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Upper limbs motion analysis in cerebral palsy, towards performance assessment

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1. Introduction

The International Classification of Function (ICF) framework distinguishes between capacity (what a child can do) and performance (what a child actually does), highlighting the gap between potential and real-world function (OMS, 2001). The Assisting Hand Assessment (AHA) consists in a directed 20 minutes play session and is considered a gold standard for evaluating bimanual performance (Krumlinde-sundholm & Eliasson, 2003). However, such observation-based assessments are limited by their ability to detect small changes, and by the amount and type of outcomes accessible to the naked eye.

Recently, there has been an increased interest in quantifying upper limb function in cerebral palsy (Philp et al., 2022; Rozaire et al., 2024).

Instrumenting a directed bimanual play session such as the AHA would provide a unique opportunity to quantify the quality of movement during unconstrained tasks, where children are free to express individual strategies.

However, assessing unconstrained movement is a major difficulty. Schambra et al. (2019) proposed a taxonomy to break down functional motions into levels ranging from activities (cooking dinner) to functional primitives (reach, stabilize) through functional movements (cutting vegetables), based on motion duration and number of goals achieved. Inspired by this taxonomy, a methodology was developed to divide an AHA acquisition into phases in which functional primitives such as reaching, transporting and manipulating an object were identified. The aim of this study is to kinematically characterise and analyse these

phases. A future aim will be to compare this primitive-based analysis with clinical outcomes.

2. Material and methods

Five children with unilateral cerebral palsy were recruited within the CMCR des Massues after ethical endorsement by the French CPP ethical committee (n° 2023-A00303-42). Eventually, 5 more children will be recruited. Inclusion criteria included age between 18 months and 13 years and no severe cognitive impairment. Data were collected using Optoelectronic Vicon Cameras 100Hz. Five clusters of markers were positioned on trunk, arms and forearms and one marker on the 3rd finger. Local coordinate systems were defined following ISB guidelines (Wu et al., 2005). Assessments were conducted during AHA Small Kids and School Kids editions. The origin of the global coordinates system was defined as coincident to the trunk system at the beginning of the test (when the patients stood in a stable posture) which is centered on the intrajugular process with the y axis pointing up.

According to the AHA recommendation for rating the assessment, the item reach is defined as any hand movement exceeding a distance of one forearm length (Krumlinde-sundholm & Eliasson, 2003). Thus, based on motion capture measurements, circles with a radius equal to the distance between the elbow and third metacarpal joint were defined around each shoulder joint. Intersections between the hand path and these circles were identified for both arms, considering only occurrences where the hand spends more than half a second outside the circle. To identify when reaching starts and stops, local minima were identified in the hand's velocity profile. The reach start was defined as the last minima under 10% of the maximum velocity of the hand before an outward intersection. The following was designated as the reach stop. This procedure is depicted in Figure 1.

The definition for the transport phase followed the same logic as the reach phase, but used the inward intersection of the hand path with the shoulder circles. The manipulation phase was defined as occurring between the transport stop and the reach start.

3. Results and discussion

These are preliminary results; 5 children were included (5 MACS II) on the 10 expected.

The AHA acquisition was successfully divided into phases for both hands for the 5 participants.

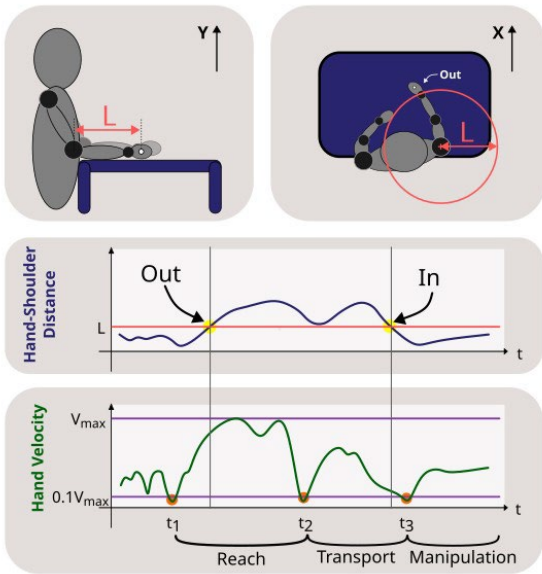


Figure 1. Functional primitives' extraction procedure

Based on this post-treatment, several parameters can now be calculated to understand the level of function of the patients and understand their functional strategies to overcome the difficulties of their impairment:

- Velocity, fluency or straightness during reach tasks to inform on the ease of use of the assisting hand (examples in Table 1),
- Trunk contribution to the reaching movement to appreciate the patient ability to move their arm.
- Hand use ratio to understand in involvement of the assisting hand

Table 1. Preliminary results

ID	Age (y)	AHA	Mean value across reaches		
			Mean Velocity*	Max Velocity*	Fluidity ^a
1	3.32	52	0.19	0.34	0.41
2	7.79	58	0.27	0.54	0.47
3	8.44	60	0.28	0.56	0.20
4	12.80	60	0.33	0.73	0.50
5	6.45	82	0.39	0.81	0.18

* Velocity in m.s⁻¹

^a Number of acceleration-deceleration phase

This approach is interesting because it happens during existing clinical consultation time and allows to gain insights on spontaneous movement. One limit is that it depends on the quality of the AHA conduction. For example, to identify the maximal possible extension

during reach, the clinician must encourage this extension.

4. Conclusions

The AHA acquisition was successfully divided into phases. It is yet to be determined whether the inclusion of more participants will allow for the replacement of certain clinical items by kinematic parameters or if the instrumentation will provide new insights into the differences in strategies between patients.

Conflict of Interest Statement

Declarations of interest: none

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