Wearable devices to help children with autism overcome toe walking

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Abstract. One of the first symptoms of Autism Spectrum Disorder is "Toe-Walking", a walking mode in which the person uses only the tip of the foot, without bringing the heel to the ground. Common in toddlers, children with ASD continue to use this pattern growing up. Toe Walking can lead to the development of secondary motor deformity, the shortening of a heel cord, whose treatment may require surgery (eg. tendon lengthening).
Aim of this study is to analyze behavioral interventions, which are non-invasive and easily integrated with rehabilitation activities already in place in the centers and homes of many young people with ASD. The research team will then present a proposal for a technological evolution on this issue, in order to develop a system for early diagnosis and treatment.

Keywords: autism, gait, toe walking.

1 Introduction

Autism is a neuropsychological condition that can be diagnosed in the first years of life and accompanies the individual throughout his life [1]. Autism is often associated with hypo or hypersensitivity to sensory stimuli, often with numerous and unpredictable shift between the two [2].

This altered sensitivity could also be one of the causes of toe-walking, a stereotypic behavior frequently adopted by individuals with Autism Spectrum Disorder [3]. Toe-walking is a term used to describe “the condition in which children walk with a toe-toe gait pattern in the absence of any known cause” [4]. There are no definite data on the prevalence of idiopathic toe-walking, but some studies record this type of behavior in 20% of subjects with Autism Spectrum Disorder [5].

Although a direct cause-effect relationship has not been identified, toe-walking often accompanies difficulty in developing language. One study in particular highlights the association between toe-walking and language difficulties also in subjects without a diagnosis of neurodevelopmental problems [6].

Often, toe-walking in autism can lead to a secondary motor deformity, who needs to be medically treated, in particular with stretching exercises, casting, braces, Botox and

heel cord surgery [7]. Early intervention is the key to avoiding more invasive procedures.

In recent years, advances in technology have led to the development of increasingly complex applications for the habilitation and the rehabilitation of subjects with ASD. Hardware and software came together [8] in order to guarantee therapeutic advancements in fields such as communication [9], leading for a future of convergence where the machine facilitates, not monopolizes, the opportunities for growth of the individual. The purpose of this paper is to highlight the joint efforts between technology and behavioral sciences [10], trying to develop an intervention model for toe-walking in the Autistic Spectrum Disorder.

2 Interventions for toe walking in autism

2.1 TAGteach

Teaching with acoustical guidance, or TAGteach [11], is a behavioral intervention based on the use of clickers as a conditioned reinforcer. It uses a conditioned auditory stimulus (a "click" made by a low tech device) as a positive reinforcement to correct behaviors. The “click” is paired with an already established reinforcing item, in order to increase positive behaviors.

Despite the empirical evidence on the effectiveness of the intervention, the available studies are scarce and on a small number of people.

A study published in 2014 by Persicke, Jackson, and Adams [11], evaluated the effectiveness of the intervention on a 4-year-old child with a diagnosis of Autism Spectrum Disorder. The study was divided into the following phases: baseline (A), correction only (B), and correction + TAG phase (BC). At the end of each phase a reversal (A) was performed, identical to the baseline phase, and the intervention ended with two generalization probes to novel environments. Five sessions a day were performed for 2-5 days each week. The sessions were videotaped and subsequently analyzed to extrapolate data on the walk. The correction phase involved the physical intervention of the therapist, while the subsequent one aimed to increase the number of correct steps, modifying the reinforcement ratio. Once the intervention was concluded, the child had gone from an average of 24.6% steps performed correctly to a percentage higher than 73%.

2.2 GaitSpot

GaitSpot Auditory Shoe Squeakers [12] are a low-tech device to stick inside or outside shoes. On this accessory is mounted a squeaker in correspondence with the heel. By compressing this squeaker between the heel and the ground, it is possible to hear immediate sound feedback, working both as a stimulus prompt and as an auditory consequence.

A study published by Marcus et al. in 2010 investigated the effectiveness of the simplified habit reversal training procedure and differential reinforcement of incompatible

behavior using GaitSpot with three boys, aged between 8 and 9 years, with a diagnosis of autism. A delayed multiple baseline with changing criteria across participants design was used. The intervention, videotaped, was carried out 5 days a week, inside a special school attended by all three children.

Before the procedure, the squeakers were paired with small food reinforcements or tokens. The procedure included multiple baseline sessions (lasting 10 minutes), in which the children walked freely. In the training phase, the child's walk was accompanied by vocal verbal prompt, with the reinforcement delivered every three steps performed correctly. After ten minutes of walking without toe-walking, the researchers started the next phase.

Phase C, lasting 10 minutes per treatment session, differs from the previous one due to the absence of verbal vocal prompts and the VR5 reinforcement ratio. Phase D, on the other hand, involves the use of GaitSpots for the entire school day, with the prompt given only once at the beginning of the recording.

During phase E the recording took place when the children did not wear GaitSpots, while in the following ones the less controlled environment and the fading of the aids determined the generalization of the newly acquired behavior.

The results of the study were positive, with the mean percentage of target behaviour in all phases “showing a substantial decrease in habitual toe-walking behaviour from baseline”, although the limited sample and the difficulties in intervening outside the school context led to a lack of generalization.

2.3 CARE.ME Walk

Although the methodology used, strongly based on the analysis of behavior, provides interesting application cues, the low-tech approach of current studies is one of the reasons why the aforementioned works are difficult to apply to heterogeneous and numerous populations. The need to create a baseline for each user, the request for 1:1 treatment and the dependence on devices that are too simple for real-time reporting require extra effort from therapists, parents and above all young patients. At the same time, high-tech, reliable but cheap wearable devices are available on the market today. With these devices, it is possible to partially solve these problems and enhance the work of the clinician.

In order to build a prototype, a Tactigon ONE [13] device was used. The device, small and easy to place on patients' shoes, is equipped with 3 axis gyroscope and 3 axis accelerometer and can communicate via Bluetooth to a device such as a smartphone or to a small receiver in the environment, bridging physical and digital world together [14].

The data, collected and processed in real time using a proprietary algorithm [15] trough an Android smartphone, can be used to trace the movements of the foot, measure the three angles of rotation (pitch, roll, and yaw) and identify regular walking from toe-walking. The app that collects the data will present the patient with a summary of what has been measured, using a gamified environment [16] capable of motivating [17] the person to reach the next goal. The app interface is personalized with an avatar capable

of guiding the subject in the training up to the final stage, in which the functional behavior will be reinforced with digital tokens, redeemable with rewards in the real world with the help of parents, teachers, and caregivers.

The feedback, managed locally by the device, can consist of customizable sounds or a slight vibration, in order to provide information to the patient without becoming a source of stress [18].

An ad-hoc cloud platform [15] takes care of storing data, performing advanced statistical processing and allowing an overview of the work performed both by clinicians and researchers involved in the project.

3 Conclusions

Toe-walking is a known symptom of autism which, if not treated properly and at the right time, often leads to serious effects for the person. Some behavioral protocols, combined with low-tech tools such as the aforementioned TAGteach and GaitSpot, have shown promising results, paving the way for new research.

Today it is possible to tap into the market of wearable devices in order to have technologically advanced sensors at reasonable prices, and modern smartphone calculation skills allow data processing compatible with real-time feedback results.

Our prototype makes it possible to enhance the consolidated behaviorist approach, automating expensive processes such as data analysis and allowing constant use, even in unsupervised environments.

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