory, complex systems, non linear systems, chaos or chaotic patterns and dynamic pattern formation> In the area of human motor development the preferred term is dynamic systems (Sporns & Edelman, 1993; Thelen, 1995; Turvey, 1993; Ulrich, 1997).

A number of principles define the characteristics character and nature of dynamic systems. The interaction of multiple subsystems is a fundamental property of such systems with changes in human behaviour emerging spontaneously from the cooperation of these multiple subsystems. These changes are self organised showing that development is not a process of maturation which is specified a priori in the brain, but is a combination of intrinsic and extrinsic constraints, which include anthropometric variables such as limb length, muscle strength, joint structures, neural integrity, motivation and arousal, context, task demands and environmental support (Thelen, 1986, 1995; Thelen, Kelso & Fogel, 1987; Thelen & Ulrich, 1991; Ulrich, 1997). The work of Thelen and colleagues has shown that young infants when learning to walk respond immediately to the dynamics of a task showing all the properties of spontaneous self organization thus presenting powerful arguments against the notion of atop down hierarchical system with an homunculus specifying actions a priori and in detail. Infants who were not yet walking were supported on a treadmill and leg responses were immediate and constant to changes in treadmill speed even when different inputs were given to each leg (Thelen et alii, 1987; Thelen & Ulrich, 1991). The infants were responding not only to within the constraints of their neural development but also to the external demands of the treadmill. Changes in children's motor development involves non linear phase shifts with changes being abrupt as the multiple inputs take effect and the system moves into a different type of organisation.

These shifts evolve toward mature patterns of motor behaviour and are the result of the intrinsic constraints such as physiological properties and external constraints such as context and the nature of the task demands. Development thus involves both stability and non linear changes bringing both constancy and flexibility to the system.

The work of Nicolai Bernestein (1967) is well known and has run alongside and supports proposal from the advocates of dynamical systems. He examine the concept of coordination asking how an organism with many muscles and millions of nerve can coordinate these into smooth purposeful movements without involving some homunculus that the programmed already stored. This became known as the degrees of freedom problem and Bernstein and others have proposed that the movements are not programmed in detail but are planned at an abstract level and then are honed and refined by the demands of task. An important question for our work surrounds the issue of how much the task demands can influence actions when the neural system is impaired as in the case of children with cerebral palsy.

The potential for some of these ideas has been initially explored in the context of reaching and grasping in children with hemiplegic cerebral palsy (Sugden & Utley, 1995; Sugden & Utley, in, preparation; Utley & Sugden, 1998;). Some of the difficulties children with cerebral palsy encounter with reaching and grasping has been well documented (Brown, van Rensburg, Walsh & Wright, 1987; Eliasson, Gordon & Forssberg, 1991, 1992; Twitchell, 1958, 1959). General characteristics include a general slowness in speed of the affected limb together with a slowness of flexing of the fingers to grasp the object. A second general characteristic is over -extension of the fingers and occasionally the wrist which is in marked contrast to normal preparation for grasping where the fingers remain in a semi fixed position. Grasp is often weak with an undulating change in grip power rather than a gradual reduction of power after the grip has been established. Twitchell in his observational studies reported a difference in control of the fixating muscles of the wrist during the process of grasping. Normally the fingers flex around the object and the wrist extensors fix the wrist to act synergistically with the flexors of the finger to provide efficiency and power. The children with cerebral palsy did not do this but instead flexed their wrist to wards the object disruption the fixation of the wrist and lessing the leverage advantage of the fingers. It was suggested by Twitchell that this was part of a flexor synergy of the upper extremities, not seen in normal reaching and grasping and presumably brought on by impaired neural structures. A neural explanation is a powerful and obvious one knowing the impairment that is present in children with cerebral palsy and linking this with their movements. This type of explanation involves an intrinsic constraint where the neural properties directly provide a direct link to type of movement observed. External constraints such as a task demands and contextual influences have only recently been investigated (van der Weel, van der Meer & Lee, 1991).

Our studies have used kinematic analysis and video analysis to examine hand functions in children with hemiplegic cerebral palsy (Sugden & Utley, 1995; Utley & Sugden, 1998), and focus on description of the reaching movement when the hands move unimanually and comparing this to when they are moved bimanually. In particular the interest has been on the possibility of the hands coupling during the bimanual movement with the hemiplegic side being influenced by the movement of the less involved limb.

Our first study involved three experiments of reaching and touching and reaching and grasping and during unimanual movements the hemiplegic limb exhibited the typical characteristics associated with hemiplegia During bimanual movements all children coupled to some degree; in most the coupling involved timing with the hemiplegic hand speeding up to the less involved side; in others it involved trajectory changes with the hemiplegic limb talking on a lower trajectory during bimanual movements; and in a few cases hand posture was positively affected during bimanual movements. In dynamic systems terms these studies illustrated the self organization of reaching and grasping with the hemiplegic limb being drawn to work as a single unit with the less involved side. This is an example of an intrinsic constraint with the bimanual movement drawing the system to work as a unitary unit.

In the second series of studies using the same experimental paradigms, we introduced the extrinsic constraint of time as a variable and again this had an effect by promoting coupling of the limbs during the bimanual movement (Utley & Sugden, 1998). Here we were manipulated an external constraint or influence that of speed or time. This again did have an effect and this effect was variable across subjects.

The third study involving two experiments examined the influence of space as a variable. Time is one type of extrinsic constraint and is one that is present in our everyday movements. Another extrinsic constraint involves spaces, often interacts with time when we attempt to solve movement difficulties, and manipulation of the spatial environment in particular the visual array, may influence the spatial characteristics of any movement. Ecological psychology encompasses the view that the environment has "affordances" or "invariant properties" which allow us to perceive the potential uses of objets (Gibson, 1979). The visual system does not need to decipher the visual environment by piecing together bits of visual information; the optical array itself contains adequate information to immediately specify the environment and influence movement. These affordances have been shown to influence movements in adults, infants and with "swinging" rooms having an effect on stability children (Lee & Aaronson, 1974; Lee & Lishman, 1975).

In these experiments we changed the angle of the table on which the child was asked to reach and grasp. In one experiment the table was sloped toward the child and in the other it was sloped away from the child. As in the time experiments the sloping table did have an effect on the hemiplegic side particularly during the bimanual condition. The primary target of sloping the table was an examination of the trajectory of hands. There was an effect for this but it was not a consistent effect across subjects, and there were still other effects such as timing and posture changes.

A number of tentative conclusions are emerging from our work. First both intrinsic and extrinsic constraints do have effect on the reaching and grasping of children with hemiplegic cerebral palsy. This is an important finding because of the implications manipulating task variables can have for therapeutic purpose. Secondly, we examined changes in timing, trajectory and posture and while in most children during the bimanual conditions, changes did occur, they rarely occurred across all of the three variables. The most common change was in timing followed by trajectory and finally posture.

Occasionally we found multiple effects, but this was usually timing and trajectory, which could of course covary, while posture changes usually occurred in isolation. Finally, the effects were variable across children leading us to believe that single subject analysis is the most appropriate way of presenting the findings, and one of future aims is to take individual children and examine their profile across as many experiment as possible-in some cases this will as many as 8. This will provide us with evidence of the consistency of an individual's response across experimental conditions as well as within experiments.

ABSTRACT

DYNAMIC COUPLING: INTRINSIC AND EXTRINSIC INFLUENCES ON REACHING AND GRASPING IN CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY

The purpose of the present study was to investigate the influence of task and organismic constraints on the dynamic coupling, during reaching and touching, and reaching and grasping tasks in individuals with hemiplegic cerebral palsy. Executions with a hand and with both hands were compared. Thus, three different studies were acomplished: 1) envolving reaching and touching; and reaching and grasping; 2) envolving the same tasks, with under speed pressure; 3) envolving the same tasks, but with a change in the angle of the table upon which the object rested. In generally, the results showed a coupling between the body sides during the bimanual movement. The influence of the constraints introduced in the task was different among the subjects. The results of this study were discussed in the light of the dynamic systems approach, which emphasizes the role of organismic, task and environment constraint upon behavior

UNITERMS: Cerebral palsy; Motor control; manual prehrnsion.

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