A model to estimate the channel capacity using assistive communication devices in children with cerebral palsy

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The brain injury in children with dyskinetic cerebral palsy (CP) often lead to a combination of excess involuntary movements (hyperkinesia) and slowed voluntary movements (bradykinesia) that together interfere with normal motor function. This may further affect the ability of children with CP to transmit information using the Assistive Augmented Communication (AAC) devices to communicate with the outside world. The information rate, using AAC touch-screen devices, is defined both as the amount of buttons activated per unit time and the number of different possible buttons in the screen layout. Consequently, the channel capacity can be defined as the maximum information rate a child can achieve with an optimal screen layout. Therefore, we hypothesized that one consequence of brain injury in children with CP may be a reduction of channel capacity while interacting with AAC devices. The goal of this study was to develop a mathematical model to estimate the channel capacity in children with CP. We recruited eight children with CP (13.8 years, SD = 3.4) and eight age-matched control subjects (14.1 years, SD = 3.6). The model was fitted based on the number and size of buttons on the screen underlying the Fitts' and Hick's Laws. Since the Fitts' Law relationship is also influenced by both the perceived cost to miss the target and prior information related to the correct target location, these factors were included in the model. Custom software on the iPad® was used in a discrete pointing movement varying number (n = 9 and 16), size (w = 1 and 3 cm), space between targets* (s = 1.05 and 1.5), and included experimental conditions of either a highlighted information about target location on the screen prior to movement (HL-1) or unknown information of the location (HL-0). The subjects started the pointing movement from a start button close to the edge of the iPad® screen. They were asked to touch as fast as accurate as possible a target displayed randomly within a square grid of n buttons. The total time, the sum of reaction and movement time, was used as the outcome to construct the model for estimating the information rate and computing the maximum channel capacity of all possible values of n, w, s and HL for each child. Interestingly the results showed that the model predicts the difference in information rate between groups. The model estimated a lower channel capacity for children with CP, 2.5 and 3.0 bits/s than controls, 7.1 and 12.5 bits/s, for the HL-0 and HL-1 respectively. It is worthy to notice that children with CP channel capacity with the highlighted condition (HL-1) was about 20% greater than HL0, instead the control subjects showed an improvement of 76% with HL-1. This suggests that the limited channel capacity in CP is primarily due to inefficient motor execution (rather than visual acuity, attention, planning). The results support the hypothesis that brain injury in cerebral palsy reduces throughput of the sensorimotor system to transmit information through upper limbs. Moreover, information theory may be exploited to understand how injuries of the sensorimotor system limit the ability to deliver information and interact with communication devices. The finding will be further used to optimize subject-specific user interface of assisted devices to maximize communication rate in children with motor and speech impairments.

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* The space between target factor (s) was defined as the ratio of the distance between target centers and the target width (w).

This work was supported in part by grants from the Don and Linda Carter Foundation, the Crowley-Carter Foundation, the National Institutes of Health (NS064046), and the University of Southern California Department of Biomedical Engineering.

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