Design for interface consistency or embodied facilitation?

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Abstract
This paper explores how tangible interaction, despite the development of specific frameworks and classifications for system modeling and description, still relies on the body of knowledge from the graphical user interface (GUI) paradigm to guide the design and development of its interfaces. In particular, this paper focuses on this issue in the domain of tabletop computing. Its goal is to explore the tradeoff between insights derived from applying an existing body of knowledge to a new area (e.g. GUI design to tabletops) and those derived from new domain-specific design guidelines and methodologies. It proposes an evaluation that compares two different interfaces for a collaborative tangible system: one built with recourse to the GUI guideline of *consistency*; the other rooted on a theory of *embodied cognition*. The results of this evaluation should be a valuable resource for researchers trying to develop specific methodologies and guidelines for the tangible interaction paradigm.

Keywords
Tangible interaction, embodied cognition, interface consistency, design guidelines.

ACM Classification Keywords
H5.2. HCI: User Interfaces.

Introduction

As the field of tangible interaction matures, frameworks and classifications have been introduced to aid developers in the creation of rich interactive systems (e.g. the TAC paradigm [5]). Such frameworks provide a common ground on which to compare different tangible systems. They typically focus on manipulable tokens and how they can be used to interact with an application. However, in the specific case of systems based on tabletop surfaces (e.g. [3]), most visual interfaces are still built with reference to methods and guidelines derived from GUIs. This is most likely due to the fact that typically these systems rely heavily on multi-touch input and pen-based interaction [6].

This paper questions the suitability of applying design guidelines created for GUIs to the development process of tabletop tangible systems. It also proposes the theories of *embodied cognition* as foundational material for guidelines that aid the design of rich tangible interaction, with a particular focus on how humans off-load cognition onto their surrounding environment. The rest of this paper is organized as follows: (1) a brief introduction to an important design guideline – *interface consistency* – and its implications for tangible interaction; (2) a short introduction to one of the aspects of *embodied cognition* – how users manage cognitive load by using their surroundings; (3) the description of a tabletop tangible application for collaborative routine creation that was developed for evaluation purposes; and (4) a plan description for user studies so as to determine how group performance is affected if a guideline like *consistency* is overshadowed by design decisions rooted on the body of work related to *embodied cognition*.

Related work

Interface consistency

Striving for consistency is an important part of any process regarding the design of interaction or interface. It is Shneiderman's first *Golden Rule of Dialogue Design* [7], and has been the focus of diverse research over the last three decades. A user interface can be consistent: with external features in the real world [2]; with other familiar interface designs; and with itself. One of the key characteristics of tangible interaction is its existence in the real world, normally leading to an interaction that is consistent with the users' real-world knowledge and skills [4]. Additionally, recent work from Ullmer *et al.* [1] has focused on how to develop tangible elements that are valid across different interactive systems. In contrast, this paper explores how can an interactive tangible tabletop application be consistent with itself if critical parts of the interface, such a token representing a tool, can be moved and dropped in diverse locations (even out of the systems' sensing capabilities). It also discusses whether spatial consistency should be enforced, and what the most effective way to achieve this is.

Embodied Cognition

Embodied Cognition is a perspective in cognitive science that grants the body a central role in how the mind operates, and it is clear that many advantages conveyed by tangible interaction can be explained through these theories [8]. In regards to systems based on interactive tabletops, one interesting theory is of how humans exploit the surrounding environment to reduce the cognitive workload required to complete or understand a task. Users can make use of the interface (and surrounding areas) to hold or manipulate information for them, and they then harvest that

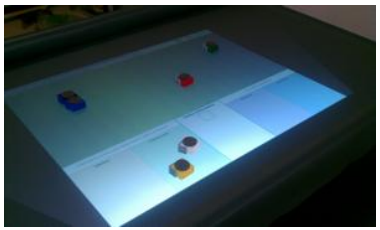

Figure 1. The version of the Eco Planner tangible system that was developed using the GUI design guideline of *interface consistency.*

information on a need-to-know basis only [8]. If users are in control of how they organize the interface (to some extent), will it increase or decrease group performance in collaborative tasks?

Eco Planner

Eco Planner is a tangible system that tackles the issue of energy consumption at home, as it allows users to create, manage and analyze their daily routines through tangible objects that serve as physical representations of their activities. It is composed by a set of tokens and an interactive tabletop interface. Each token physically represents an activity (e.g. watching TV, doing the laundry), and users can collaboratively create their household's routine by laying the tokens on the tabletop. The 2D space of the tabletop represents a day of the week (from 7am to 11pm), so tokens placed closer to the left will represent activities to be completed in the morning, while tokens placed closer to the right will represent activities to be performed at night. Likewise, tokens that are vertically aligned on the tabletop represent concurrent activities. Additionally, small objects (pyfos) representing 30 minutes can be aggregated in front of the tokens. These are not recognized by the system, and serve only to help users create a more complete and understandable routine. Also, by placing a token on an options for the activity (e.g. with the laundry token, users can choose to commit to always do the laundry with a full tank). Users are also able to choose between ecological or financial motivational cues, changing how the system interprets their routine and the recommendations it offers. Furthermore, due to the physicality and visibility of the tangible elements, Eco Planner aims to facilitate understanding and coordination of activities between users in a household.

Evaluation Plan

In order to determine if design guidelines derived from the theories of *embodied cognition* might be particularly valid and useful as aids in the development of tangible systems, two different versions of Eco Planner were developed. The purpose of this decision is to perform a sort of A/B testing against a version of the interface built with resource to a classic guideline – *consistency*. The first interface contains key areas in the interface where users can drop the activity tokens when not in use. These areas are color coded, each representing an area of a house (e.g. living room, kitchen). The goal of this interface is to provide users with a coherent and consistent drop/pick up point for tokens. The second version of Eco Planner doesn't provide users with such areas in the interface, allowing them to freely explore both the interaction space and the space around the tabletop as drop/pick up points for tokens. This version of the interface will provide insights of how allowing users to organize a physical interface can impact their performance.

Several metrics will be used in order to compare group performance between the two versions of Eco Planner:

- Time that takes a user to find a desired token, and reach it.
- Occurrence of verbal requests between users.
- Moving of tokens from the interaction space to the periphery of the system (and vice-versa).
- Occurrence of interaction between users when dropping/picking up a token.
- Repositioning of users around the system's surface.
- Variations in these values after a period of learning.

Conclusion

This paper argues that if the field of tangible interaction is to continue to develop, it will need to adopt specific design methodologies and guidelines that reflect its unique features and constraints. Although frameworks such as the TAC paradigm [5] are useful for developers when describing and documenting their systems, many interface decisions are still rooted in knowledge created for GUIs – this is particularly common in graphically rich tangible tabletop applications. This paper considered theories of *embodied cognition* as source for guidelines that might be better matched to the development of tangible interaction. In particular, it focused on how users might take advantage of the interaction space and surrounding area to better understand and complete tasks.

This paper also presented a tangible system for users to collaboratively manage their daily routines. Two different interfaces were developed for this system: one rooted on *consistency*, an important design guideline for GUIs; and the other based on a particular theory in *embodied cognition*. The goal is to study differences in group performance when: (a) users are offered a coherent location to drop tokens when not in use; and (b) users are free to explore the space around them to rest such tokens. This paper ends by proposing how such an evaluation should be conducted.

It is clear that concrete methodologies and unique guidelines are required for tangible interaction to fully take advantage of its users bodies and environment. This paper argues that the theories of *embodied cognition* are suitable starting point for generating this knowledge. Evaluations such as the one proposed here will help researchers to learn how to apply GUI knowhow to tangible systems, and also to generate dedicated new guidelines for tangible interaction.

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