Bend Assisted Rehabilitation

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Abstract
We propose an ethnographic exploration of the therapeutic methods currently used to address chronic debilitating conditions of the hand with the aim of identifying possible interventions for flexible devices. We will use a participatory design methodology, including both individuals receiving physical therapy and their therapists, to create prototype flexible devices which will be tested for their effectiveness in a therapeutic environment.

Author Keywords
Deformable devices; flexible devices; bend; physical therapy.

Introduction
The central motivation of research in human computer interaction (HCI) is to explore how devices fit into and can improve our lives. Designing for the majority of users has led to many technological advances: keyboard, mouse, touch, and tangible interfaces among others; but these have limitations with regards to their ability to address the needs of users that require different degrees of accommodation.

People who experience limitations in the mobility and fine motor control of their hands face challenges not only when using computing devices – where many interfaces fail to accommodate their needs – but in everyday tasks such as tying shoes, fastening buttons and snaps, or using cutlery while eating. Many different factors influence hand dexterity including cerebral

palsy, fetal alcohol syndrome, multiple sclerosis, Parkinson's disease, stroke, arthritis, and injury to the head or hands. Current physical therapy strategies for improving manual dexterity focus on improving hand movement through space, rather than object manipulation, and use objects that are acted upon [19] rather than as facilitators or guides for therapy.

There is a rich history of technology used to assist those with disabilities, more recently we see a shift towards using technology for rehabilitation [9]. Therapy regimens that use or occur in conjunction with robotic therapy have shown a positive impact on upper limb impairments due to strokes [4,5,6] as well as cerebral palsy, multiple sclerosis, and spinal cord injuries[9]. Other research explores the tracking of therapy tools' movement or location in physical space and their use as a means of interaction in therapy, particularly when paired with games [2,13,16,17]. This work uses familiar objects, like cups and balls, to engage users in manipulation tasks related to existing physical therapy techniques.

Flexible devices, those than can be interacted with through deformations like bending, squeezing, and twisting, offer one avenue of augmenting current physical therapy methodologies. Deformable gestures, which we apply broadly to cover any interaction which changes the physical form of the device such as bending, twisting, and squeezing; leverage users' understanding of their own bodies and the physical world to create intuitive interactions [1,7,8,10,11,12,14]. The tangible affordances of flexible devices could complement the work currently being done to bring HCI and concepts of gamification into therapy for chronic conditions of the hand.

Research Aims

We believe that the novel methods of interaction offered by flexible devices can be adapted to support new therapeutic techniques. The physical forms and interaction languages offered by deformable devices are themselves highly flexible: their form factors and the interactions they allow are defined by the needs of groups using them; in this inquiry: primarily those undergoing physical therapy and their physical therapists.

The primary goal of this research is to find the areas where physical therapy can be augmented or facilitated using flexible devices. Potential applications may be as guides for in-home therapy, tools for targeting specific regions of the hand, and/or as data collection tools which could provide highly detailed information of the movement and function of the hand. This will lead to a requirements list that will determine the form of the flexible device(s), the gesture language, and the type of sensing that will be needed to track the interactions.

Achieving this goal will require that therapists and patients be engaged in the process of developing test devices. The ability to determine the form and function of the therapy device may lead to new therapeutic approaches for physical therapist to explore. Patient comfort is also important; new flexible devices may lack the familiar looks of the household objects currently used in some physical therapy interventions, but they may borrow the characteristics of these or other items to create interactions which still feel natural and familiar.

Once we develop flexible prototypes it will be important to determine their effectiveness as tools for physical therapy and propose next steps.

Literature Review

Flexible devices can be used to create rich interaction languages that can be adapted to an array of different scenarios and usages such as: one-handed interactions [7], mobile games [12], or as a potential means of interaction for people with visual impairments [3]. While a common form adopted by these devices is similar to that of a mobile phone or tablet, flexible devices can take on a diverse range of shapes dictated by their usages; for example: a flexible paintbrush device for artists could allow digital interactions more similar to the experience of using traditional media. Likewise, interactions with flexible devices can use inputs like bend [3,7,12], pressure [18], and/or touch [18]. Feedback and feedforward can make use of visual cues provided by a display [7,12] or use tangible cues like haptics [3].

Robotic therapy has proven to be a good example of the efficacy of technological interventions in physical therapy. The MIT-MANUS, used to provide rehabilitation focused on the elbow and shoulder post-stroke, showed that robotic therapy can lead users towards improvements in their motor control [5], these results were replicated by the devices' successor, InMotion2 [6], which used a four month follow-up to show that improvements in motor function persisted. Both MIT-MANUS and InMotion2 replicated tradition physical therapy elements like proper positioning, range of motion, and motor retraining exercises using robotic tools under the supervision of a physical or occupational therapist.

Current explorations of technology and physical therapy have turned mundane devices into interactive objects [2,13,15,16,17]. Bringing the realms of HCI and physical therapy together, Hammond, Shay, and Szturm [2] devised a method of tracking the 3D position of objects fitted with sensors and used it as means of assessing manual dexterity and hand function. Szturm et al. [16] took advantage of the functional properties of these sensor-equipped objects in conjunction with games to deliver therapy to users with reduced finger and hand function due to spinal injury, stroke, and cerebral palsy, with positive results. This approach is adaptable to different use contexts, allowing this therapy to be extended to telerehabilitation [13] or to work with children in classrooms to improve motor control in an educational context [17]. Finally, work is currently underway to explore the suitability of this object-driven game therapy for people with rheumatoid arthritis and osteoarthritis [15].

Research Plan

Research Questions

The contributions made to physical therapy for chronic conditions of the hand by HCI can be complemented or augmented by flexible devices. Thus, the primary questions we ask are: where can flexible technologies be used to augment current interventions and practices, as well as where can flexible technologies allow new interventions, new forms of therapy, and provide therapists with new or more accurate data?

Second to this, how can physical therapists and those receiving therapy participate in the design process? What insights can they provide? What are their needs and concerns? How can flexible technologies, or

technological interventions in general, better accommodate and help these users to achieve their goals?

Methodology
We propose, as an initial inquiry, an inductive exploration of current physical therapy practices and the experiences of the different stakeholders involved, leading to a participatory design process that will result in the creation of one or more flexible prototypes to be tested in a therapeutic environment.

We would first endeavour to gain a more direct understanding of the therapeutic processes employed in the physical therapy for the hand. We would achieve this by conducting interviews with physical therapists, as well as through pursuing first-hand observational experience by shadowing patients through their physical therapy regimens including initial evaluations, in-clinic therapy sessions, and at-home exercises.

Through interviewing with physical therapists, we endeavour to better understand the short-term and long-term aims of the therapeutic process, how and why they employ specific tools and exercises, and what information they use to guide their choices and to evaluate the success of interventions. The interviews will allow us to probe the limits of the current toolsets available for hand therapy, to identify gaps in data acquisition, and to leverage the experience and insight of physical therapists to identify areas where the implementation of flexible devices may prove useful.

This initial exploration will establish which therapeutic methods can be best augmented using flexible devices and which sub-populations of patients, if any, may need to be targeted. It may also provide insight with regards to other areas in the process of physical therapy that may benefit from the applications of flexible devices or HCI design principles as well as suggest preliminary forms for flexible prototypes.

The second phase of the research is the participatory design of flexible prototypes for physical therapy. Both physical therapists and patients should be involved in this process as they bring unique perspectives and knowledge that will be beneficial to the creation of successful flexible prototypes. Therapists have intimate knowledge of the human body, therapeutic methodologies, and tools; ideally participant therapists will also bring critical perspectives and unique insight on where current methods and tools are not adequate. Patients, particularly those receiving treatment for chronic conditions, bring an understanding of the experience of receiving therapy included their likes and dislikes regarding current practices and the ability to share how changes to those practices affect them in terms of comfort, confidence in therapy, and the suitability of new tools to address their specific needs.

Due to the indeterminate nature of flexible devices, users will be given a collection of existing therapeutic devices along with low-fidelity prototyping materials that they may use to suggest forms and functions for new devices. Examples being: modelling clay, urethane foam of varying thicknesses and densities, latex or rubber sheets, and wire.

We will then use the initial concepts devised through the participatory design process to develop prototypes using higher-fidelity materials equipped with sensors, lights, speakers, or haptic motors.

Finally, we will test the prototype devices in-clinic with our participants and evaluate against existing tools and methods using both qualitative (user satisfaction, comfort, and confidence) and quantitative (performance on tasks with regards to accuracy, precision, and time) metrics.

Ethical Considerations

Working with people undergoing physical therapy demands we remain aware that any new intervention or change to their current therapy program may be less effective or even harmful. We will mitigate this risk by involving of physical therapists in the design and testing of prototypes, ensuring that they have confidence in the intervention and are able to monitor the progress and experience of participants to avoid any harm.

Conclusions

From this inquiry, we hope to gain an understanding of how flexible technologies can contribute to the field of physical therapy, specifically focused on rehabilitation of the hand for individuals suffering from chronic debilitating conditions. Our initial ethnographic inquiry and subsequent participatory design practice will result in prototype flexible devices which will then be tested in a therapeutic environment.

References

[1] Ahmaniemi, T.T., Kildal, J., and Haveri, M. What is a device bend gesture really good for? *Proceedings of the 32nd annual ACM conference on Human factors in computing systems - CHI '14*, ACM Press (2014), 3503–3512.

[2] Andersen Hammond, E.R., Shay, B.L., and Szturm, T. Objective Evaluation of Fine Motor Manipulation-A New Clinical Tool. *Journal of Hand Therapy 22*, 1 (2009), 28–36.

[3] Ernst, M. and Girouard, A. Bending Blindly: Exploring the learnability and usability of bend gestures for the visually impaired. *Submitted to CHI 2016*, 13p.

[4] Fasoli, S. Upper Limb Robot-Assisted Therapy: Exploring Limitations and Future Directions. *Archives of Physical Medicine and Rehabilitation 96*, 10 (2015), e3.

[5] Fasoli, S.E., Krebs, H.I., Stein, J., Frontera, W.R., and Hogan, N. Effects of robotic therapy on motor impairment and recovery in chronic stroke. *Archives of Physical Medicine and Rehabilitation 84*, 4 (2003), 477–482.

[6] Fasoli, S.E., Krebs, H.I., Stein, J., Frontera, W.R., Hughes, R., and Hogan, N. Robotic therapy for chronic motor impairments after stroke: Follow-up results. *Archives of Physical Medicine and Rehabilitation 85*, 7 (2004), 1106–1111.

[7] Girouard, A., Lo, J., Riyadh, M., Daliri, F., Eady, A.K., and Pasquero, J. One-Handed Bend Interactions with Deformable Smartphones. *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, (2015), 1509–1518.

[8] Jacob, R.J., Girouard, A., Hirshfield, L.M., et al. Reality-based interaction: a framework for post-WIMP interfaces. *Proceedings of the 26th*

international conference on Human factors in computing systems - CHI '08, ACM (2008), 201–210.

[9] Krebs, H.I., Dipietro, L., Levy-Tzedek, S., et al. A paradigm shift for rehabilitation robotics. *IEEE Engineering in Medicine and Biology Magazine 27*, 4 (2008), 61–70.

[10] Lahey, B., Girouard, A., Burleson, W., and Vertegaal, R. PaperPhone: Understanding the Use of Bend Gestures in Mobile Devices with Flexible Electronic Paper Displays. *Proceedings of the 2011 annual conference on Human factors in computing systems - CHI '11*, (2011), 1303.

[11] Lee, S.-S., Kim, S., Jin, B., et al. How users manipulate deformable displays as input devices. *Proceedings of the 28th international conference on Human factors in computing systems - CHI '10*, (2010), 1647.

[12] Lo, J. and Girouard, A. BENDY: An Exploration into Gaming with Mobile Flexible Devices. *Submitted to the International Journal of Human Computer Studies*, .

[13] Lockery, D., Peters, J.F., Ramanna, S., Shay, B.L., and Szturm, T. Store-and-feedforward adaptive gaming system for hand-finger motion tracking in telerehabilitation. *IEEE transactions on information technology in biomedicine : a publication of the IEEE Engineering in Medicine and Biology Society 15*, 3 (2011), 467–73.

[14] Schwesig, C., Poupyrev, I., and Mori, E. Gummi: A Bendable Computer. *Proceedings of the 2004 conference on Human factors in computing systems - CHI '04*, (2004), 263–270.

[15] Srikesavan, C.S., Shay, B., Robinson, D.B., and Szturm, T. Task-oriented training with computer gaming in people with rheumatoid arthritisor osteoarthritis of the hand: study protocol of a randomized controlled pilot trial. *Trials 14*, 1 (2013), 69.

[16] Szturm, T., Peters, J.F., Otto, C., Kapadia, N., and Desai, A. Task-Specific Rehabilitation of Finger-Hand Function Using Interactive Computer Gaming. *Archives of Physical Medicine and Rehabilitation 89*, 11 (2008), 2213–2217.

[17] Szturm, T., Polyzoi, E., Marotta, J., and Srikesavan, C.S. An In-School-Based Program of Combined Fine Motor Exercise and Educational Activities for Children with Neurodevelopmental Disorders. *Games for health journal 3*, 6 (2014), 326–332.

[18] Wightman, D., Ginn, T., and Vertegaal, R. BendFlip: Examining Input Techniques for Electronic Book Readers with Flexible Form Factors. In *Proceeding INTERACT'11 Proceedings of the 13th IFIP TC 13 international conference on Human-computer interaction*. 2011, 117–133.

[19] Yancosek, K.E. and Howell, D. A Narrative Review of Dexterity Assessments. *Journal of Hand Therapy 22*, 3 (2009), 258–270.