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**Investigation into the Development of Children's Apparel that Addresses  
Sensory Integration Dysfunction.**

**Abstract**

This paper discusses an ongoing research project which provides context for the development of garments that aid in the integration of tactile (touch), vestibular (movement) and proprioceptive (body position) sensations for children who live with the developmental disorder sensory integration dysfunction. This dysfunction prevents the sufferer integrating sensory information in order to behave in a consistent & meaningful way (Cribbin, Lynch, Bagshawe, & Chadwick, 2003). Garment interventions have been shown to be effective in addressing this disorder (Grandin, 1995). My concern is of the lack of functional, appealing and inclusive clothing for children seeking sensory stimulation input from garments. The research study begins with a focus on understanding sensory integration dysfunction and existing treatments, in particular methods that provide deep pressure. Development of garments uses the framework of single case studies for each client (child who has sensory integration dysfunction) in conjunction with the use of the design process to inform the overall design. Possibilities of modular components that can be

individually tailored are explored. The study deepens interdisciplinary knowledge to inform this specialised area of garment design.

## **Introduction**

The long term aim of this study is to design and manufacture customised contemporary garments for children with sensory integrative issues arising from the developmental disorder sensory integration dysfunction (SID). Garments which allow the wearer to modify sensation, specifically the experience of deep pressure, in order to effect a sought internal state change of a; physiological, cognitive or psychological nature. This process assists the garment wearer's integration of tactile (touch), vestibular (movement) and proprioceptive (body position) sensations which 'normalises' behaviour by reducing symptoms, as well it facilitates improvements in daily life functioning and well-being. This topic originated from my personal questioning regarding the lack of functional, appealing and discreet clothing for children which addressed the need for specific sensory feedback.

This preliminary research study involves a simple individual case study pilot project and proposes an elaborated methodology for use in a future case study. The literature review begins with a consideration of what sensory integration and SID are, before considering the effectiveness of different types of deep pressure sensory feedback as a therapeutic tool.

## **Literature Review**

### **Sensory Integration**

The concept of sensory integration developed during the 1960's from a body of work by occupational therapist A. Jean Ayres. The way in which sensory processing and motor planning disorders interfere with learning and daily life interested Dr Ayres (Cribbin, Lynch, Bagshawe, & Chadwick, 2003). Since then sensory integration theory has evolved into one of the most studied and developed theoretical frameworks in occupational theory (Cermak, 1994). Sensory integration is defined by Ayres (1979) as

“The organization of sensory input for use. The ‘use’ may be a perception of the body or the world, or an adaptive response, or a learning process, or the development of some neural function. Through sensory integration, the many parts of the nervous system work together so that a person can interact with the environment effectively and experience appropriate satisfaction” (:184).

All the information we receive from our body and surroundings comes to us through our sensory systems. Our seven senses; touch (tactile), movement (vestibular), body position (proprioception), sight (vision) sound (auditory) smell (olfactory) and taste (gustatory), gather information which then enters our brain where it is organised and interpreted (Cribbin, et al., 2003). It provides us with a sense of who we are.

### What is Sensory Integration Dysfunction?

When sensory information does not integrate in the brain as it should, or the brain cannot sort out, filter, analyse or organise sensory messages this is known as SID (Ayres, 1979). As a result a person experiencing this disability is unable to respond to sensory information in order to behave in a consistent and meaningful way (Cribbin, et al., 2003).

There are many signs of SID. These include; over or under sensitivity and reactivity to touch, movement, sight and sounds, co-ordination difficulties, in relation to whole body and/or fine hand movements, as well as complications in organisation of behaviour, such as planning and carrying out everyday activities (Cribbin, et al., 2003). Children living with SID often have other issues such as; impaired motor development, a learning disability or nervous system and brain disorders, such as autism (Fisher & Murray, 1991).

SID is commonly classified into specific types, using frameworks to identify levels and relationships within the individual's dysfunction. One of these is somatodyspraxia, which is a focus in this study. It is a specific type of dysfunction associated with processing tactile, vestibular, and proprioceptive sensations (Bundy & Murray, 2002).

### Treatment of Sensory Integration Dysfunction

Historically children with SID including somatodyspraxia have been effectively treated by the application of deep pressure sensation in order to lessen anxiety and arousal. For example Ayres (1979) reported that wrapping a child with SID in a gym mat produces a calming effect. This is not such a foreign reality; as across most cultures newborns are swaddled, many of us relate to the stress relieving properties of massage or the security provided by a hug.

It is not just those who have significant perceptual problems who show positive responses to deep pressure sensation. Normal adults reported an air mattress apparatus that applied squeezing pressure to the body enhanced relaxation and reduced anxiety (Krauss, 1987).

There have been a number of studies which have considered the application of deep pressure sensation as a SID symptom management tool. Most have involved the wearing of weighted or compressive pressure garments, without a self adjustment

facility, by people who repeatedly show either conscious or unconscious sensory feedback seeking behaviour. Researchers have then observed or monitored and reported behavioural change.

### Weighted Garments

Fertel-Daly, Bedell & Hinojosa (2001) examined the effectiveness of using weighted vests in preschool children with a form of SID known as pervasive developmental disorder (PDD). Generally the children's attention span increased while self-stimulatory behaviour reduced, (this is repetitive, introverted and possibly soothing activity; such as looking at light through rapidly flicking fingers). However they concluded that additional research is needed to build consensus regarding the effects of wearing weighted vests.

Grandin (1995), a Texan university lecturer who has autism and sensory integration issues has described the sensory feedback benefits of a padded and weighted vest,<sup>1</sup> as well as snug Egyptian mummy-type sleeping bags which provide both pressure and comfort.

There are a number of therapeutic products prescribed by occupational therapists to wear or drape on the body which provide deep pressure sensory feedback. The range includes weighted collars, torso garments, weighted cushions to be placed on

a lap while sitting, or quilts to provide extra weight while lying ("The Adaptive Child," 2007).<sup>2</sup> Many of these items are also available for purchase without a specialist prescription via the internet.

### Pressure Garments

A case study of a thirteen year old boy with severe autism and developmental delay, who received deep pressure via the application of padded and wrapped arm splints, saw a reduction during splint wearing of self stimulating and self injuring behaviour. Once splints were removed he sought alternative deep pressure input by wrapping his arms in fabric and stuffing cloth inside his shirt (McClure & Holtz -Yotz, 1991). Zisserman (1992) monitored self-stimulatory behaviours, such as the banging of hands together and hitting of surfaces, of an eight-year-old girl with autism, while she wore an anti-burn scar pressure garment which provided deep pressure sensory feedback. Both during the wearing of the scar pressure garment and in earlier observations of the child while wearing arm length gloves made from support pantyhose, the normally frequently evident self stimulatory behaviour of banging hands together decreased.

### Self - Administered Deep Pressure Sensation

Temple Grandin is a world authority on the humane management pre-slaughter of farmed animals. Interestingly Grandin noticed that when cattle are placed in a customised cradle which restricted them while applying pressure, they calmed considerably. This raised her curiosity. After trying the cattle system herself, she

developed a human squeeze machine prototype<sup>3</sup> in order to self administer pressure over her own body surface. She observed significant anxiety reduction, increased ability to focus and to tolerate touch (Grandin, 2000).

A pilot study undertaken during 1999 by Edelson, Edelson, Kerr, & Grandin, investigated the effects of self-administration of lateral body deep pressure on arousal and anxiety reduction in children with autism, using Temple Grandin's Squeeze (Hug) Machine. Two groups of six children with autism were studied over a period of six weeks. One group; the experimental group, received deep pressure, and the other placebo group, did not. The arousal levels of the children were measured behaviourally using Conners Parent Rating Scale (1978) and physiologically using galvanic skin response readings. Their preliminary finding was that deep pressure may have had a calming effect, especially for children who are anxious.

As early as the 1970's researchers reported people with SID calming themselves by seeking deep pressure, and that they often preferred to provide this stimulation themselves, frequently avoiding tactile stimulation controlled by others (Delacato, 1974 cited in Edelson, et al., 1999).

Utilising Clothing to Provide Deep Pressure Sensation



Dress-up themed costumes<sup>4</sup> are available, designed specifically to consider SID issues for pre-school wearers during play therapy sessions (Blacksburg, 2004).

Developing a customised garment which is portable, comfortable, everyday wear that incorporates a discrete means of self-administering additional deep pressure sensation, as required, is a logical next step.

### Refining the Research Focus

When considering the perspectives of families who live day to day with the reality of SID, Williamson & Anzalone (1997) (cited in Case-Smith & Bryan, 1999) described three important focuses for research.

These are:

1. "Helping parents understand their child's behaviour and foster nurturing relationships.
2. Helping parents and teachers modify the environment so that it matches the child's sensory needs.
3. Helping children organise responses to sensory input" (: 490).

The second and third points defined by Williamson & Anzalone (1997) are of importance to this research. The design and development of a customised clothing item which enables the wearer to address their sensory needs by manipulating this garment is a particular focus. The reviewed studies investigating treatment of SID by applied deep pressure have focused predominately on the use of traditional

therapeutic garments rather than comfortable, discrete contemporary wear. What is useful in relation to my study is the generally positive response of participants to the application of deep pressure via weighted or compression garments. However an anti-scar pressure garment is not easily manipulated by the wearer, as it is difficult to put on and remove. It can restrict movement and is not common in a playground environment. Significantly an anti-scarring garment delivers a constant maximum pressure. This is not an appropriate way to meet the 'squeeze needs' of a child with sensory integrative issues. Any source of constant pressure below pain perception threshold ceases to be registered as stimulation over time and becomes ignored or acclimatised too. This phenomenon is called habituation. To avoid this, stimuli must be applied then withdrawn, before the perception of sensation is extinguished (Joe, 1998. Zissermann,1992).

### **Design and Methodology**

After reviewing the relevant literature, a pilot case study of one child, an eight-year-old boy renamed "Ben", with significant SID issues was proposed as a simple introductory study. The rationale being that some of the child's sensory integrative issues will be unique and therefore best addressed individually, also that this will constitute an effective first trial of the study's methodology.

The functional design process and strategy selection outlined by Watkins (1984) in 'Clothing; The Portable Environment' informed the relationship forged between researcher/designer and the client in relation to his internal and external environments. This was the process.

1. The creative problem is defined.
2. What are the sensory integrative issues this individual has?
3. How can a garment be customised to best meet client needs?
4. Development of a toile.
5. Trialling of toile across activities and environments.
6. Evaluation of effectiveness - how well the design meets needs.
7. Revise toile as appropriate.
8. If necessary revisit 4, 5, 6 & 7 until number 3 has been achieved.

The personalisation of the design process in this case study is as follows:

1. There are no contemporary wearable and discrete therapy garments which address this child's (Ben) current sensory integrative issues.
2. Ben's sensory integrative issues are complex. They can be summarised into the following categories
  - Touch processing - abnormal perception of touch stimuli (hyper-sensitivity as well as low reactivity).
  - Multi-sensory processing - difficulties with the simultaneous interpretation of multiple sensory stimuli.
  - Vestibular processing - balance problems.
  - Proprioceptive modulation - perceptual difficulties with awareness of body position and movement in space.

These issues have a significant effect on Ben's psychological well-being as well as his capacity to engage in age appropriate daily life activities.

Ben's mother and teachers have observed that the child craves deep pressure and seeks out activities that fulfil this need. He is often seen hugging or pushing into caregivers, peers and furniture, or crawling on all fours. He particularly enjoys being in small spaces, such as boxes, cupboards or under his desk at school, and often squeezes between mats and pillows. When stressed he can be invited to participate in calming sensory activities. With encouragement he will engage in carrying or pushing heavy objects. He appreciates a firm bear hug, deep pressure massage, joint compression or being allowed to retreat to the comfort of being under heavy pillows. These activities have been suggested by occupational therapists. Together the multidisciplinary therapy team, (which includes occupational therapist, speech and language therapist, specialist teachers) as well as classroom teachers and parents, have devised a sensory diet which assists Ben to reach and sustain desired levels of arousal, in order to be able to function maximally in daily life; at school, in his therapy settings and at home. This includes garment recommendations and the use of therapeutic media such as a weighted vest. As Ben has got older he has become increasingly able to self regulate his deep pressure seeking behaviour. He will now ask for a 'wrestle' or to be 'sat-on', and will seek out small spaces when necessary.

3. How can a garment be customised to best address Ben's sensory integrative issues arising from his experience of somatodyspraxia, as well as his needs as an active, eight-year-old child?

Mother reported Ben's preference for firm fitted clothing, particularly on torso. She found the weighted vest helpful if Ben experiencing anxiety and hyperactivity. However sometimes more practical to physically compress or 'squash' Ben rather than add extra clothing during a period of agitation. Once compressed, he would become calmer and return to task.

The questions then are;

Can a customised piece of clothing meet sought deep pressure needs using fabric pressure rather than weight to provide this feedback?

The work of numerous researchers; such as Krauss, (1987) Zissermann, (1992) McClure & Holtz-Yotz, (1991) and Edelson, et al., (1999) indicate that applied pressure addresses squeeze seeking needs effectively. Using pressure rather than a weighted garment, has the advantage of being practical outside the therapy environment, as it is invisible and more readily adjustable.

As deep pressure seeking behaviour varies in frequency and intensity (of sought feedback), within each individual, how can a garment address these issues?

Ben's need for pressure is a constant feature in his day, however time spent sourcing feedback, as well as the quantity or intensity needed has been observed to vary greatly over the course of the day. To solve this, an adjustable system, which Ben is in control of, is required. This will circumvent the problem of habituation or acclimatising to sensation, as pressure will be applied and then released, allowing the beneficial effects of pressure to be optimised.

Can the amount of pressure delivered by the garment be assessed?

In order to obtain a full and objective assessment of Ben's customised garment's effectiveness, a baseline measure is required of the passive compressive pressure delivered to the skin by the garment's inherent or 'at rest' fabric tension (i.e. without the inclusion of additional self-administered pressure). Some experimentation using toiles may be necessary in order to establish the optimum baseline pressure for this child, as it may well vary from normal ranges. A new measuring device, called the 'Textilpress' developed by the Tricotextil Institute in Poland, utilises an ingenious indirect means of assessing compressive pressure

(Bogdan, 2006). Maklewska, Nawrocki, Kowalski, Andrezejewska, & Kuzanski (2007) found this tool highly valuable when investigating the actual pressure delivered by pre-rated compressive pressure textile dressings used to prevent scars. A cylinder comparable in size to the relevant human body part was covered in neoprene to simulate the skin's surface. A band of knitted elastic fabric which has been sized according to the parameters of La Place Law will have the same compressive pressure against the model's neoprene skin, as that of a pre-rated burns dressing when worn on a cylindrical body part of the same diameter. La Place (1806) (cited in Maklewska, et al., 2007) established that, pressure equals tension divided by radius  $P = T \div R$ . If the diameter of a cylinder increases, as occurs when a child's chest and hips grow wider but the tension is not increased, for instance, as they continue wearing last year's swimsuit, rather than a larger size, the garment's compressive pressure against the skin at the now expanded sites will be lower. This is because the textile fibres are stretched to cover a wider area. (Liu, Kwok, Li, Lao, & Zhang, 2006). Using the La Place equation, variations in body circumference can be accommodated by manipulating the fabric quantity so that the delivery of pressure can be kept constant. The 'Textilpress' uses a sophisticated matrix system to provide an indirect measurement of pressure and is ideally suited for use with children, as it does not require they keep still, as in a direct method of baseline assessment.

In addition to baseline measurement, a wearable and built in pressure assessment tool is required in order to monitor pressure delivery at specific body sites when in use and in situ. This will prove more difficult as the proposed tool requires the worn garment be wired to a computer for load analysing. A flexible elastomeric textile which is pressure sensitive such as Dynacon C® (Dynacon Industries, Leonia, New Jersey, USA) has a conductive substrate. When compressed its electrical conductivity increases (Watkins, 1984). Sensors can be made of aluminium film placed either side of a piece of Dynacon C®. When insulated they can be incorporated into the child's garment. The conducted impulse is read, and then the load analysing programme calculates the pressure being administered to the body surface in kilograms per centimetre squared (Watkins, 1984).

This study proposes that a customised strategic overlay or matrix of elasticised webbing built into a garment will allow the child to deliver additional pressure to his body, as and when required. Recording and decoding this will yield a map, of the amount and duration of pressure delivered to the skin surface, which can then be cross-matched to independent observations of activity and psychological state. It will then be possible to see whether a correlation exists between these variables, and to accurately assess the garments effect on experience and behaviour. This information will address the question of whether the self-operated pressure delivery system facilitates an improvement in the child's functioning and well-being.



The following specifications were initially devised for Ben's customised garment.

- Firm form fitting upper body garment to be worn under school uniform.
- Smooth, soft handling, firm fit and shape retentive fabric.
- Additional in built support across Ben's shoulders, chest, back and hips, utilising compressive force rather than applied weight.
- Allowing full range of movement.
- Wearer controlled method of garment manipulation (subsequently added see 7. Revised Toile).

Singlet shape selected as invisible under uniform and allows the addressing of particular areas where deep pressure sought. Smooth soft handle lycra/nylon fabric selected for stretch capability, shape retention, non restrictiveness as well as ease with which the completed garment can be put on and taken off wearer's body. Soft non-roll woven rubber/elastic will give garment additional built in support, chosen for its strength,

stability, shape retention and laundering qualities. Fine, wide and smooth satin ribbon used to encase elastic.

#### 4. Toile Development.

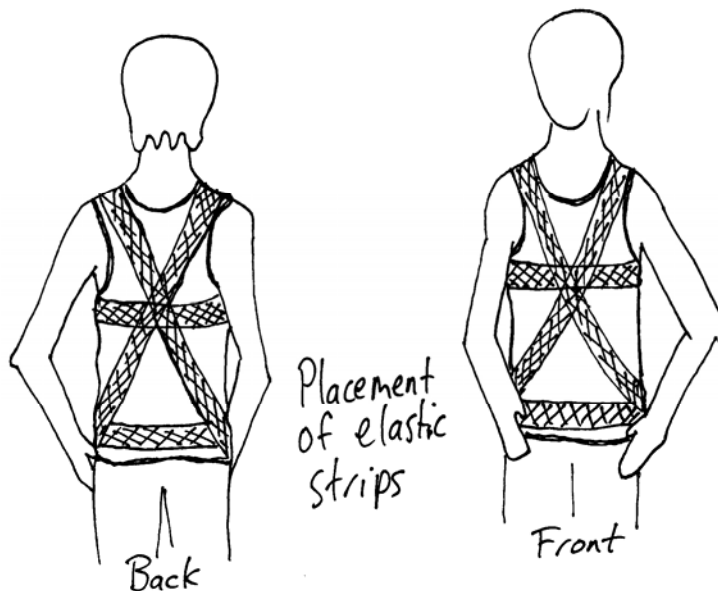


Figure 1. Placement of elastic strips within garment.

Construction of body hugging lycra singlet with extra length to cover hips (Figure 1.). Elastic was directly sewn to inside of garment crossing the torso in lines, forming an 'X' shape front and back delivering compression to chest and back but avoiding the stomach. Strips of elastic were placed around chest below arm pits and at hip line of garment. These are body areas where additional sensation frequently sought. This toile considered support placement needs but not wearer adjustability. Ben said "Cool Mum, it's squashing me."

#### 5 & 6. Trialling and Evaluation.

Garment trialled in home, school and therapy environments. Dressing assistance required as on/off ease less than desired. As expected, deep pressure effect noticeable initially and then of less consequence over time, due to habituation. As Ben still sought additional feedback in classroom, garment adjustability is essential. Current garment delivers equal compressive pressure front and back. Observation of Ben's enjoyment of supine postures (lying on back) suggests increased pressure on upper back could be beneficial.

## 7. Revised Toile

In order to facilitate garment manipulation the following design alterations were incorporated.

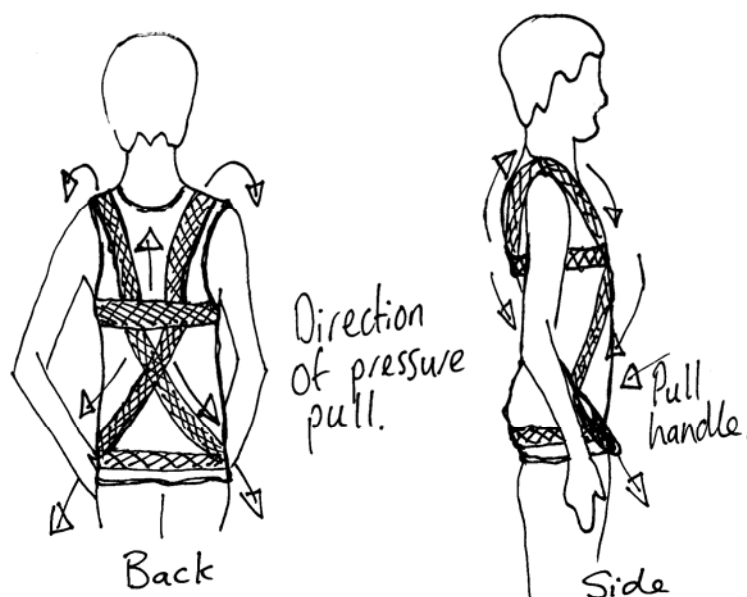


Figure 2. Placement of elastic strips on garment.

The elastic was placed on the outside of garment within satin ribbon casing with a handle length protruding from casing at the side of the garment on hip

level (Figure 2). The joined elastic strips of the handle form a 'V' shape, which Ben can grasp and pull to increase the amount of sensory feedback delivered to the front and back of his body. He can adjust the pressure delivery with the strength and direction of his pull. In addition by activating upper limbs Ben gains 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 elasticated 'X' shape on the back of the garment was altered, so that two strips now sat perpendicular to the shoulder blades and joined the chest band of elastic at ninety degree angles. The elastic below the chest band forms an 'X' shape. The crossing point is the mid-back (lower thoracic) region. This serves 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, 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 robots to sleek mechanical objects). This was delightful feedback for all of us.

### **Results and Concluding Discussion**

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 classroom 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.

Parents, teachers and therapists observed improvements in functioning and well-being. When wearing the garment Ben's teacher aide observed his attention span increased, his concentration improved and he remained on task for longer periods. Over a one month period Ben engaged more purposefully in one-to-one and group activities, completing more set work. Parents and teachers were thrilled with progress. Ben enjoyed the resulting acknowledgement. Periods of anxiety, tantrums and non-compliance with requests reduced, which everyone appreciated. Ben is choosing to wear his garment most days.

### **Future Directions**

Further design modifications:

- Use of indirect and direct in-built pressure measurement tools to obtain objective data.

- Hide in-built support system beneath an additional layer.
- Locate handles inside pockets at hip level for increased discretion.
- Devise contemporary fashion outer garment in appealing colour with surface design motifs.
- Further case studies may highlight individual similarities and differences between individuals regarding their sensory feedback needs. It may be appropriate to devise a modular system of specialised support garment components. These may then be combined by consumers and therapists in order to develop a customised garment.
- There may be a variety of people who could benefit from wearing a personalised sensation modifying garment. Potential client groups may include people with mental health issues such as anxiety, or physical problems arising from neurological injuries (Barbagallo, McKenna, & Daffner, 1999).

### **Therapy Garment Potential**

This study considers one aspect of the interface between design and well-being. It draws together the knowledge of; the fashion designer, the client, parents as well as varied health and education professionals. In future as science and technology continue apace more skills will be available to be added too the mix. Potential fabric innovations may include; a gel based compressive pressure delivery system or the

use of lightweight and malleable plastic or metal-based fabrics offering compression perhaps more intelligently. The inclusion of wireless electronic measuring tools and media may allow multiple issues to be addressed simultaneously, for instance compression combined with the emission of a relaxing scent or sound. The delivery of a customised pattern of 'squeezes' could be automatically activated in response to heart rate changes and be of benefit to very young clients or the more impaired.

In future a customised well-being enhancing garment may be an important feature in each of our lives.

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## **Endnotes**

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<sup>1</sup> Weighted vests link

<http://www.weightedvest.com/>

<sup>2</sup> Adaptive Child link

<http://www.adaptivechild.com/index.asp?PageAction=VIEWCATS&Category=11>

<sup>3</sup> Temple Grandin's squeeze machine link

[http://images.google.com/imgres?imgurl=http://i15.photobucket.com/albums/a369/veewee20/Jenna-Lynn/About\\_Us.jpg&imgrefurl=http://www.hug-machine.org/DrTG\\_Original\\_Device.htm&h=195&w=872&sz=54&hl=en&start=11&tbnid=3jBIUG3mkcFGRM:&tbnh=33&tbnw=146&prev=/images%3Fq%3Dtemple%2Bgrandin%2Bsqueeze%2Bmachine%26gbv%3D2%26hl%3Den%26safe%3Dactive%26sa%3DG](http://images.google.com/imgres?imgurl=http://i15.photobucket.com/albums/a369/veewee20/Jenna-Lynn/About_Us.jpg&imgrefurl=http://www.hug-machine.org/DrTG_Original_Device.htm&h=195&w=872&sz=54&hl=en&start=11&tbnid=3jBIUG3mkcFGRM:&tbnh=33&tbnw=146&prev=/images%3Fq%3Dtemple%2Bgrandin%2Bsqueeze%2Bmachine%26gbv%3D2%26hl%3Den%26safe%3Dactive%26sa%3DG)

<sup>4</sup> Therapeutic themed costumes link

<http://www.mediarelations.k-state.edu/WEB/News/Webzine/0103/clothes.html>