Compression Garments: Informed by Sensory Integration Dysfunction.

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Abstract
This paper describes a user focused approach to the design of made-to-measure pressure emitting contemporary garments for children who are affected by the development disorder sensory integrative dysfunction (SID). These garments aim to aid the integration of tactile (touch), vestibular (movement) and proprioceptive (body position) sensations. The approach builds on previous pressure garment studies and design, focusing on the extension of the fabrication within the pressure providing textile structures. An individual case study informed the garment design. New directions in the development and prototyping of pressure garments are explored and enhanced through collaboration with the wearer, his family and therapists. The design process informs and addresses the needs of the child and his support community.

Keywords
Pressure Garments**,** Sensory Integration Dysfunction **(**SID)**,** User Focused,

Context
My personal interest in a user focused approach to garment design stems from the experience of running a small made-to-measure business. A number of my clients had physical disabilities. Frequently clients offered possible garment engineering solutions to their individual clothing problems. I enjoyed this collaborative approach to designing and making. I now have a family member with an Autism Spectrum Disorder (ASD). Many of his sensory needs relate directly to clothing. Part of his early intervention therapy included wearing a weighted vest, which was unappealing on a visual and practical level. This experience motivated me to questioning the lack of functional, appealing and inclusive clothing for children needing sensory stimulation input from garments.

Sensory Integration
Sensory integration is the ‘putting together’ of sensation. All the information we receive from our body and surroundings comes to us through our sensory systems. The reception and processing of tactile or touch sensation is dealt with by two systems. We have both protective and discriminative mechanisms. Our protective touch system

responds to light and unexpected touch. Our discriminative touch system tells us when we are being touched, what we are touching and in which places.

Our vestibular system integrates our awareness of movement. It tells us where our body is in relation to gravity and whether it is moving and how fast. The movement receptors are located in the inner ear and are important for body posture, balance, muscle tone and bilateral integration [1].

Proprioception is the sense that gives us an awareness of body position. Messages from our muscles, tendons and joints let us know where we are in space and how our limbs are moving, including the force of movement and the effect of gravity [1].

Sensory Integration Dysfunction (SID)

In everyday life, we are not often aware of any one sense; they usually work together and integrate in an automatic way, providing us with a sense of who we are. Sensory Integration gives meaning to sensations and enables us to formulate a plan of action. When sensory information does not integrate in the brain as it should, the brain cannot adequately sort out, filter, analyse or organise sensory messages. This is known as sensory integration dysfunction (SID).

With this condition a person is unable to use sensory information in order to respond and behave in a consistent and meaningful way. Some signs of the dysfunction include being over sensitive or under reactive to sensation such as touch, movement, sight and sounds, as well as experiencing difficulties in organisation of behaviour, such as planning and carrying out everyday activities [2].

SID is commonly classified into specific types using frameworks to identify levels and relationships within the individual's dysfunction, Somatodyspraxia is a specific type associated with processing tactile, vestibular, and proprioceptive sensations [3].

Somatodyspraxia is the dysfunction of focus in this study. Children with Somatodysparaxia struggle to manage the bewildering whirl of sensation. In order to simplify and reduce this extraneous noise they may seek additional sensory feedback in the form of deep pressure sensation. For example a child may curl up inside a small cardboard box, seeking deep pressure feedback. Children may repeatedly seek out this stimulation and may resort to self injuring or risky behaviour in their desperation to get a sense of order or personal control.

Existing treatments

Dr Jean Ayres [4] an Occupational Therapist working in this field in the 1960's discovered that wrapping a SID child in a gym mat caused a significant calming in mood, and better regulation of behaviour. She also noticed that people often preferred to provide this feedback themselves, avoiding tactile stimulation controlled by others.

Temple Grandin [5] is a high functioning adult with ASD who designs cattle management systems and is well known for her work around the world. She noticed that when cattle were placed in a special cradle for example, in a cattle yard in order to allow vaccination, they received firm pressure over their body from this cradle and they calmed significantly in an otherwise very stressful situation. Grandin wondered whether this controlled pressure system would have a similar benefit for her. So she tried it! She developed her own squeeze machine so she could self administer pressure as required. This machine reduced her anxiety, increased her tolerance of touch and made a significant difference in her quality of life.

A number of products to wear or drape on the body are now available, mainly through occupational therapy catalogues and via the internet. These garments range from

weighted collars and vests, shoulder wraps, belts, through to snug sleeping bags which provide both pressure and comfort for the user. [i] Therapists advise that any source of constant pressure below pain perception threshold ceases to be registered as stimulation over time, and becomes ignored or acclimatised to. This phenomenon is called habituation. To avoid it, stimuli must be applied, and then withdrawn, before the perception of sensation is extinguished [6].

Many parents and therapists adapt an item of existing clothing to create a therapeutic garment. I observed these modified garments were noticeably different from age-appropriate contemporary clothing. I also wondered whether an all-or-nothing weight application system could be improved upon, as self administered, variable sensation is preferred.

Design and testing of pressure garments

I considered how to incorporate a feature into a garment that would allow the wearer to discretely administer pressure, to control pressure location, strength of pressure and pressure duration. I then set about designing a made-to-measure contemporary garment with an inbuilt invisible pressure delivery system that provided the wearer with multiple deep pressure delivery options.

An individual pilot case study was proposed. The subject was an eight year old boy named Ben (pseudonym). Observations, self-reports and interviews with caregivers and therapists provided information about Ben's needs, his sensory integrative issues and stimulatory behaviours, as well as his clothing preferences. The design process provided the methodological framework for this study.

Two focal questions were identified, to address how best to customise a garment to meet Ben's deep pressure seeking needs.

1. How could deep pressure needs be met using textile tension rather than weight?

2. How could we best address the variation in frequency and intensity of the subject's deep pressure seeking needs?

Toile 1

Devising a system of pressure delivery which Ben had complete control over was essential. A singlet shape was selected as it is a form-fitting foundation garment, invisible under a school uniform and could be modified to provide pressure in the specific areas where it was required - across Ben's shoulders, chest, back and hips. Smooth, soft handle, shape retentive Lycra fabric was chosen for comfort and non-restrictiveness as well as ease with which it could be put on and taken off by the wearer. Soft, non-roll woven rubber/elastic was selected for the built-in pressure delivery system. Strips of elastic were placed around chest, below armpits and in an X-shape front and back also at the garment hip line (Figure 1).

This prototype toile considered support placement needs but not wearer adjustability. Ben said "Cool Mum, it's squashing me". As expected, the deep pressure effect was noticeable initially and then of less consequence over time, due to habituation. Ben still sought additional feedback, therefore garment adjustability was essential. This toile delivered equal compressive pressure front and back. Observation of Ben's contentment when lying on his back suggested increased pressure on his upper back would be beneficial.

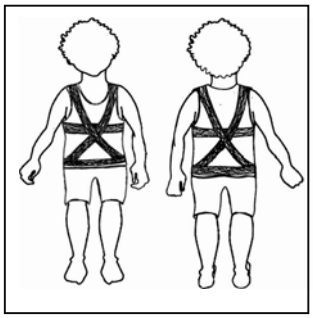

Figure 1: Toile 1

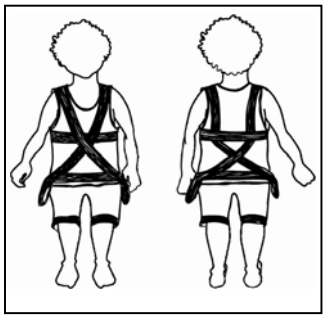

Figure 2: Toile 2

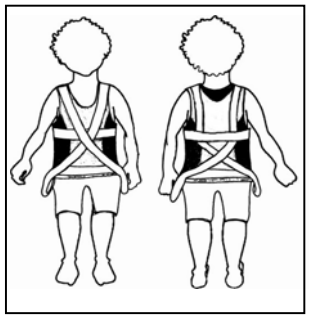

Figure 3: Toile 3

Toile 2

In order to facilitate wearer controlled garment manipulation and increase the pressure delivered to Ben's back the following modifications were incorporated. Elastic was placed on the outside of the garment within satin ribbon casing with a handle length protruding from the casing at the side of the garment on hip level. The joined elastic strips of the handle formed a 'V' shape, which Ben could grasp and pull to increase the amount of sensory feedback delivered to the front and back of his body. He was able to adjust the pressure delivery with the strength and direction of his pull. In addition, by activating his upper limbs, Ben gained valuable proprioceptive feedback and a satisfying feeling of working muscles and joints. To improve the delivery of deep pressure sensation to the back of Ben's body the elasticised 'X' shape on the back of the garment was altered so that two strips sat perpendicular to the shoulder blades and joined the chest band of elastic at ninety-degree angles. The elastic below the chest band formed an 'X' shape. The crossing point was the mid-back (Figure 2).

This design served a dual purpose, giving pressure where needed and providing a stable support structure on a Lycra/elastic combination garment. These modifications proved successful. When Ben used the handles he felt firm and direct pressure across his shoulder blades and back. He told his parents he was transforming (a reference to popular concept toys which transform when manipulated from sleek mechanical objects to robots), delightful feedback for everyone involved in Ben's care.

Ben understood immediately how to operate the garment handles in order to tighten the singlet at will. His delight was obvious. He was also able to utilise the handles without prompting. Ben showed enthusiasm for his customised garment, selecting it to wear when given choices. His parents appreciated that a therapeutic garment could be completely discreet. Significantly Ben sought less additional deep pressure stimuli while wearing his garment and seated in a learning situation. When engaged in outdoor activities, it appeared helpful but a little less effective, as he still sought direct physical contact from his peers and adults. However, this behaviour may also have a communicatory function. Significant improvements in Ben's functioning and well-being were observed during the trial period.

Toile 3

Since the initial pilot case study a number of pressure emitting singlets have been constructed for Ben. In addition to the enlarged sizing, to fit the growing boy, varied elastic textiles have been trialled. Increases in stretch qualities of domestically sourced Lycra elastane fabrics has lead to the garments being cut in form fitting panels to achieve a more streamline appearance. Resulting in a more intense 'hugging' of Ben's

torso, elastic strips continue to provide the self-organising system, whilst maintaining Ben's moveability (Figure 3).

The ribbon casing has been replaced with smooth handle Lycra, resulting in the whole garment returning more evenly to its original size and shape after the internal elastic strips have been pulled by Ben. Unfortunately these elastic strips have a limited recovery lifetime as they progressively soften and lengthen, eventually becoming slack, therefore ceasing to provide the desired pressure. Construction techniques within the pressure garments have also been limited by inadequate access to commercial machinery, and my personal skills.

Fabrication of contemporary pressure-providing textiles

Observations of the inclusion of pressure emitting textiles within sophisticated sportswear, led to the next stage of my process: design research derived from the advances in textile and garment technologies within contemporary sports apparel.

A relationship between athletes wearing compression garments and their muscle performance has been the focus of a number of studies [7]. Findings consistently show wearers of compression garments have increased accuracy of perception of movement (proprioception). Vestibular sense is also helped through wearing compression garments, subjects described a better sense of where they were and how their body was moving and positioned in space. It is noted the Lycra elastane fabric '…does this by exerting subtle pressure on the nerve receptors in the skin, muscles and joints' p.216. The type of compression garment and amount of Lycra did affect responses. Garments need to include enough compression to enhance perception while retaining mobility.

Optimal sports compression garments are also utilizing elasticised knitwear constructions techniques. Wear comfort is achieved through a blending of fibres (nylon & Lycra) and knit structures (rib and honeycomb) that are soft to the skin. High-tech seamless whole garment knitting technologies, teamed up with three-dimensional body scanning and modelling, enables precisely engineered garments.

Future direction

The next logical step to continue the development of the prototype made-to-measure garments addressing SID is to cross over into a more commercial apparel environment. This direction will enable the possible uptake of high-tech fabrications and construction methods currently functioning in the development of compression sportswear.

Whole garment knitting technologies will enable the all-in-one construction of the garment shell and inclusion of knitted tubes will encase the elasticised strips, allowing a more unified complete garment. Industry strength elastic pull strip will decrease the likelihood of non-retention and stretching over prolong use.

My initial questioning of the lack of functional, appealing and inclusive clothing for children needing sensory stimulation input from garments, has within this individual case, been effectively addressed as a descent undergarment. There may be a variety of people who could benefit from customized pressure garments, potential clients include individuals with mental health issues such as anxiety or physical problems arising from neurological injuries [8].

As performance sportswear continues to position itself more as leisurewear, appearance and fabrication of compression garments is likely to be even further

mainstreamed. Garments that specifically address sensory integration could sit alongside stylish and fashionable streetwear.

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Figure Credits

Figures 1-3. Authors working drawings.

Endnote.

[i] http://www.sencostuff.co.uk/1105-body-awareness?orderby=name&orderway=asc