SomaTech: An Exploratory Interface for Altering Movement Habits

Qiao Wang
Arizona State University
950 S. Cady Mall
Tempe, AZ 85281 USA
qiao.wang@asu.edu

Grisha Coleman
Arizona State University
950 S. Forest Mall
Tempe, AZ 85281 USA
grisha.coleman@asu.edu

Pavan Turaga
Arizona State University
950 S. Forest Mall
Tempe, AZ 85281 USA
pavan.turaga@asu.edu

Todd Ingalls
Arizona State University
950 S. Forest Mall
Tempe, AZ 85281 USA
todd.ingalls@asu.edu

CHI'14, April 26–May 1, 2014, Toronto, Canada.

Abstract

We propose SomaTech, a Kinect-based system that encourages users to expand understanding and awareness of their everyday movements. The system creates real-time auditory feedback based on the user's whole action, aiming toward re-education of habitual, potentially unsound movement patterns which are often ingrained within the brain. To do this, we draw inspiration from the field of somatics, which has well-studied prophylactic benefits. Our initial evaluation shows promising results that users become more aware of movement choices and are able to improve their efficiency after using the system.

Author Keywords

Movement; learning; awareness; exploration; somatics; sonification; Kinect; interface

ACM Classification Keywords

H.5.2 [User Interfaces]: Auditory (non-speech) feedback; H.5.1 [Multimedia Information Systems]: Evaluation/methodology; K.3.1 [Computer Uses in Education]: Computer-assisted instruction (CAI).

General Terms

Design, Experimentation, Human Factors

Introduction

A large class of human movement disorders arises out of long years of habitual unsound movement patterns, which are often unconsciously executed by the person. The excessive repetition of such movements not only affects the periphery but also becomes ingrained within the brain as a form of maladaptive neural plasticity [14]. Unfortunately, these issues often do not give rise to any immediate symptoms but present themselves much later in life when accumulated damage has already happended to the musculoskeletal system. Somatic re-education techniques, such as the Alexander Technique (AT) [2], which aim at increasing body awareness, have been clinically shown to have long-term benefits for several conditions including chronic back pain [8, 3] and Parkinson's disease [13]. However, such practices are not widely adopted because of several reasons, including cost, lack of insurance coverage and limited numbers of certified practitioners [1]. A low-cost computer-aided learning system can help overcome some of these limitations and bring the benefits of somatic practice to a broader populace.

This paper introduces a prototype design, which aims to assist people with somatic learning, using principles of the Alexander Technique. In order to apply the principles and provide useful guidance, the system needs to examine the user's whole motion, as opposed to comparing only concluding postures. It also needs to help the user relearn and change movements they are already familiar with. These requirements pose challenges which have rarely been undertaken in past HCI systems. In the following sections we will describe the design of our SomaTech system and how these challenges are addressed.

Related Work

With the increased availability of low-cost motion sensors, especially the Microsoft Kinect sensor, various works have been presented in recent years exploring using HCI systems for improving physical movements. These systems usually aim to help the user practice certain body exercises, such as yoga [12], tai chi [11], or ballet poses [9]. Similar systems provide real-time feedback to improve the user's posture [15] or balance [4] when standing or sitting. Without regard to a predetermined routine or posture, some designs use similar technologies to increase body awareness by letting the user "touch" a virtual object in the darkness [16], or create expressive visual patterns using the body as input [7].

Most existing systems treat movements only as postures or sequences of postures. The objective when using such a system is to strike and maintain a certain pose, and the feedback is given by comparing the user's posture at each moment with an ideal template. In some cases the movement is represented as a series of postures and feedback is provided such that these postures are assumed sequentially. This model of representing movements is desirable only when adopting specific postures is the main concern. However, in many situations, not only the initial and final poses, but also the transition between them, is important (e.g. ballet dancing). Everyday movements such as sit-to-stand or walking are especially of this kind where numerous different motor strategies can be applied between the same starting and ending postures (e.g. [10]). Thus, in order to design a system that can help the user change their everyday movements, the whole process of a movement must be considered, and a new method of movement modeling and feedback generation is needed.

Design

Principles from the Alexander Technique (AT)

Aside from its effectiveness mentioned above, an advantage of AT is that it can be applied and practiced even during simple activities without requiring special routines of movement or unnatural postures. For our pilot study, we focus on the sit-to-stand movement (STS). The choice of this important everyday action is also motivated by its relevance in various clinical measures of mobility (the timed up-and-go test, for instance) as well as its importance in AT for learning to develop a better general coordination [2].

The philosophy of AT indicates that, to learn a new and better way of moving, the student must first learn to inhibit unnecessary habitual movement pattern, and also explore alternative ways to carry out the movement [2]. In order to change, one must first be aware of the choices they have. Thus our system must allow and encourage the user to explore different ways of completing the movement. This suggests that simply dividing a movement into several snapshots of postures and demanding the users follow the sequence of postures would not be an effective way to change their movement habits.

A pioneering study on AT [5] found that the profile of head speed over time is a kinematic measurement that shows a significant difference before and after AT exercise. The head-speed-versus-time plot only has one peak when standing up in a preferred manner in AT, as opposed to two peaks in habitual STSs (see Figure 1). This smoothness in movement is positively correlated with benefits that are expressed as subjective feelings such as lightness, ease, etc. [5].

Thus, a high-level measurement of the whole motion, such as the smoothness of head speed, may be a suitable metric to represent the movement and generate feedback, along with other proper kinematic measurements, because it both gives the user space for exploring different strategies and can provide distinctive feedback that separates desired motions from undesired ones.

System Description

In our system design, we provide real-time audio feedback that conveys temporal knowledge, timing, and multi-joint synchronization. Sonification also allows one to move about in a relatively unrestricted manner, whereas visual feedback delivered via display screens has a tendency to "lock" the eyes and the head in a fixed position in order to see the feedback.

Our system utilizes a Kinect sensor, which can track the 3D positions of up to 20 joints on a human body. We use the 3D coordinates of these joints to calculate several features, including: a) the head speed profile, b) the angular speed of the torso opening, and c) the extent of task completion as measured by normalized head height.

These features are then sent to drive the sonification engine, which generates a combination of audio streams that is aesthetically neutral, so that the user would not be discouraged from their early exploratory attempts, nor would they be tempted to improvise a musical piece while using the system. One feedback stream sonifies the head speed, and is geared toward reducing multiple acceleration-deceleration patterns in habitual movements. The other feedback streams aim to reduce the extent of forward lean in the process of standing up. The head-speed feedback uses a simple mapping to control a sine wave that was run through a basic waveshaping effect [6]. The frequency of the sine wave can be changed within a one-octave range. The second stream is a mapping from the hip angle (defined as the angle formed by the trunk, hip and thighs) to the intensity of the waveshaping which increases the distortion of the sine wave. A third stream indicates when angular movement around the hip changes direction, with the strike of a synthesized drum.

By using high-level feedback, we provide a large space of movement strategies for the user to explore. We also studied the set of verbal exchanges typical in an AT session on sit-to-stand and extracted two pieces of verbal instructions, used in conjunction with the abstract auditory feedback in the system to narrow the space of explorations to a meaningful subspace.

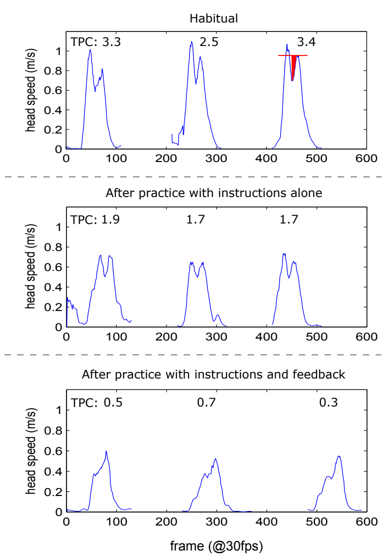

Figure 1: Head speed profiles of one subject's three measurement sets (with the definition of TPC shown in red)

Evaluation

Our system has been demonstrated in multiple showcases on campus. Most people, even without prior knowledge about the Alexander Technique, could understand and effectively use the system after one or two minutes. Many of them expressed surprise when exploring the system that they had not realized they could do sit-to-stand in a very different way compared to their habitual methods. Among these users, we observed that about half of them could change their movement patterns to some extent, after using the system for five to ten minutes.

Under the approval of the Institutional Review Board, we did a pilot study with four young, healthy subjects (3 male, 1 female). Two of them had known nothing about AT before using the system, and the other two were briefly introduced about the technique in a class a few months before the study. None of the subjects knew the inner mechanism of the system. Each subject was asked to first do a few STS habitually, then practice with the system with only verbal instructions for about 10 minutes, rest for an hour, and practice again with both instructions and auditory feedback for another 10 minutes. The kinematic characteristics of their STSs were measured before, in-between, and after the practice sessions.

We use two metrics to measure STS movement quality. The first one is named Two-Peak Coefficient (TPC) of the head speed, which is defined as an area of the triangle determined by the second highest peak, the valley and lines parallel to the axes on the head-speed-versus-time plot (see example in Figure 1). A smaller TPC implies smoother head movement and thus correlates to better movement quality (it should be noted that TPC is influenced by many factors including height, weight, etc., thus is only intended for intra-subject comparison).

Head speed profile Two-Peak Coefficient (*smaller implies better*)				
Subject	**P1**	**P2**	**P3**	**P4**
Habitual	3.1	3.7	1.2	1.4
After practice with instructions alone	1.8	0.8	1.2	0.4
After practice with instructions and feedback	0.8	0.6	0.3	0.3

Minimum hip angle (*larger implies better*)				
Subject	**P1**	**P2**	**P3**	**P4**
Habitual	90	51	89	85
After practice with instructions alone	103	82	84	96
After practice with instructions and feedback	110	90	100	100

Table 1: Summary of average kinematic measurements for each subject.

The second metric used is the minimum hip angle during STS. A smaller minimum hip angle indicates that the subject leaned their trunk forward more during STS. Biomechanical studies show that older people tend to flex their trunk more in STS because of their lower postural control ability and reduced muscular strength [10]. For young and healthy subjects, we believe a larger minimum hip angle implies better movement quality.

The preliminary results from our pilot study are summarized in Table 1. It can be seen that most subjects improved their STS quality after practicing with instructions alone, and that in all subjects the kinematic measurements further improved after feedback was also given to the subject. It can be speculated that the further improvement was simply due to the positive effect of an additional practice session instead of the auditory feedback. However, a closer examination of the collected data (not shown in Table 1) shows that when practicing with instructions alone, most of the progress was made near the beginning of the practice session, and the measurements near the end of the session indicate that repetitive practice in this case would only contribute a small fraction of the further improvement.

Conclusion and Future Work

We have designed a prototype system that generates real-time auditory feedback from Kinect data, for the purpose of changing people's movement habits. Preliminary evaluation shows that users can increase their awareness of movement choices, and promising kinematic improvements were observed.

For future work, we plan to add more features into the system to promote long-term usage. We would like to include more movements (e.g., walking) and test various combinations of feedback streams. We also want to conduct a more comprehensive evaluation that includes more subjects, collects more qualitative feedback, tracks measurements in a longer span of time, and correlates kinematic measurements with movement quality ratings from human experts. We are especially interested in the long-term retention of movement changes. We would like to discuss all these topics with researchers in related areas.

Acknowledgements

We would like to thank Dr. Fay Horak, Andrea Silkey, Dr. Daragh Byrne, the School of Arts, Media and Engineering at ASU, and the students who participated in our study.

References

[1] The American Society for the Alexander Technique. http://www.amsatonline.org/.

[2] Alexander, F. M. *The use of the self*. E. P. Dutton, 1932.

[3] Cacciatore, T. W., Horak, F. B., and Henry, S. M. Improvement in automatic postural coordination following alexander technique lessons in a person with low back pain. *Physical therapy 85*, 6 (2005), 565–578.

[4] Chiari, L., Dozza, M., Cappello, A., Horak, F. B., Macellari, V., and Giansanti, D. Audio-biofeedback for balance improvement: an accelerometry-based system. *Biomedical Engineering, IEEE Transactions on 52*, 12 (2005), 2108–2111.

[5] Jones, F. P. *Body awareness in action: a study of the Alexander technique*. Schocken Books New York, 1976.

[6] Le Brun, M. Digital waveshaping synthesis. *Journal of the Audio Engineering Society 27*, 4 (1979), 250–266.

[7] Leite, L., and Orvalho, V. Shape your body: Control a virtual silhouette using body motion. In *Ext. Abstracts CHI*, ACM Press (2012), 1913–1918.

[8] Little, P., Lewith, G., Webley, F., Evans, M., Beattie, A., Middleton, K., Barnett, J., Ballard, K., Oxford, F., Smith, P., et al. Randomised controlled trial of alexander technique lessons, exercise, and massage (ateam) for chronic and recurrent back pain. *BMJ: British Medical Journal* (2008).

[9] Marquardt, Z., Beira, J., Em, N., Paiva, I., and Kox, S. Super mirror: a kinect interface for ballet dancers. In *Ext. Abstracts CHI*, ACM Press (2012), 1619–1624.

[10] Papa, E., and Cappozzo, A. Sit-to-stand motor strategies investigated in able-bodied young and elderly subjects. *Journal of biomechanics 33*, 9 (2000), 1113–1122.

[11] Portillo-Rodriguez, O., Sandoval-Gonzalez, O. O., Ruffaldi, E., Leonardi, R., Avizzano, C. A., and Bergamasco, M. Real-time gesture recognition, evaluation and feed-forward correction of a multimodal tai-chi platform. In *Haptic and Audio Interaction Design*. Springer, 2008, 30–39.

[12] Rector, K., Bennett, C. L., and Kientz, J. A. Eyes-free yoga: an exergame using depth cameras for blind & low vision exercise. In *Proc. SIGACCESS*, ACM Press (2013), 12.

[13] Stallibrass, C., Sissons, P., and Chalmers, C. Randomized controlled trial of the alexander technique for idiopathic parkinson's disease. *Clinical Rehabilitation 16*, 7 (2002), 695–708.

[14] Tanabe, L. M., Kim, C. E., Alagem, N., and Dauer, W. T. Primary dystonia: molecules and mechanisms. *Nature Reviews Neurology 5*, 11 (2009), 598–609.

[15] Taylor, B., Birk, M., Mandryk, R. L., and Ivkovic, Z. Posture training with real-time visual feedback. In *Ext. Abstracts CHI*, ACM Press (2013), 3135–3138.

[16] Vongsathorn, L., O'Hara, K., and Mentis, H. M. Bodily interaction in the dark. In *Proc. CHI*, ACM Press (2013), 1275–1278.