Design of Haptic Interfaces for Therapy

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ABSTRACT
Touch is fundamental to our emotional well-being. Medical science is starting to understand and develop touch-based therapies for autism spectrum, mood, anxiety and borderline disorders. Based on the most promising touch therapy protocols, we are presenting the first devices that simulate touch through haptic devices to bring relief and assist clinical therapy for mental health. We present several haptic systems that enable medical professionals to facilitate the collaboration between patients and doctors and potentially pave the way for a new form of non-invasive treatment that could be adapted from use in care-giving facilities to public use. We developed these prototypes working closely with a team of mental health professionals.

Author Keywords
Health Care, Tangible User Interfaces, Haptics, Wearable Computing, Touch Therapy, Psychotherapy.

ACM Classification Keywords
H.5.2 Haptic I/O; Prototyping; Interaction styles (e.g., commands, menus, forms, direct manipulation

INTRODUCTION
Medical science is only beginning to understand the importance of touch in mental health. Weighted blankets and vests have been used for years to prevent crisis states with children, adolescents, adults and the elderly. Heavy blankets and vests can actually prevent these panic attacks and allow children and adults to resume normal activities [10]. Recently, similar kinds of touch therapy have been shown to be effective at comforting patients and reducing violence. With the exception of medication, few psychotherapy alternatives exist outside a care-giving facility. We are building the first generation of computerized touch therapy devices to assist therapy with the potential to transform the way touch therapy is conducted in care-giving facilities.

RELATED WORK
Sensory integration
Recent initiatives and studies suggest that mental health can be strongly influenced by the sense of touch. The new controversial field of *Sensory Integration* [8] treats sensory problems associated with a number of mental disorders. Two sensory integration therapies are shown most effective: the Wilbarger Protocol and therapeutic holding. The Wilbarger Protocol describes three kinds of touch practiced as part of sensory integration therapy: brushing, joint compression and weight [9]. Therapists use their hands to apply deep pressure to various parts of the body, followed by the application of a soft brush to the skin and concluded by the application of a heavy weight such as a weighted blanket. This treatment is practiced every couple of hours for several minutes for as long as one year [26]. Studies reveal that these kinds of touch therapy can help treat disorders such as dementia, depressive and anxiety disorders [14, 24]. In related studies, enhanced psychotherapeutic outcomes were reported when massage was included as part of a psychotherapy regimen [11].

Therapeutic Holding
The US Department of Health's Restraint and Seclusion Reduction Initiative promotes touch therapy as an alternative to seclusion and restraint in severe psychiatric disorders [1]. Seclusion and restraint are the most common means to manage aggressive children. Researchers have found an alternative to this method: *therapeutic holding*. Therapeutic holding is akin to hugging, where the arms are wrapped and held around the shoulders, chest and back by a care-giver. It has the potential to reduce the number of episodes of mechanical restraints and to be perceived by children as less punitive [2]. Weighted blankets and vests have been used for years to prevent crisis states with autistic patients [10]. When placed on an autistic child this type of distributed pressure can prevent a panic attack. Temple Grandin is an autistic inventor who developed a *Squeeze Machine* based on her own needs when faced with a panic attack [17]; the bed-sized machine compresses the body between padded boards to provide comforting pressure [17]. Various devices have been proposed to replicate hugging, from an object that receives and transmits touch to distant family members [16], to the huggable sculptures of artist Ernesto Neto that literally embrace the body. The Hug-Over-A-Distance jacket contains air compartments that inflate quickly all around the torso to simulate a real hug [20]. Heart2Heart [18] is a wearable electronic garment that physically and emotionally links two remote individuals. If developed according to existing protocols for therapeutic holding, new medical devices could offer the benefits of touch therapy in convenient, portable and desirable designs.

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Sensory Grounding

Another promising touch therapy involves *grounding the senses* through contrasting touch sensations. Previous research explored means to comfort the body through tactile stimulation [25]. Non-invasive systems and methods have been designed to manage pain or to distract children from burn treatment by immersing them in a virtual world on a hand-held video game [7]. Because of its grounding effect, pain could be a useful stimulus to substitute destructive and harmful tendencies. Self-mutilation is a common symptom to various psychological disorders. Some individuals with borderline personality disorder attack their own skin as a way to test the solidity and reliability of their limits [12]. Controlled pain could serve as a support to treatments for pathologies where the patient is prone to self-mutilation.

DESIGN

A number of computer-mediated therapies are showing promise in the treatment of mental problems because of their ability to distract patients through immersion in a virtual world, their capacity to enrich patient-therapist collaboration [22]. Virtual Reality (VR) has been an effective part of psycho-therapy regimens to treat anxiety disorders [3] and autism [23]. A number of psychotherapeutic devices are comfortable and desirable enough to be seamlessly integrated into everyday life. Self-illuminating bedding was designed to combat seasonal affective disorder in which the insufficiency of day-light causes the onset of depression [27]. Another device allows people to scream in public without being noticed [13]. Electronic touch T-shirts can communicate affection between two lovers [15]. Communicating a sense of touch through a tangible interface demonstrates that a sense of human presence can be established through the communication of haptic motion [6]. Our previous work in haptic devices focused on designing systems that allowed affectionate touch to be shared and comfort remote persons [4], later used for psychotherapy [5] and for people on the move [25]. We propose that sensory therapies could be administered with haptic devices in order to facilitate therapy in care-giving facilities and make it possible to receive non-invasive treatment outside the home or hospital. We built four haptic devices for this research based on existing touch therapy protocols and the availability of robust touch simulation (haptic) technologies today. The devices rely on vibrotactile, pneumatic and heat pump actuation because of a desire for comfort and portability. We use sensors based and mechanically driven technologies. Our devices have been technically tested over a period of eight months, and their long term stability will be tested as part of our future work.

Touch Me

Touch Me is a system for the remote application of touch therapy similar to the Wilbarger Protocol. Currently touch therapy is applied directly by therapists touching patients or through the use of surgical brushes. *Touch Me* permits touch therapy to be explored and administered on a personalized basis without the risks associated with direct touch.

Fig. 1. Touch Me.

Touch Me consists of a flexible vibrotactile motor array in a soft enclosure that can be applied to large areas of the body and remotely actuated by a care-giver through a remote switch array. The long, narrow geometry of the vibrotactile array is designed to provide soothing touch simulation over an entire part of the body: an arm, a leg, the back or the chest. A remote controller allows mapping of the location and intensity of vibrotactile actuation by a caregiver. *Touch Me* is made from a pink felt wrap connected by ribbon cable to a music keyboard in which each key corresponds to a band of vibrotactile motors in the wrap. *Touch Me* is intended primarily as a tool for patient and therapist to explore touch together and determine the kinds of touch that are soothing to the patient.

Squeeze Me

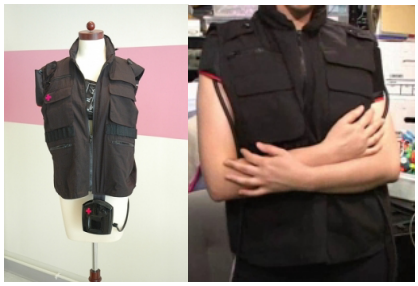

Fig. 2. Squeeze Me.

Squeeze Me is a vest that simulates therapeutic holding. Pneumatic chambers around the shoulders, chest and back are inflated by a portable air compressor to momentarily provide distributed pressure in ways that have been shown to lessen panic attacks in autistic children [14] and to help manage aggressive children [2]. A digital control system administers the 'hug' by direct control on behalf of the wearer. A physical safety system prevents over-inflation or over-compression through pressure-release valves and fasteners with engineered strain releases. Users have to fasten the pneumatic sleeve tight to their chest before closing the conventional vest. Actuation of the vest is not visible since the bladders inflate inwards, so the device remains discrete and could be inconspicuously worn outside the care-giving facility. In the current prototype, air compressors and bladders were adapted from conventional blood-pressure cuffs since these are accepted medical devices with proven safety measures. Users press a button to initiate the inflation and subsequent deflation of the vest, which is fixed in pressure and duration.

Hurt Me

Hurt Me is a wearable haptic device that generates controlled pain as a form of sensory grounding for persons with tendencies towards self-harm. It aims to substitute the need to self-mutilate by supplying a painful stimulus controlled by the patient and designed with built-in safety limits.

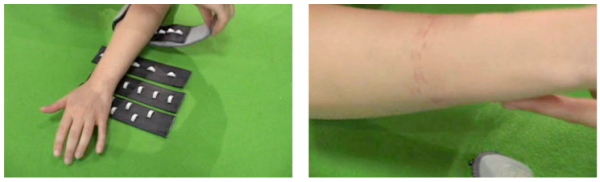

Fig. 3. Hurt Me.

A computerized pneumatic bracelet inflates a pressure bladder studded with plastic teeth to generate a sensation akin to being bitten on the part of the arm to which it is fastened. A physical safety valve and sufficiently rounded teeth guarantee that the pressure and sharpness of the actuators do not cause any type of injury to the wearer.

Cool Me Down

Like biting pain in *Hurt Me*, a sudden strong temperature change in *Cool Me Down* is intended to ground the senses. *Cool Me Down* is a flexible electronic cold wrap containing electronic heat pumps. A neoprene substrate insulates the hot and cold sides of the heat pumps and maintains the structure of the device, which resembles a small bandage. Peltier Junctions glued to aluminum plaques generate a substantial temperature difference from one side to the other (~15ºC). The plaques act as heat sinks, and are hinged together by the neoprene insulator so that the entire object can be wrapped around different parts of the body. Thin, porous covering fabric conducts the temperature from the heat sinks directly to the skin. The device can be discretely worn and only activated when necessary to help patients self-administer soothing sensory grounding treatment. In its current form, *Cool Me Down* is activated by a momentary push-button switch and its power is limited so that it never burns or freezes the skin.

Fig. 4. Cool Me Down.

FOCUS GROUP

A dual moderator focus group study with expert clinicians was chosen as the most appropriate method with which to consider the suitability of the proposed interfaces for the clinical environment. Before a new method or medical device can become part of clinical treatment or even to be tested by patients, it must first be subjected to strict standards and evaluation guidelines that are unique to the medical field. The current medical treatment context relies on hospital and insurance infrastructure that is largely systematized by law and medical codes of ethics. The determination of a device's suitability for the clinical context is made by data resulting from empirical standards, namely, randomized controlled studies with large sample sizes, double blind experimenters, and placebo control groups [19]. A device proposed for the therapeutic context cannot be subjected to this kind of research study until it at least passes the critical evaluation of an impartial panel of experts from multiple related health-care disciplines. Over a period of seven months, we organized five focus groups sessions that lasted each an hour. Each focus group was composed of a panel of clinicians working in a psychiatric hospital. During the sessions, the two moderators progressively introduced new design elements as part of the prototypes, reflecting our previous focus group discussions. Our panel of clinicians was formed from the practitioners of the inpatient psychiatric department of a local Hospital. The panel consisted of a psychiatrist (director of the department), the nurse manager, physicians, a psychiatric nurse specialist, registered nurses, and occupational therapists. The diversity of the consulting physicians reflects a broad scope of practice so as to allow for the proposed haptic systems to be evaluated from multiple treatment perspectives. During the last session, the focus group tested the prototypes, inviting a discussion on the pros and cons of each prototypes, and to reflect and compare the prototypes with each other.

DISCUSSION

Hurt Me is a nuanced stimulus that the patient and therapist design together. As in electroconvulsive therapy, a seizure is induced in the patient not for its painful aspect, but for its ability to ground the senses. *Hurt Me* could be an opportunity for the patient and the therapist to better relate to one another, by having the therapist working with the class of pain the patient is experiencing psychologically and externalizing viscerally. The clinicians noticed that the bracelet could be a therapeutic device so that 'nobody had to know' that the person was using it for therapy. With *Hurt Me* clinical consultants immediately saw the potential in using the device outside of the clinic. To be tested within the clinic, the misleading name of the device would have to be changed, this to not violate the Hippocratic Oath. With *Cool Me Down* they were more interested in hospital applications. This maybe due to the form factor of *Hurt Me* compared to *Cool Me Down:* the size, weight and power requirements of the heat pumps make it the least likely to become a portable device. The result of the expert interviews confirm that our prototypes are suitable for initial testing with patients, and we plan to conduct clinical trials on the next generation of prototypes to confirm medical efficacy. We sought the professionals' opinion of our prototypes to determine whether they are suitable for initial testing on patients. They concluded that *Touch Me* and *Cool Me Down* would be the easiest to evaluate clinically. Some concerns regarding *Cool Me Down* include the wire and the power consumption of the device, which

will have to pass internal technical valuation. They expressed concerns regarding *Squeeze Me* because its current version can be painful or ineffective without more precise control. They conclude that it may be possible to test all the devices presented because in all cases there will be sufficient clinical staff available to provide any additional necessary safety measures. The hospital ward expressed enthusiasm to try out the current prototypes on their patients and to develop a next generation for more widespread clinical evaluation. Our prototypes will need to allow for customization, because the patients most likely to respond to therapeutic touch exhibit drastically different preferences.

Even though our devices simulate the sensation of various kinds of touch, we do not intend to replace human contact. In *Touch Me*, we propose to use technology as a means for sensory defensive patients to discover the physical sensation of touch, while not overwhelming the patient with human contact. In our research, the devices are tools for the therapist to communicate better with the patient and, for three of the prototypes, to comfort the patient in the therapy.

CONCLUSION AND FUTURE WORK

We created the first series of haptic interfaces to be used in psychotherapeutic treatment. Our prototypes have been accepted for initial evaluation by a panel of medical experts. Once these devices begin to be considered for clinical trials, we will have to find the most appropriate method to evaluate their efficacy. Because the realm of touch therapy is still considered experimental, we will have to address a number of issues when presenting this work for clinical trials, especially the development of placebo control groups, complementing existing therapies and potential dangers or side effects. In conventional medicine, invasive treatments are evaluated against a placebo. This practice is gaining acceptance in psychotherapy as well, and is known as *Evidence-Based Practice*. With most Complementary and Alternative Medicines, the placebo effect becomes an integral part of the treatment and a source of positive therapeutic outcomes. If a placebo can be as effective as an invasive treatment, then the placebo effect itself could be explored as one of the mechanisms by which haptic systems treat patients. Critics of VR therapy point out that the technique is not compatible with several psychotherapeutic approaches. Because we are working with medical professionals and directly addressing their needs, we hope to design a generation of devices that facilitates and expands existing therapy seamlessly. Furthermore, any new technology meant for clinical intervention, such as haptic devices or VR, may have as-yet-unknown side-effects [21]. Careful design of our haptic devices and technical consultations will be necessary to assure the safety of haptics for psychotherapy. In order to evaluate our devices for use in a clinical environment and ultimately at home, we will have to design control systems and autonomous behaviors including bio-feedback that correspond to the patient's and therapist's needs.

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