Motor control and children with autism: deficit of anticipatory function?

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Abstract

This study aims at investigating how do anticipatory postural adjustments develop in children with autism, during a bimanual load-lifting task that required maintaining the stabilisation of the forearm despite imposed or voluntary unloading. Elbow angle and electromyographic were recorded on the child forearm supporting the load. The forearm stabilisation was as good in children with autism as in the control group. However, in children with autism, the latencies for both kinematics and muscular events indicated an increase of the duration of unloading. These results indicate the use of a feedback rather than a feed-forward mode of control. Impairments in both the building of internal representations and the mastering of timing parameters, could explain the deficient postural anticipation reported in children with autism.

Keywords: Autism; Anticipation; Motor development; Electromyographic; Kinematics

Voluntary movements are the first means of communication between a baby and its relatives. The functions of anticipation, co-ordination and adaptation enable children as they grow up to exercise an action towards a goal that is integrated in their environment. The intact development of such functions is essential for a harmonious and efficient motor development. The main deficit observed in autism is a lack of communication, and the poverty of the interactions between the person with autism and its environment. Various studies in children with autism reported a deficit in the organisation of the action towards a goal [4,13]. Analyses of the movements involved in the major motor milestones in development indicate that movement disturbances are present early during infancy in these children, and that they may be considered as the earliest signs indicating autism [1, 18]. However, until now there have been a limited number of studies investigating anticipatory function in autism.

Anticipatory postural adjustments (APA) occur before the onset of disturbance due to movement, and therefore they prevent the forthcoming disturbance of posture. The general process underlying the acquisition of APA implies the transformation of feedback postural corrections to feed-forward control associated with voluntary movements that are causing the postural disturbance [14]. This implies that internal representations of both the constraints inherent to the body itself, and those linked to action are built and used. The bimanual load-lifting task involves the coordination between a manual task: lifting a load placed on the controlateral forearm, and of a postural task: stabilising the postural forearm that supports the load. Previous studies on children aged 4–8 [15,16] has enabled us to notice a clear developmental sequence in the acquisition of APA: first the selection of an efficient electromyographic (EMG) pattern underlying the forearm stabilisation, and second the mastering of timing adjustments. Furthermore, these results suggest that representations of both the load and the stability consequences of unloading the forearm, which are needed to anticipate a forthcoming disturbance, slowly build up during childhood.

The main question of the present study was to investigate the building processes of the function of anticipation during the bimanual load-lifting task in children with autism as compared to healthy children. Our hypothesis was that the development of their feed-forward mode of control was impaired.

Eight right-handed children with autism, with ages ranged from 5.9 to 10.6 years participated in this experiment (mean ± SD, 7.9 ± 1.3 years, two girls and six boys). They were selected on their ability to perform the task and on a developmental quotient superior to 70, among patients attending a child psychiatry day-care unit of the University Hospital of Tours (France). They were assessed by a trained child psychiatrist and met criteria for the diagnosis of autism.
according to the Diagnostic and Statistical Manual-IV [2] and Childhood Autism Rating Scale (CARS) [17]. Sixteen healthy right-handed children with ages ranged from 4.1 to 8 years participated in this experiment (age 6.0 ± 1 year, nine girls and seven boys). The parents of all subjects gave their informed consent prior to the experiment, in accordance with the declaration of Helsinki. The experiment obtained ethical approval from the INSERM Ethic Committee. The experimental arrangement was the same as the one described in a previous paper [16]. The subjects were seated on a hard-back chair. Their left forearm, placed in a support, was horizontal and semi-prone during the entire session. A bracelet, placed near the wrist, was equipped with a strain gauge and supported a platform on which a load could be placed either below or onto the forearm. The angular displacement of the forearm was measured by a potentiometer situated along the elbow joint axis. During the imposed unloading situation, the load suspended below the forearm was released by the experimenter switching off the electromagnet circuit. During the voluntary unloading situation, the subjects lifted with their right hand the load from a platform resting on the left forearm. As with previous studies in children [15,16], a 300 g load was chosen for the 4-year-old children, a 350 g load for the 5/6-year-old children, and a 400 g load for the 7/10-year-old children. The procedure was as follows: first an imposed situation session of five trials, and then ten lifts in the voluntary situation. Several training trials were proposed to the child, until the experimenter was sure that the task was correctly performed. Force and angular elbow displacement signals were recorded, digitised and stored on a computer disk (sampling rate: 500 Hz) along with EMG signals for analysis. The onset of unloading (t₀), was aligned according to the first visible deflection of the force signal (see Fig. 1). The upward movement of the postural forearm was quantified by means of the maximal angular amplitude (MA) and the latency of the MA. During the session of voluntary unloading, the MA was expressed for each child in percentages of the mean value obtained in the first series of imposed unloading. The duration of voluntary unloading was determined by measuring the difference between t₀ and the return to near zero of the force trace, which indicated the end of unloading. Bipolar surface electrodes (integration surfaces: 2.5 mm²) were placed over the surface of two muscles implied in the forearm postural stabilisation: one flexor (Biceps brachii) and one extensor (Triceps brachii). EMG were amplified, filtered (10–200 Hz band pass), rectified and integrated with a 10 ms time constant. During the imposed unloading situation, latency and duration of the unloading reflex were measured on the flexor by means of averaged trials for each subject. In children, during voluntary unloading, two main EMG patterns were previously identified [16]: one consisting of a simultaneous increase of activity on the two antagonist muscles (co-contraction), and one consisting of a reduction of activity on the flexor while the extensor stayed silent or shown an increase of activity (flexor inhibition). However, in this study, we chose to focus on the flexor inhibition pattern. Thus, during voluntary unloading, in each trial where a decreasing activity was defined, the latency and the duration of the inhibition were determined on the B. brachii. The latency was measured as the time-interval between the onset of unloading and the onset of the reduction of activity, and the duration was measured between the onset and the end of the reduction of activity. An analysis of variance was performed to compare the performance of the two groups for both kinematics and EMG data. Differences with a P value < 0.05 were considered to be statistically significant.

Examples of force, elbow rotation and EMG traces are shown in Fig. 1 on one trial obtained in a 7-year-old control child, as compared with one trial obtained in a 8-year-old child with autism, during the voluntary unloading situation. After unloading, the values of the MA were rather low in the two children, indicating an efficient stabilisation of the postural forearm. Nevertheless, the force trace revealed an increase of the voluntary unloading duration in the child with autism. In the control child, the onset of the reduction of activity on the B. brachii appeared prior to the onset of unloading (−10 ms in this trace). On the contrary, the reduction of activity appeared late after the unloading onset (+84 ms in this trace) in the child with autism.

Part A of Fig. 2 shows the mean absolute values of the MA obtained during imposed unloading. No differences appeared between the two groups. No difference appeared neither concerning the MA measured during voluntary unloading (Part B of Fig. 2). On the contrary, the comparison of the MA latency (Part C of Fig. 2) showed a
significant difference between the two groups ($F_{1,22} = 11.23; \ P < 0.01$). Furthermore, a significant difference appeared between control and autistic children ($F_{1,22} = 8.13; \ P < 0.01$) concerning the mean value of the duration of voluntary unloading (Part D of Fig. 2).

The latency and the duration of the B. brachii decrease of activity during imposed and voluntary unloading are reported in Table 1. Concerning the latency and the duration of the unloading reflex, no difference was found between the two groups of children. On the contrary, during voluntary unloading, there was a clear difference for the latency of the B. brachii inhibition between the two groups ($F_{1,22} = 21.34; \ P < 0.01$). Indeed, the mean values were about 15 ms ($\pm 27$) for the control children and about 51 ms ($\pm 45$) in children with autism. No significant differences appeared between the two groups of children concerning the duration of the flexor inhibition.

It appears from our study that the forearm stabilisation was as good in children with autism as in the control group. Nevertheless, the increase of the duration of voluntary unloading as well as the MA latency indicate that such stabilisation was associated with a slowing down of the movement involved in lifting the object. This was confirmed by the delayed latency of the B. brachii inhibition, which indicates that the muscular event enabling the postural stabilisation was not anticipated, but corresponded to a feedback response during voluntary unloading. The integrity of the characteristics of the unloading reflex indicates that there is no peripheral damage to the neuro-muscular system, which may account for a slowing down of the movement.

This slowing down enables proprioceptive information to be exploited to control postural stability during movement, and it also minimises the effects of the perturbation. Thus, for autistic children, the slowing down may be a strategy to succeed which enables them to adopt a means of control to react to – rather than to predict – the stimuli of the environment. The fact that anticipatory control is not used by autistic children during such a bimanual task raises more general questions on the use of the anticipation function, whether it be for postural control, during motor control, or more generally to anticipate with relation to the external world. Anticipation requires the characteristics of an object and the interactions between the object and the subject’s body to be built into an internal representation [19]. Since the consequences of a motor command change with growth and depend on the objects children interact with, internal representation cannot be innate and needs time to mature in childhood [9]. In the bimanual load-lifting task, the internal representation allowing the transformation of a feedback process into a feedforward control, is not yet completely mature at 8 years of age [16]. The fact that children with autism do not follow an anticipatory mode of control is an initial result which would support the assumption that the building of internal representations may be affected in these children because of their disorders in the integration of environmental constraints.

The sensitivity of the anticipatory mode of control to the mastering of subtle temporal parameters could also be one cause of its dysfunction observed in children with autism. Indeed, in reaching and in lifting tasks, the timing of anticipatory adjustments seems to be the main difficulty to be
mastered during childhood, and the latest to reach the adult-like precision [3,8,12,16]. The dysfunction of temporal adjustment may be caused by the impaired development of a structure such as the cerebellum, which plays a significant role in the temporal and spatial organisation of muscular activities [7,10]. This structure obviously interferes with the execution of an anticipated motor program. Current anatomical studies strongly suggest that the cerebellum is a damaged structure in autism [6,11]. Abnormal regulation of brain growth, including more precisely cerebellum, resulting in early overgrowth followed by abnormally slowed growth has also been found in young children with autism [5]. A dysfunction of this structure may also be the cause of deficient anticipated control.

To conclude, our study clearly indicated a deficient postural anticipation function in autistic children. Retroactive control substituted for proactive control by autistic children nevertheless ensures that performance can be maintained during a task of bimanual co-ordination. However, the damage of the anticipatory mode of control might be secondary to a more general impairment in the building of internal representations. Further investigations coupling motor outputs and cortical correlates should help us to better understand the central origin of the anticipation deficit that we have highlighted in children with autism.

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