A Haptic Interface to Enhance Sensory Processing in Children with ASD

Luis M. Zamudio
Center for Scientific Research and Higher Education of Ensenada, Baja California(CICESE)
Ensenada, Mexico
lzamudio@cicese.edu.mx
Instituto Politécnico Nacional IPN-CITEDI
Tijuana, Mexico

Christian González
Center for Scientific Research and Higher Education of Ensenada, Baja California(CICESE)
Ensenada, Mexico
christiantronix@gmail.com

Jesus Favela
Center for Scientific Research and Higher Education of Ensenada, Baja California(CICESE)
Ensenada, Mexico
favela@cicese.edu.mx

Monica Tentori
Center for Scientific Research and Higher Education of Ensenada, Baja California(CICESE)
Ensenada, Mexico
mtentori@cicese.mx

Abstract

Children with Autism Spectrum Disorder (ASD) often experience atypical sensory processing, affecting their engagement in daily activities. Traditional tactile therapies rely on subjective observations, while recent advances in haptic technology offer more quantitative interventions. This study introduces a haptic interface for digital tactile therapy, a digital application developed with a customized crayon base vibrotactile stylus pen to simulate various textures through a coloring activity. We conducted a formative prototype test with six sensory therapists and explored engagement with eight preschool children with ASD to observe a traditional tactile therapy dynamic and how the children use our prototype, revealing that all participants engaged with the haptic interface for an average of more than five minutes, some requesting additional use. Therapists found the tool to be novel and valuable, suggesting new digital exercise to integrate into sensory therapy. Future work will refine the app with exercises recommended by the therapist and explore long-term engagement, highlighting the importance of developing digital therapeutic tools for more engaging and effective sensory interventions.

Keywords

Digital Phenotype, Digital Therapy, ASD, Sensory Processing

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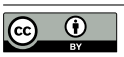

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1 Introduction

Children with Autism Spectrum Disorder often experience atypical sensory processing, manifesting as a difference in hypersensitivity or hyposensitivity to touch [2], which can interfere with their daily activities and learning processes [8]. Traditional therapies, such as sensory brushing or texture bins, are effective but largely rely on subjective observations of the therapists [9]. Significant efforts have been dedicated to the development of innovative tactile and haptic technologies for therapeutic applications. Early initiatives laid the groundwork with computerized touch therapy devices, ranging from vibrotactile remote therapies to temperature-based grounding tools, that offer portable, discreet, and personalized treatment options [10]. Subsequent research explored the application of vibration stimuli to reduce stereotypical behaviors in children, highlighting both the potential of these approaches and the need for a precise calibration of the intensity and stimulation patterns [3, 7]. More recent advances, such as the social assistive robot [4] and the CAretaker RoBOt (CARBO) [6], have further expanded these interventions by integrating tactile sensitivity with social interaction, opening new avenues for structured therapeutic protocols. Collectively, these studies represent a cumulative effort to refine tactile therapy technologies and underscore the promising opportunities for future research to enhance and personalize sensory interventions for children with autism. However, these studies are more focused on reducing stereotypy and increasing social communication than studying the hypo- and hyper-tactile differences in children with ASD. Although digital applications offer promising benefits, their effectiveness depends on how well they are integrated into practice. Factors such as initial resistance, the learning curve associated with new technology, and the perceived value of the tool all play an important role. Thus, there is a need to assess the participation and adoption of the users with the technologies proposed to assist these sensory therapies.

2 Methodology

Following a user centered design methodology we develop a haptic interface for digital tactile therapy an Android app running on a Samsung tablet S6-Lite and customized crayon base stylus pen,

which together mimic traditional tactile sensory therapies such as crayon rubbing over textures [1] which focuses on touch sensing and tactile exploration, helping children develop fine motor skills and sensory awareness (see figure 1 left). Our development uses vibrotactile patterns that were designed to mimic texture sensation like smooth as an apple, rough as a melon, bumpy as a corn, adhesive as a banana, or sharp as a pineapple[5], providing children hands-on experience supporting tactile learning and sensory processing (see figure 1 right).

Figure 1: Left: Shows an example of crayon rubbing over textures. Right: illustrates the free exercise designed to provide digital texture sensations while coloring.

From the children's interaction, it is capable of collecting data such as the stroke coordinates, distance, timestamp of the stroke, the color, and the favorite texture to further study the progression of therapy.

2.1 User-Centered Prototype Testing

As part of the user-centered design methodology, we tested our prototypes in two scenarios. First, we understand how therapists would use the haptic interface for digital tactile therapy. Second, we assessed children's engagement with our developed haptic interface for the digital tactile therapy app in a therapeutic setting.

2.1.1 Therapist Testing Session

We conducted a prototype testing session with six sensory therapists using the haptic interface for digital tactile therapy. Each of them had the experience throughout the free exercise to perceive the five vibrotactile patterns mimicking the textures smooth, rough, bumpy, adhesive, and sharp while coloring. They also explore the features to change the texture, the color and the width of the brush (see figure 2, left).

To conclude the session, the therapists were given 15 minutes to reflect on their experience with the haptic interface and document their insights. They provided written feedback on the usability to describe a specific therapeutic scenario in which the prototype could be integrated to enhance sensory therapy sessions. This exercise aimed to gather practical perspectives on how technology could support their therapeutic approaches (see Figure 2, right).

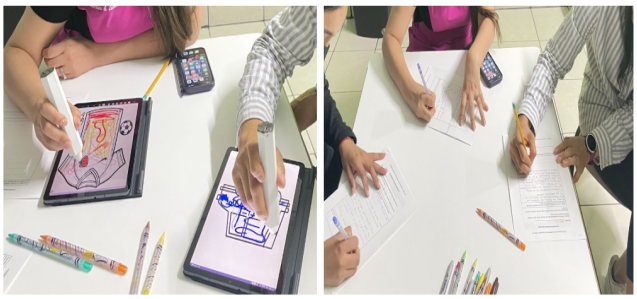

Figure 2: Left: Shows therapists using the haptic interface; Right: Therapists describing possible uses in therapy.

2.1.2 Child Engagement Testing

We conduct a formative engagement test in a structured therapeutic setting over 1 day, to observe how traditional therapy is performed and how children use and engage with the haptic interface of the digital tactile therapy app in a therapeutic setting. The engagement test consisted of two sets of conditions. First, in the traditional therapy setup, the therapist arranges a table with various textured surfaces, including a sharp sensory seat, a rough mat, adhesive rubber, and a bumpy tray. Each texture is covered with a sheet of white paper, and crayons are provided for the activity (Figure 3).

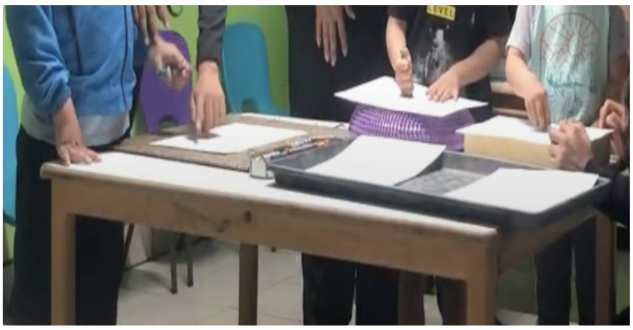

Figure 3: Shows the table with different textures over the top covered with paper.

In traditional therapy setup, the therapist instructs the children to pick up a crayon, select a sheet of paper, and rub the crayon on it. After some time, the therapist prompts them to switch to a different texture (see Figure 3). Second, in the digital tactile activity setup, the therapist prepares a table with two tablets running the haptic interface for digital tactile therapy and a customized stylus pen. They will use the free exercise to guide the children to coloring while mimicking the crayon rubbing. (Figure 4).

In the digital therapy setup, the therapist guides the children to pick up the stylus pen and interact while maintaining the grip with

Figure 4: Illustrates two participants using the digital tactile activity setup.

the haptic interface to engage coloring, simultaneously the children will perceive a tactile sensation that mimics the traditional crayon rubbing over the texture. By default, the digital tactile sensation is set to rough; however, during the activity, the therapist or the child can switch between smooth, adhesive or sharp textures and revert to rough as needed (see Figure 4).

3 Participants

Participants were recruited from a Therapeutic Institute located in Tijuana Mexico. The inclusion criteria were children in preschool, with Autism Spectrum Disorder diagnosed. Sensory therapists lead the children during the study.

4 Results

From the prototype testing session with the sensory therapists, we obtained their feedback that recognized the prototype as a promising and useful tool, expressing curiosity about its potential in tactile sensory therapy. They proposed integrating additional exercises to further extend its therapeutic benefits and facilitate its incorporation into structured therapy sessions (see figure 5).

During the study we observed in the traditional therapy the therapists guided the children. Some of the children rubbed the crayon over textures, and changed between the textures, while others were observing the activity without rubbing the crayon over the textures. Additionally, some children showed resistance to the activity, requiring persistent encouragement and structured guidance from the therapist to engage in tactile exploration. In contrast to traditional therapy, where some children required significant encouragement to participate, all children engaged more actively and for a longer duration when using the haptic interface for digital tactile therapy. On average, they interacted with the prototype for five minutes and seven seconds, demonstrating some insights of engagement

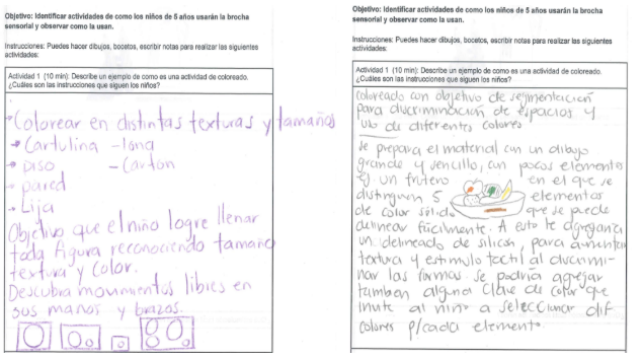

Figure 5: Highlights two examples of the exercises proposed by the sensory therapist. Left: Texture on geometric figures. Right: Texture discrimination.

with less prompting. Unlike the traditional therapy, where some children avoided the activity, the digital interface appeared more intuitive and inviting.

Additionally, participants 1 and 3 expressed a strong interest, requesting to use the prototype again (as shown in Table 1). These results suggest that the digital tactile experience has the potential to serve as an engaging alternative for sensory therapy; however, further studies are needed to confirm its suitability for therapeutic practice.

5 Conclusion and Further Work

Our findings provide empirical evidence that the haptic interface for digital tactile therapy can be effectively used by children with Autism Spectrum Disorder (ASD), as demonstrated by their initial engagement with the free coloring exercise while experiencing digital textures in a therapeutic setting. The results suggest that

Table 1: Summary of children participants

Participant	Gender	Age	Condition	Time (minutes)
1	Male	5	ASD	03:26
1	Male	5	ASD	03:19
2	Male	5	ASD	03:26
3	Female	5	ASD	06:40
3	Female	5	ASD	09:56
4	Male	5	ASD	02:40
5	Male	5	ASD	05:00
6	Male	5	ASD	02:10
7	Male	5	ASD	09:00
8	Female	3	ASD + SPD	05:32
			Average Time	05:07

ASD: Autism Spectrum Disorder, SPD: Sensory Processing Disorder

this digital tactile approach may encourage participation, even among children who are typically reluctant to engage in traditional therapy.

Sensory therapists also found the prototype innovative and potentially beneficial, expressing interest in its application within tactile sensory therapy. They suggested incorporating additional exercises—such as texture recognition on geometric figures and texture discrimination tasks—to expand its therapeutic scope and facilitate integration into structured therapy sessions.

Future research will focus on two key areas:

- **Developing and integrating additional exercises** into the haptic interface to create a more comprehensive therapeutic tool.
- **Conducting a larger-scale study** with more participants and multiple sessions to collect both qualitative and quantitative data, enabling assessment of sustained participation, effects on sensory processing, and adoption of the technology by therapists.

Finally, this study highlights the critical role of collaboration between developers, therapists, and researchers in the creation of effective digital therapeutic tools. Continued interdisciplinary efforts will be essential to refine these technologies and maximize their impact in both clinical and educational settings—opening new possibilities for engaging and effective sensory therapies in the future.

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ChatGPT was used to improve grammar and clarity when translating from Spanish to English, as the author is not a native English speaker. After using ChatGPT, the author reviewed and edited the content as needed and took full responsibility for the content of the published article.

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