

Tactile and Visual Sensory-Based Adaptive Functional Clothing for Children with Autism Spectrum Disorder

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Abstract

Autistic children belong to a sect of the population that is usually ignored in design, especially to prepare them for the challenges and problems they will face in everyday life. Children with autism are more sensitive to their physical surroundings than the average person, which often leads to them feeling overwhelmed by the environment. This syndrome is primarily due to sensory processing deficits, which create challenges in understanding and adapting to the environment, resulting in anxiety. Emotional and behavioral issues frequently co-occur at a higher prevalence in children with autism compared to typical controls, which often disrupts intervention efforts and exacerbates functional impairment, parental distress, parent-child relationships, and the health-related quality of life for caregivers.

In recent years, with the evolutionary segment of the technical textiles market, clothing has crossed conventional boundaries to integrate various domains like medicine, biotechnology, nanotechnology, etc. with design. Functional clothing exemplifies apparel design that consistently aligns harmoniously with individuals having specific needs. Due to the wide variety of fibers, yarns, fabrics, and manufacturing techniques available for producing products tailored to specific end-use applications, it offers unparalleled versatility in system design. Textile becomes an optimal medium for information processing, as it possesses the potential to incorporate redundancies for fault tolerance.

This research article demonstrates the integration of functional clothing with electronic sensory designs, both tactile and visual, to help children with autism cope effectively with and adjust to change. The ability of this garment to gather data from the user or its surroundings and utilize that input to activate or modify the state of an attached technology makes this garment different from other types of clothing. The number of sensors and their ability to sense context, process information, and effectuate changes

determine how intelligent a garment is. The study highlights the dearth of design considerations for children with autism spectrum disorders and awakens the urgent need for sensory textiles in functional apparel to help autistic children.

Keywords: Autistic children, functional clothing, sensory mechanism, interactive design, tactile and visual experience

Introduction

The term 'Autism Spectrum Disorder' (ASD) refers to a group of conditions that are characterized by challenges with speech and nonverbal communication, repetitive activities, social skills, and distinctive strengths and traits (Yates, 2016). It is classified under the category of Neurodevelopmental Disorder (NDD), which is defined as a category of conditions that manifest during the developmental stage and cause deficiencies that eventually lead to functional impairments. Assimilation and processing information from various environmental sources are often challenging for people with autism. They may be overly sensitive, completely devoid of senses, or both. Other additional characteristics of ASD include atypical patterns of behavior and activity, such as difficulty switching between activities, attention to details, and unusual reactions to sensations (World Health Organization, 2023). While some children with ASD may have a decreased sensitivity level, others may be more sensitive than typical to environmental stimuli like noise, light, clothing, etc.

Children with ASD may experience severe challenges as a result of unpredictable changes in schedules and routine (Cañete and Peralta, 2022). They often display anxiety, lack of motivation and attention, and abnormal responses to various stimuli, which makes them different from their peers (Chakrabarty, 2019). Speech is either delayed or predominantly absent. It leads to deficiencies or departures from normative development in the three main domains, i.e., social cognition, communication, and imaginative capacity, particularly in social imagination. People with autism exhibit atypical responses to sensory stimuli. Individuals with autism may display impairments in one or more senses. These difficulties may manifest in their behavior, causing individuals with autism to engage with others, objects, and events in their environment in unusual ways. Autistic children may exhibit a wide range of symptoms or characteristics, from mild to severe, making it a spectrum condition (Willis, 2006). As a result of these social challenges, children with ASD are vulnerable to social rejection and isolation (Douglas et al., 2022). Delays in communication and social interaction, obsessions with particular objects, repetitive body motions, and obsessively following specialized routines and

rituals are all characteristics of ASD (Kommu, 2011). The symptoms of ASD typically occur in the age group of two to three years old (Wright and Wright, 2005). In certain situations, it can be identified as early as 18 months (Perrin and Coury, 2012).

The type and characteristics of ASD make it a very complex disorder. There are five types of ASD. Kanner's Syndrome, also referred to as the classic autistic condition, includes uncontrollable speech, an obsession with handling objects, and an inability to form emotional bonds with others. The individual demonstrates advanced abilities in rote memory and visuospatial skills but experiences challenges in interpersonal interaction and communication. They also struggle a lot in different areas of learning and education (Sruthi, n.d.) Children with Pervasive Developmental Disorder Not Otherwise Specified (PDDNOS), a type of autism in which their traits are different from those of other autistic children and are typically diagnosed after the age of three. PDDNOS is characterized by significant challenges in social and language development, and it can coexist with a wide range of intellectual abilities, like other forms of autism (Autism Speaks, n.d.). Children having Asperger's Syndrome develop social skills and communication like adolescents, but they struggle with coordination, vocal intonation, depression, violent reactions to change, and a proclivity for ritualistic behavior (Mikami and Matsumoto, 2007). Rett Syndrome is a distinct neurodevelopmental condition that primarily affects girls and is initially identified in infancy (Indian Rett Syndrome Foundation, n.d.). This syndrome causes severe impairments in almost every aspect of a child's life. Common symptoms of Rett syndrome encompass diminished mobility or abnormalities in walking, decreased muscle tone, microcephaly (reduced head size), impaired speech, loss of hand functionality, involuntary hand movements, seizures, breathing difficulties, sleep disturbances, and scoliosis (abnormal spinal curvature). Childhood Disintegrative Disorder (CDD) is characterized by the disintegration of mental function and the regression of acquired language and intellectual skills in a child following a period of normal development (Verma and Mohapatra, 2016). After two years of normal growth and development, the child may start to show signs of CDD. This condition usually manifests between the ages of three and four, but it can occur at any time before the child turns ten (Sruthi, n.d.). The initiation of CDD could occur all at once or over time. Children might possess an understanding of what's going on with them and inquire about the nature of their illness. Parents or experts might fail to notice developmental changes in areas such as the child's language, communication, social relationships, and emotional development (Kommu, 2011). Children may experience hallucinations, which are when they see, hear, or smell things that do not actually exist (Sruthi, n.d.). A child who used to be able to talk in two or three sentences may experience a progressive

cessation of speech. A child who used to enjoy affectionate embraces may now be very against any kind of physical contact.

Sensory processing and autistic children

Sensory processing denotes the capacity to assimilate information from the environment and the body, evaluate its significance, and arrange it into motor and social responses (Chakrabarty, 2019). An individual constantly learns and perpetually acquires knowledge about their surroundings through their senses. Sensory processing impairment is common in children with autism and other forms of ASD, along with emotional and behavioral problems (Tseng et al., 2011). Sensory processing includes reception, change, integration, and organization of sensory information, along with the behavioral reaction of people to such information. The neurological system's ability to adjust input partially determines how a person reacts to different types and amounts of sensory stimuli. The nervous system works rapidly when sensory input is appropriately regulated or controlled. It makes precise assessments about input and changes the nervous system's arousal state to prepare it ready for action. Children with sensory processing impairments may have trouble in understanding and interpreting what they see, hear, and feel, which can slow down their fine motor skills development. Individuals with a sensory processing disorder have challenges regulating and organizing their behavioral responses to sensory stimuli in a way that fits the needs of their environment.

Children with ASD have unusual sensory reactions ranging from hyper-responsiveness to hypo-responsiveness (Kyriacou, Forrester-Jones and Triantafyllopoulou, 2021), which interferes with their daily life. Hyper-responsiveness refers to the sensory channel being too open, allowing too much stimulus into the brain, whereas hypo-responsiveness refers to the sensory channel being too closed, allowing too little stimulation into the brain and depriving it of sensory input (Ghazali, Sakip, and Samsuddin, 2018). Since autistic children are more sensitive to their physical environment, they react to sensory inputs with conduct that is not proportional to the degree and kind of the sensory stimulation. When an autistic child is unable to comprehend or adjust to their surroundings, unacceptable behavior ensues, resulting in significant levels of anxiety, stress, and confusion. In addition, the challenges they pose in terms of planning and organizing abilities result in reduced self-autonomy and an incapacity to self-manage.

Children having autism sometimes exhibit severe symptoms of anxiety (South and Rodgers, 2017). The sensory-based anxiety subscale, along with the subscales for

performance-related anxiety and challenges with uncertainty, plays an important role. Because of this, individuals with autism may display sensory soothing behavior that repeats or makes sensory experiences stronger. Sensory soothing behavior needs strong sensory inputs to produce a calming response. Different responses to a variety of input modalities like taste, smell, sound, sight, and touch have been found in autistic children. This implies that a “one size fits all” approach to design is not right for every autistic child. Sensory-based interventions are frequently employed to address behaviors in autistic children impacted by sensory processing difficulties (Case-Smith, Weaver and Fristad, 2015). Sensory-based intervention may include weighted blankets, weighted vests, and sensory clothing to help with sensory processing variations. To enhance the sensory experience in functional clothing, two of the senses, touch and sight, are heavily focused upon. Children with autism are often diagnosed to be more sensitive towards sensory inputs like touch, hearing, and sight (Grandgeorge and Masataka, 2016). They often depend on visual stimuli to understand their surroundings, as they struggle to interpret spoken cues (Shin, Smith and Gaines, 2015). This study builds on earlier research that used autistic hyposensitivity and hypersensitivity as the foundation for design inclusion (Seyedi, 2019). The design’s visual component emphasizes color a lot, with brighter colors being more distracting to hypersensitive individuals than muted colors, and the reverse is true for hyposensitive individuals (Gaines et al., 2016). The basic mechanism of categorizing colors perpetually remains consistent between individuals with ASD and those without. However, the heightened sensitivity to sensory stimuli that is typical of ASD may affect color perception, with individuals having this condition leading to a dislike of certain colors that are generally preferred by neurotypical individuals. 85 percent of children with ASD perceive colors with greater intensity than usual children and are aroused by environments rich in color (Paron-Wildes, 2005).

Variations in materials and surfaces can significantly affect the way autistic children perceive touch, leading to alleviation or stimulation. Soft organic textures are more calming and delightful to them. The tactile sensory experience aids in social and emotional development (Shin, Smith and Gaines, 2015). To meet the needs of autistic individuals, multisensory textiles offer important features that enable them to enjoy tactile interactions and alleviate behavioral disorders such as anxiety (Ahlquist, 2015). Textile artist Ellie Turner creates intricate textures that depict the visual connections and sensory experiences of autistic children with various materials and objects. Children with autism are highly sensitive about their clothing and overall appearance (Kyriacou, Forrester-Jones and Triantafyllopoulou, 2021). An autistic individual’s choice of attire influences their moods and emotions. The fabric’s tactile quality determines

their enjoyment experience. Stress, anxiety, and disorientation are brought on by a bad experience with fabric texture. Therefore, adaptive features pertaining to modified body form, strength, and movement limitations, as well as psychological and social needs, would be taken into consideration during the design process to integrate functional clothing with sensory-based experiences. In case of tactile hyper-responsiveness, which the autistic child frequently experiences, the placement of texture in different areas of functional clothing will make it easy for them to access the material, and once the texture is deemed enjoyable, it can be used as a calming tactic (Smith and Sharp, 2012). As a coping strategy to lower stress and improve well-being, some individuals with autism choose appropriate clothing and repeatedly stroke or touch a specific texture of a fabric (Jones, Quingney and Huws, 2003). This also helps them to experience soothing sensory experiences (Ashburner et al., 2013).

Functional clothing and sensory implementation

Apparel is a fundamental necessity for humans, alongside sustenance and shelter. The body protection feature of clothing has been enhanced by its aesthetic qualities. Clothing can be a personalized and adaptable information platform in addition to its protective and aesthetic roles (Park and Jayaraman, 2001). Clothing significantly influences the daily lives of children with autism, just like it does for everyone else. It is a fundamental psychological and physiological necessity, as it provides comfort and safeguards against adverse external influences (Yellow Bus ABA, 2025). Clothing is even more important for children with autism since it allows them to be independent, safe, and comfortable while making dressing easier by reducing the challenging aspects of dressing, such as buttons, zippers, and closures. It is significantly influential in enhancing the quality of life for them (Kaur and Chhabra, 2024).

By definition, functional clothing is tailored to fit the needs of each user and engineered to meet performance standards under difficult conditions (Gupta, 2011). It may have technological features that can be applied in telemedicine, therapy, rehabilitation, communication, and other fields. Functional clothing assemblies are ergonomically designed to maximize comfort and performance for the wearer and minimize movement restriction. There are three essential qualities upon which the integration of electronic sensors into functional clothing relies. Firstly, it is worn rather than carried, thus becoming an extension of the user; secondly, it is controllable by the user, not always requiring conscious thought or effort; and finally, it functions in real time, remaining perpetually active while possessing a sleep mode, allowing for interaction with the user at any moment (Kumar and Vigneswaran, 2016). It also results in biosensing

clothing, which, when worn adjacent to the skin, is utilized to monitor essential physiological characteristics such as heart rate, blood oxygen levels, pulse rate, and core body temperature. It can additionally facilitate a behaviorally regulated experience for children with ASD by addressing their individual skills and interests through the development of tactile interfaces, thereby creating a visually and physically appealing environment (ibid.).

Research has well established the incidence of sensory processing challenges in children with ASD. One of the main ways to assist them is through adaptive functional clothing that is made to help with sensory sensitivities. Various research and studies in this field underscore the necessity of applying therapeutic and practical elements to clothing designs to enhance participation, comfort, and overall well-being. Kaur and Chhabra (2024) examined the development of functional clothing for autistic children, highlighting the challenges that sensory sensitivities present in everyday life. Their work emphasizes the necessity of specialized clothing that not only helps in tactile defensiveness but also prioritizes comfort, safety, and ease of wear. The research focused upon functional clothing ought to alleviate sensory discomfort while fostering independence in dressing, a common challenge for the children on the spectrum. Their systematic review indicated that sensory-based techniques, including wearable interventions, have demonstrated potential in modulating sensory responses. However, additional empirical evidence is required to validate the long-term efficacy of sensory functional clothing as a therapeutic intervention, as the results of the studies are not always the same. Further, sensory clothing can positively affect engagement in daily activities, improve self-regulation, and reduce stress levels (Lawson et al., 2022). Through temporal analysis the research reinforces the argument to include sensory garments as assistive tools that extend beyond mere comfort to promote enhanced participation in social and educational settings. Khalid (2021) made a contribution by focusing on the design development of adaptive and sensory-friendly clothing for autistic children. Her work emphasizes practical design solutions like tagless labels, adjustable fasteners, seamless construction, and breathable fabric. Khalid's research indicates that clothes should strike a balance between therapeutic benefits and aesthetic value, enabling children with ASD to wear clothes that alleviate discomfort while preserving their sense of style and social identity.

Functional clothing development directly addresses sensory and tactile issues, though there is a deficiency in evidence concerning its long-term effects (Khalid, 2021). Quantifiable advantages are demonstrated in participation through experimental studies, while design-oriented research offers pragmatic methodology for garment

development. These collectively advocate for an interdisciplinary methodology that integrates design, sensory understanding, and occupational therapy to enhance clothing options for children with autism. Based on the literature review and the need for further research, the objectives of the study were framed as follows:

- To examine the efficacy of sensory processing interventions, encompassing clothing-based approaches, in the management of sensory sensitivities in autistic children.
- To evaluate the impact of sensory-based adaptive functional clothing on the engagement and daily functioning of children with Autism Spectrum Disorder (ASD).
- To explore adaptive and sensory-based apparel design that harmonizes comfort, aesthetics, and practicality for children with ASD.

Methodology

The research is an exploratory study that aided in getting insights into the sensory experience of clothing on autistic children, ultimately leading to an acceptable experimental approach to design development and sensory integration. A pretest-posttest repeated measures design was used for two weeks to examine if the sensory garment led to behavioral change in autistic children when in distress. Informed consents were provided by the parents and caregivers to undertake the study in the presence of clinical psychologists. Purposive sampling was followed to select 30 autistic children of age group 6-14 years from the Autistic Society of West Bengal. Each selected autistic child exhibited at least one sensory pattern that was either significantly different from typical patterns or less pronounced than those of their peers.

To gain a more comprehensive understanding of the psychological and behavioral indicators in children with Autism Spectrum Disorder (ASD) and to identify the appropriate design requirements, interviews were conducted in the presence of special educators and caregivers. Data was collected through a questionnaire based on a sensory assessment, and the chi-square test was employed to test the significance of the data. For sensory assessment, engagement and impact in four categories were highlighted as Category 1: Tactility on Daily Objects, Category 2: Tactility in Clothing, Category 3: Visual Sensation, and Category 4: Auditory Sensation. The chi-square test results, based on the observed and expected data values, are presented in Table 1 as $X^2a=1.23$, $X^2b=0.97$, $X^2c=2.35$, and $X^2d=0.17$.

Table 1: Data set based on sensory assessment for autistic children

Category A: Tactility on daily objects

	Agree		Neutral		Disagree		
	O	E	O	E	O	E	
Individual	17	15.55	10	8.34	28	31.10	55
Tally	24	25.44	12	13.65	54	50.89	90
	41		22		82		145
		(O-E) ² /E					Chi-Square
		0.12		0.28		0.34	1.23
		0.09		0.23		0.18	

Category B: Tactility in clothing

	Agree		Neutral		Disagree		
	O	E	O	E	O	E	
Individual	27	29.43	9	8.45	10	8.12	46
Tally	60	57.57	16	16.54	14	15.88	90
	87		25		24		136
		(O-E) ² /E					Chi-Square
		0.22		0.03		0.35	0.97
		0.10		0.02		0.25	

Category C: Visual sensation

	Agree		Neutral		Disagree		
	O	E	O	E	O	E	
Individual	18	18.22	6	5.33	24	24.44	48
Tally	23	22.77	6	6.66	31	30.55	60
	41		12		55		108
		(O-E) ² /E					Chi-Square
		0.00		0.07		0.01	0.17
		0.00		0.07		0.01	

Category D: Auditory sensation

	Agree		Neutral		Disagree		
	O	E	O	E	O	E	
Individual	28	32.13	13	9.66	27	26.2	68
Tally	75	70.87	18	21.33	57	57.79	150
	103		31		84		218
		(O-E) ² /E					Chi-Square
		0.61		0.86		0.02	2.35
		0.23		0.62		0.01	

At significance level 0.05, the chi-square values for all four categories are < 5.99 , showing that individual and tally are not statistically different with respect to the responses within the categories A, B, C, and D. Further, an ANOVA test was conducted for the four categories for both individual (Table 3) and tally responses (Table 4) based on the data set in Table 2. The results reveal that the p-values of the categories are much greater than the level of significance of 0.05, thus concluding that the categories are not significantly different under the responses in both the individual and tally cases. This assists in examining one or two categories extensively in the posttest survey.

Table 2: Data set on 4 categories of sensory assessment under individual and tally responses

Individual responses				
	A	B	C	D
Agree	17	27	28	18
Neutral	10	9	13	6
Disagree	28	10	27	24
Tally responses				
	A	B	C	D
Agree	24	60	75	23
Neutral	12	16	18	6
Disagree	54	14	57	31

Table 3: ANOVA for the four categories under individual responses

Source of Variation	SS	df	MS	F	P-value	F crit
Responses	442.17	2	221.08	5.62	0.042085	5.14325285
Categories	98.92	3	32.97	0.83	0.520142	4.75706266
Error	235.83	6	39.30			
Total	776.92	11				

Table 4: ANOVA for the four categories under tally responses

Source of Variation	SS	df	MS	F	P-value	F crit
Responses	2366	2	1183	3.65	0.0919	5.143253
Categories	1425	3	475	1.46	0.3154	4.757063
Error	1946	6	324.33			
Total	5737	11				

The research addresses a significant challenge in the design and development of sensory-based textile prototypes: the integration of conventional hardware components with textiles. Based on earlier research, three ways to attach off-the-shelf electrical devices to fabrics were provided. The first method involves fabricating fabric PCBs, or iron-on circuits, to directly attach electronics to a textile substrate; the second method involves incorporating electronic sequins to create wearable displays and other artifacts; and the third method involves implementing socket buttons to facilitate the connection of pluggable devices to textiles.

Textile structures can be categorized into woven, non-woven, and knitted fabrics. The motivation to integrate sensory mechanisms into knitted fabric arises from their use as stretchable material in the fabrication of laminated garments and also the level of comfort it can provide to the wearer. The fabric of choice for developing the garment as a foundation is knitted fleece. The kimono-styled (Figure 1) t-shirt, which features a detachable embellished kangaroo pocket, is designed as a pattern for children with autism. The t-shirt features a shoulder opening with a magnetic button closure for convenient wear. Adornment with LEDs and other components is sewn onto the kangaroo pocket as a surface embellishment in the form of an abstract tree design (Figure 2). This type of sequin is functional, durable, and significant in its capacity to imply a diverse range of designs.

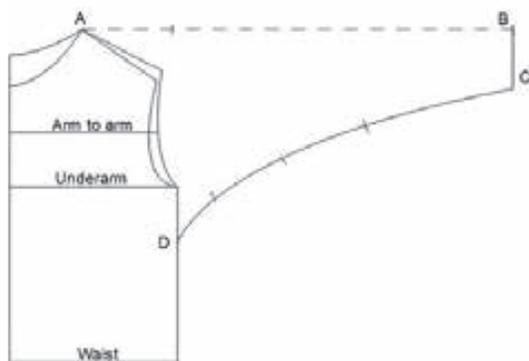


Figure 1: Kimono sleeve pattern



Figure 2: Surface embroidery using thread and LED sequins

The system design for the sensory mechanism (Figure 3) includes implementation steps as follows:

- Designing the input device: Choosing the appropriate touch sensor and integrating it with the microcontroller. The ATmega328P is the basis for the Arduino UNO

microcontroller board. It has 14 digital input/output pins (6 of which can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB port, a power jack, an ICSP header, and a reset button (Arduino, n.d.). It contains all necessary components to facilitate the microcontroller.

- Setting up the transceiver: Configure using the Wi-Fi module (ESP-8266 Node MCU 1.0) for communication. The ESP8266 Node MCU 1.0 module is a system on chip (SOC) microcontroller primarily utilized for the development of endpoint Internet of Things (IOT) applications. It is referred to as an independent wireless transceiver, available at a very economical price. It facilitates internet connectivity to various applications within embedded systems (Elprocus, n.d.).
- Designing the output device: Integrating the chosen output device (LED) with the receiver's microcontroller. Figure 4 denotes the block diagram for the sensory mechanism.

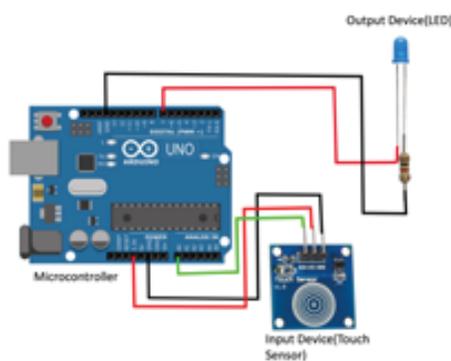


Figure 3: System design for the sensory mechanism

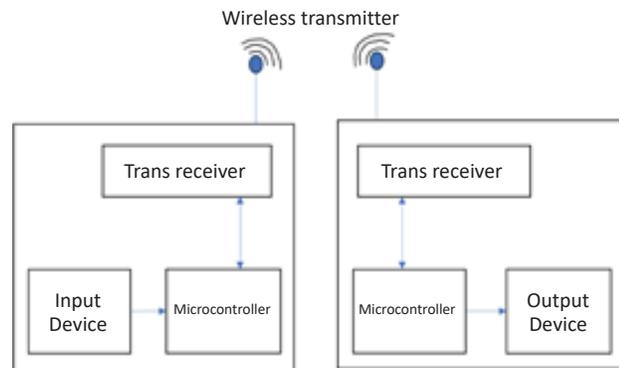


Figure 4: Block diagram for the sensory mechanism

Based on secondary research, interpretative phenomenological analysis was used to investigate design features that can be included in functional apparel to improve sensory experience. Interpretative phenomenological analysis was chosen over other qualitative methodologies since it focuses on the expressed experiences of individuals with specific social phenomena, in this case the tactile and visual sensations of autistic children through functional clothing.

Results and Discussion

The current research explores the possibility of combining interaction design with functional clothing, a relatively new and exciting segment of the technical textile group

that can be defined as a generic term including all types of clothing or assemblies that are specifically engineered to deliver a predefined performance or functionality to the user, in addition to its normal function (Pargai, Gahlot and Rani, 2015). It is ergonomically designed to have a minimal inhibiting influence on mobility while providing the autistic children with optimal comfort and performance.

The sensing mechanism is integrated into the functional garment, designed for prolonged close contact with the body. According to Chakrabarty (2019), sensory integration is a therapeutic strategy employed by practitioners to stimulate the child's neurological system, consequently facilitating the development of motor abilities, speech patterns, and appropriate socialization. An individual needs the following mechanism to self-regulate in relation to the environment:

- **Modulation:** The brain activates or deactivates neural switches to regulate its function and, consequently, an individual's activity level. The regulatory process is contingent upon the specific task or activity being performed.
- **Inhibition:** The brain diminishes the linkage between sensory input and behavioral response when specific sensory information is unnecessary for executing a certain activity.
- **Habituation:** The process by which an individual becomes acclimated to familiar sensory stimuli, resulting in the brain's automatic disregard of such inputs.
- **Facilitation:** The brain fosters connections between sensory input and behavioral output by transmitting signals of discomfort or satisfaction. Facilitation indicates when to cease activities or provides the cue to proceed with enjoyable pursuits.

The sensory mechanism embedded into the detachable kangaroo pocket of the kimono t-shirt considers variables linked to human-machine interaction, including comfort, mobility, usability, and aesthetics, and was meant for the purpose of modulation. It has augmented function and emphasizes the incorporation of technology with conventional garments, rendering the technology an integral component of the apparel. The Arduino touch sensor is one of the most basic forms of input devices that is both durable and straightforward to operate, requiring minimal physical effort. Thus, it is incorporated into the system design. The Arduino UNO microcontroller serves as the transceiver. It is equipped with a 16 MHz ceramic resonator, a USB (Universal Serial Bus) connection, a power port, an ICSP (In-Circuit Serial Programming) header, a reset button, and 14 digital input/output pins, six of which can be utilized as PWM (Pulse Width Modulation) outputs. The output device is in the form of an LED (light-emitting diode), which is

very cost-effective and simple to implement. It provides an immediate visual display in the form of light and was a facilitator in the design. The user interface is nuanced and depends on sensor input from both the user and the environment to automate tasks. It is engineered to be inconspicuous and to minimize the deliberate demands on users through the automation of functions.

People learn to adjust to their surroundings by using all of their senses, such as smell, sight, taste, sound, and touch. Sensory integration is the ability to put together information from different senses. It is essential for making sense of a situation and deciding what to do. Autistic children are more likely to have problems with touch than with other senses. Many kids with Autistic Spectrum Disorder are very afraid of being touched. These symptoms could be because of the clothes they wear or the tags and labels on them. When autistic kids are around things that make them feel bad, they feel emotional pain and worry. On the other hand, tactile modality is most often seen to provide people positive feelings when they think they can control it better.

As part of qualitative research, phenomenology, hermeneutics, and idiography are three philosophical approaches to interpretative phenomenological analysis. Phenomenology is a way to comprehend how people feel about things that are happening to them (Smith, Larkin and Flowers, 2009). The garment developed aroused immense curiosity among the autistic children, and they found it to be a playful product. Hermeneutics refers to the dynamic connection between the researchers' understanding of the participants' experiences and their own personal view of the results. The garment created interactivity for the autistic children, and like any other visual aid used for teaching schedules to perform daily activities independently, they found it to be one form of play. Idiography refers to the researcher's commitment to gather in-depth data in order to see things from the participant's perspective. The interactive experience of the autistic children paved a pathway to understanding that a garment can be a mode of playfulness, helping in creating a positive environment for the autistic child and reducing distress situations to a major extent. Autism Spectrum Disorder is a complex neurological disease that is difficult to comprehend completely. Every autistic child has unique and different needs that differ from other kids. Wearing clothes that are attractive, feel good, and are comfortable can greatly enhance the quality of life for these groups. The functional clothing design has the potential to provide tactile and visual sensory features for autistic individuals by including emotive consideration, which could promote social inclusion and improved adaptation for autistic children. Table 5 provides details about the prototype development aimed at fulfilling both functional requirements and sensory needs through touch and vision.

Table 5: Prototype development for tactile and visual sensory experience

S.No.	Functional clothing	Sensory implementation	Design description	Purpose
1.		Touch sensor as input device and light (LED) as output device	The tactile embroidery is created in the form of a geometric tree. Running stitch is used.	The natural motif of the embroidery helps the autistic children to relate to elements in the environment, enabling them to adapt in the social setup.
2.		The touch sensor and the LED are embedded in the detachable kangaroo pocket.	The double-layered detachable kangaroo pocket has a built-in circuit.	Constant stroking of the surface gives them playful experience within the garment.
3.		The output device (LED) is embroidered around the tree motif.	The kimono, which is two-colored and paneled, features a detachable kangaroo pocket. The detachable pocket has embroidery details for design interaction.	The embroidery with touch sensitivity will enable autistic children to experience tactile interaction and reduce behavioral issues like anxiety.
4.			The kimono has a magnetic closure at the shoulder, enabling hassle-free wearability, and the material used is cotton fleece.	The softer surface of the kimono helps in evoking stimulation in autistic children and helps them to feel calm and safe.

Prototype testing

Using the pretest-posttest repeated measures design as shown in Figure 5, three comparisons were made, that is, baseline: whether the outcome changes over the first week's wait period without any intervention; intervention: whether the intervention is effective; and post-test: whether there are overall changes from the first to the last meeting. 32 children having Autism Spectrum Disorder within the age group of 6-14 years were selected to carry out the testing. One parent dropped out after the baseline period without providing any reason, and one child refused to wear the garment, saying that he did not like the design. The final sample included 30 autistic children who participated in the testing process.

The study explored the effect of sensory-based functional clothing on the behavioral containment of autistic children. The various findings suggested that the children or their caregivers selecting sensory garment may improve adaptation to sudden surges of stimuli containing behaviors like anxiety, aggression, etc. This is consistent with the evidence showing significant and meaningful improvements in autistic children's attitudes and behaviors. The paired t-test shows a p-value $\approx 6.46 \times 10^{-14}$ which is far below 0.05, showing significant improvement in satisfaction level after using the sensory-based adaptive functional clothing.

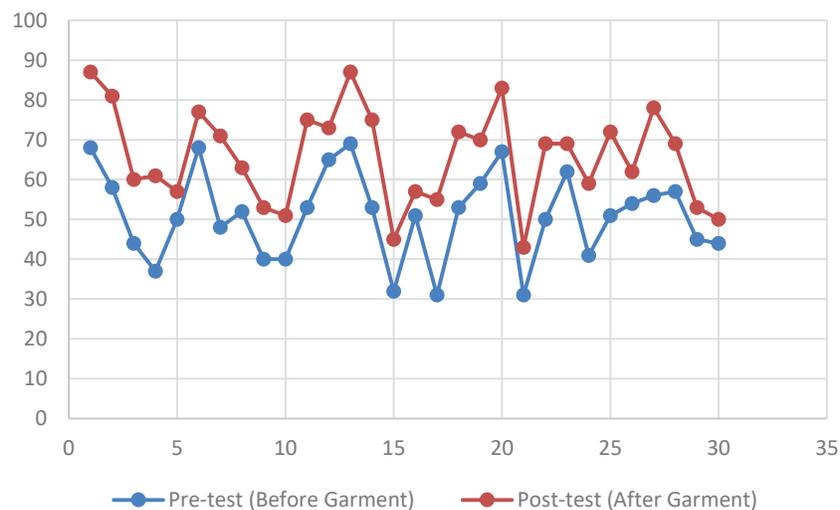


Figure 5: Graph showing satisfaction level during testing of prototype

Conclusion

Children with autism have a lifelong condition that impacts their capacity to communicate, interact with others, and control their behaviors. Due to their heightened physical sensitivity compared to typical individuals, children with autism often feel

overwhelmed by their surroundings, primarily because of sensory processing issues. This can make it challenging for them to understand and adapt to their environment, leading to increased anxiety. In the present research, integration of functional clothing with sensory design has been shown through a design direction by incorporating touch-sensitive surface ornamentation in the form of embroidery where an output device in the form of light (LED) is embedded in the tree motif, inspired by nature, and is operated by a touch sensor input device. The textured surface placements in the form of design detailing on the garments give the autistic child easy access to tactile and visual sensory experiences, enabling them to cope and adapt to change efficiently. The goal of this research was to produce a corpus of meaningful work that could be interacted with in order to provide children with autism spectrum disorders with good and engaging experiences. The research highlighted limited design considerations given to autistic children and awakened the nascent need for sensory-based functional clothing, thereby aiding autistic children and building a platform for design addressing disability.

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