The Tiresias Effect: Feedforward using Light versus Temperature in a Tangible User Interface

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Abstract
In this paper we discuss how light and temperature information can be designed to affect feedforward in a tangible user interface (TUI). In particular we focus on temperature, which has not been widely considered as a mode of information representation in feedback or feedforward. We describe a prototype that implements both information modes in a TUI. Finally, we outline a user study in which these modes are explored as feedforward coaching devices for a decision-making task. The expected outcomes are an understanding of the role of temperature as information for feedforward in TUIs and a set of design guidelines for designers of tangibles working with these physical characteristics.

Keywords
Tangible user interfaces, feedforward, temperature

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces, input devices and strategies (e.g., mouse, touchscreen), user-centered design.

General Terms
Design, theory

Introduction

Tangible user interfaces (TUIs) have emerged as an alternate paradigm to traditional graphical user interfaces (GUIs) whereby the interface is comprised of physical objects augmented with computation. Unlike GUIs, which are limited to conveying visual and auditory information, TUIs provide an opportunity to convey information to other sensory modalities: tactile and haptic. Recent research has addressed tactile and haptic modalities through force, vibration and motion information, particularly within the context of designing alternate gaming interfaces for the visually impaired [6, 7, 10, 12]. Tactile modalities also include temperature, or information about the heat (i.e., thermal energy) given off by an object. Temperature has not been widely explored in TUI research.

One way to capitalize on modalities in TUIs is through their use as a feedback medium. Feedback is typically reactionary: the actions of the user trigger a response in the TUI. This reaction results in information conveyed through the TUI's physical or digital characteristics. Providing reactionary feedback affords the use of TUIs as feedforward devices. Here, the TUI's response to an initial input action can guide the user toward some further action. Wensveen et al. [11] have developed an interaction framework whereby feedback and feedforward act as coupling mechanisms for user actions and computational functionality. While many examples of TUIs that provide feedback through different modes exist, few have investigated feedforward. This paper examines the "Tiresias Effect": like the mythological character to whom it refers, this mechanism realizes the potential of guiding the user towards future action.

The proposed user study seeks to explore how different modes of information can be represented and interpreted in TUIs that provide feedforward. The research instrument is a tangible prototype which can have one of two interfaces: one that uses temperature (heat change) and one that uses light (colour change) to convey information to the user. The study will assess whether users can perceive and interpret information in the form of heat change presented to guide future actions, and how this compares to using colour change to represent the same information for the same task.

Background

Different modalities and associated modes of information can be exploited in TUIs as feedforward mechanisms that unite user action and computer function. Wensveen et al. have developed a framework that links user action and underlying system functionality through these mechanisms. Feedforward guides user action: information is provided to the user before the user takes an action. TUIs, they argue, are appropriate for feedforward given the potential avenues for human action and natural feedback afforded by the physical properties of the interface. In this way, TUIs allow for a range of meaningful couplings between action and function. This paper proposes a user study that will test this claim empirically.

In their framework, Wensveen et al. offer three types of feedforward: inherent, augmented and functional. The prototype in this proposed research investigates inherent feedforward, which refers to how information about what actions the interface allows for and how the user can perform these actions is communicated to the user prior to enactment.

Using different modalities as feedback mediums is an established design strategy in TUIs. Examples exist across domains, contexts and purposes; Sniff [4], Slurp [13], and Wall and Brewster's visual-to-haptic interface for the visually impaired [10] are a sample of haptic feedback TUIs that exist. However, feedforward in tangibles is an area in need of empirical study. Feedforward techniques have been limited to force, vibration and motion. Also, the context of use has been limited to navigation systems; examples include CabBoots [1], ActiveBelt [8] and Tactile Wayfinder [2]. Applications outside of navigation are conceivable; in a game context of use, feedforward could support a novice user in guiding through game tasks, learning the interface or offloading cognition during tasks where attention is divided. The proposed research targets an unexplored tactile modality—heat sensation—within the context of a decision-making task.

Utilizing human's tactile modality to sense temperature change information emanating from interfaces, tangible or otherwise, remains unexplored. Interfaces that make use of temperature information from the environment as input are more prevalent; assessing these interfaces has informed the direction of this research. Iwai and Sato [3] created a touch interface that facilitates image creation through thermal vision, where heated objects act as paintbrushes. The reverse is tempting to consider: the interface providing temperature feedback in order to "paint" a user's experience. These examples showcase creative applications of temperature as input but make clear the lack of research on temperature as output. The prototype in this proposed research addresses this void by incorporating temperature as a physical characteristic that carries information. A number of research questions emerge from a review of existing research: Is heat more effective, less effective or equally effective as light in feedforward in a TUI? Do additional modes of information in an already busy interaction space benefit or hinder the user? How effective is heat as an information medium? What effect does heat have on user experience? To explore these questions, the proposed research is confined to inherent feedforward using light and heat in a TUI.

Design

The prototype (see figure 1) is a work-in-progress. It is comprised of two pieces: two TUI designs and a tabletop application. In the current iteration, heat and light feedback are functional but the task events do not trigger guiding output. It uses a "Wizard of Oz" setup, wherein a human operator observes user actions and responds with feedforward output by manually manipulating the information presented using the tangible devices. Future iterations will obviate the need for this approach with computer vision.

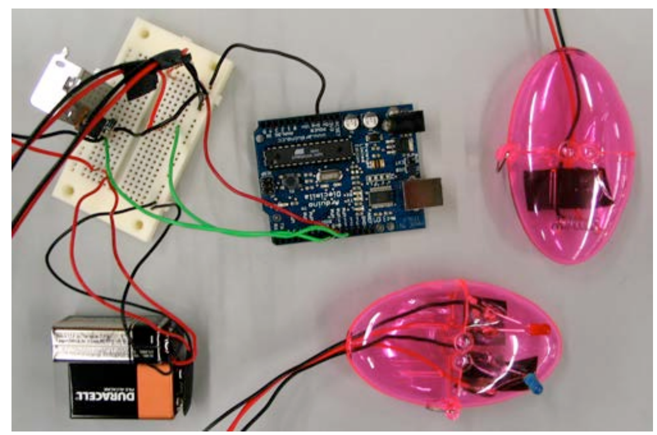

figure 1. The first iteration of the tangible prototype.

Two tangible interface designs are used. The first uses light information to provide feedforward. Light is continuous: two differently colored LEDs move gradually between off and on states such that when one is dimmed, the other is brightened (see figure 2). The second uses continuous heat information modulated by a heat circuit. The circuit is comprised of a metal coil, transistors, resistors, a heat sink and a battery. In effect, the battery is short-circuited to produce bursts of heat. The voltage is capped to keep the heat within a safe range. The temperature differential in the current prototype moves between room temperature (off) and warm; it does not yet account for cool temperatures. Further, while informal testing showed that a change in temperature is detectable, the rate of change is slow, particularly in comparison to the rate of change possible for light. We are reviewing solutions to these problems; possibilities include pre-heated or cooled blocks, or warm and cool air piped into the tangibles.

figure 2. The experimental conditions.

Both the levels of light and heat are controlled through the tabletop application, which interfaces with the Arduino board through Maxuino. Each interface is encased by the same smooth translucent pink shell, which serves to avoid potential confounding factors in having an inconsistent visual and tactile form between the interfaces. As tangible objects, the interfaces serve only to inform and guide the user and do not act as a point of control with the underlying system.

Wensveen et al. suggest that their interaction framework is suited to TUIs because of the inherent qualities of tangibles, namely the haptic and tactile modalities not found in other styles of interface. Light and heat is one coupling of TUI physical characteristics that can be used to convey information. Light is chosen in contrast to heat because of its notable presence in tabletop environments. Specifically, there is a great deal of light in tabletop environments, which contributes to visual clutter and dividing attention. A physical characteristic like heat that is expressed through a tactile modality may avoid this issue.

The use of two styles of the tangible interface will allow for comparisons of effectiveness between light and heat in providing information to the user. Having the same context of use and task will reveal differences in participants' user experience with respect to performance and preference. Visual and modal clutter will be assessed; the experiment will reveal whether light, which is visually perceived in an interface already presenting visual information, is detrimental and if heat, which is tactically perceived, avoids this issue.

The experimental task is inspired by a "Hot and Cold" children's game, and involves the user choosing between three nondescript doors, where only one is the correct choice (see figure 3). Tangible feedforward guides the user to the correct door. Both TUI styles use continuous light or heat information to provide feedforward. When the user is close to the correct door, the temperature increases or red light slowly appears; when the user moves away from the correct door, the temperature drops and the red light dims to blue (see figure 2). In this way, the task allows for two different continuous forms of information to be compared.

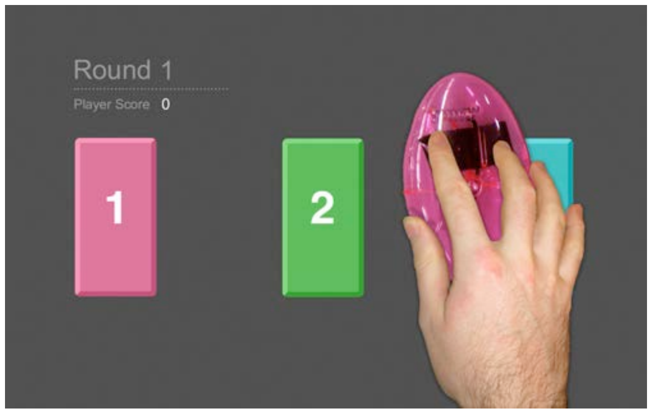

figure 3. The decision-making task application.

User Study

The proposed user study will be an exploratory mixed methods experimental evaluation. The independent variable is the TUI, and its levels are the two feedforward interface styles: light and heat. It will have a within-subjects design with participants equally distributed by gender across two patterns of two trials (corresponding to the two interface designs) such that the patterns will be counterbalanced. Sixty university students will be selected for the study. There will be 120 trials and two trials per participant. Each trial will involve a participant carrying out the experimental task; this involves choosing one of three doors as guided by feedforward. The dependent variable, user experience, will be operationalized in two ways: performance and preference. Performance data will be collected through scores (number of correct doors), which are recorded by the underlying system. A post-test questionnaire will address the user's preference for interface style. It will be comprised of two sets of questions. The first set will have ten closed Likert scale questions derived from Malone's heuristics for designing enjoyable user interfaces [5]. The second set will be open-ended and qualitative; analysis will involve coding the responses. A final question included only in the second post-test questionnaire will ask simply which interface style the participant preferred.

Future Work

The proposed user study is expected to indicate how heat and light in a feedforward tangible interface compare to one another in terms of user experience. Design implications for heat as a way of providing information in a TUI are expected to come out of the analysis of the data. In particular, whether or not heat is an appropriate medium through which to provide feedback, feedforward or other information will be exposed.

Future work could involve expanding the number of interface styles against which to compare heat. A more complex game, perhaps a game situated in a 3D world and requiring more intricate navigation, could be used to appraise feedforward involving 360-degree navigation. Finally, two aspects of feedforward—augmented and functional—were not addressed by this study; a future study could empirically explore the role of these aspects in TUI design.

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References
[1] Frey, M. CabBoots: Shoes with integrated guidance system. In *Proc. TEI 2007*, ACM Press (2007), 245-246.

[2] Heuton, W., Henze, N., Boll, S. and Pielot, M. Tactile Wayfinder: A non-visual support system for wayfinding. In *Proc. of the 5th Nordic conference on human-computer interaction: building bridges*, ACM Press (2008), 172-181.

[3] Iwai, D. and Sato, K. Heat sensation in image creation with thermal vision. In *Proc. ACE 2005*, ACM Press (2005), 213-216.

[4] Johansson, S. Sniff: Designing characterful interaction in a tangible toy. In *Proc. IDC 2009*, ACM Press (2009), 186-189.

[5] Malone, T.W. Heuristics for designing enjoyable user interfaces: lessons from computer games. In Thomas, John C. & Schneider, Michael L. (ed.) *Human Factors in Computer Systems*. Ablex Publishing, Norwood, NJ, USA, 1984, 1–12.

[6] Miller, D., Parecki, A. and Douglas, S. A. Finger Dance: A sound game for blind people. In *Proc. Assets 2007*, ACM Press (2007), 253–254.

[7] Nesbitt, K. V. and Hoskens, I. Multi-sensory game interface improves player satisfaction but not performance. In *Proc. AUIC 2008*, ACM Press (2008), 13–18.

[8] Tsukada, K. and Yasumrua, M. Activebelt: Belt-type wearable tactile display for directional navigation. In *Proc. UbiComp2004*, Springer (2004), 384-399.

[9] Valente, L., de Souza, C.S. and Fiejó, B. An exploratory study on non-visual mobile phone interfaces for games. In *Proc. IHC 2008*, ACM Press (2008), 31–39.

[10] Wall, S. A. and Brewster, S. A. Tac-tiles: Multimodal pie charts for visually impaired users. In *Proc. NordiCHI 2006*, ACM Press (2006), 9-18.

[11] Wensveen, S. A. G., Djajadiningrat, J. P. and Overbeeke, C. J. Interaction Frogger: A design framework to couple action and function through feedback and feedforward. In *Proc. DIS 2004*, ACM Press (2004), 177-184.

[12] Yuan, B. and Folmer, E. Blind Hero: enabling Guitar Hero for the visually impaired. In *Proc. Assets 2008*, ACM Press (2008), 169–176.

[13] Zigelbaum, J., Kumpf, A., Vazquez, A. and Ishii, H. Slurp: Tangibility, spatiality and an eyedropper. *Ext. Abstracts CHI 2008*, ACM Press (2008), 2565-2574.