User Perspectives on Multi-Touch Tabletop Therapy

Michelle Annett, Fraser Anderson, Walter F. Bischof

Advanced Man Machine Interface Lab
Department of Computing Science, University of Alberta
Edmonton, Alberta, CANADA

{mkannett, frasera, wfb}@ualberta.ca

cs.ualberta.ca/~ {mkannett, frasera, wfb}

ABSTRACT

Technology-based activities are becoming increasingly popular in therapy programs. In particular, multi-touch tabletops seem to be well suited for many therapy activities. To better understand the benefits of using multi-touch tabletops during rehabilitation, we examined users' attitudes towards rehabilitation activities on a multi-touch tabletop and on a non-interactive surface. Using a standardized questionnaire and semi-structured interviews, we identified many advantages and limitations of using multi-touch tabletops in rehabilitation. We discuss the implications of user expectations and experiences on the design of future activities and rehabilitation technologies.

1. INTRODUCTION

Multi-touch tabletops have become increasingly important therapy tools. Interactive tabletops and other direct-interaction devices have several advantages (Hutchins et al., 1985) that make them excellent candidates for new rehabilitation technologies. They are believed to be useful for regaining function and motor ability in patients recovering from strokes or traumatic brain injuries by encouraging lateral upper-body movement (Annett et al., 2009, Mumford et al., 2008). Multi-touch tabletops support natural and direct interaction (Wigdor and Wixon, 2011). That is, the user touches and manipulates an object or target directly instead of using a proxy device such as a mouse, keyboard, or joystick for interaction. As patients with cognitive disabilities often have trouble creating a mapping between a proxy object and target, this direct interaction provides an important advantage. Interactive tabletops also provide a large interaction space, which is needed for many patients to exercise gross motor function and fully explore their entire range of motion. Such interaction is not possible on small hand-held devices. Lastly, tabletops have the ability to support a patient's upper-body weight while performing an activity, thus allowing patients with varying abilities to benefit from activities.

Outside of tabletop-based therapy, it has been widely recognized that patient motivation and patient compliance with rehabilitation exercises are critical problems in physical therapy programs. One approach to encourage compliance and increase motivation has been to use video games, as it is believed that patients can become as highly engaged with their therapy exercises as video game enthusiasts are with their games (Rizzo and Kim, 2005). Thus, various gaming technologies such as the Microsoft Kinect (Chang et al., 2011), PlayStation EyeToy (Rand et al., 2008), and Nintendo Wii (Saposnik et al., 2010) have become pervasive in therapy programs (Flynn and Lange, 2010).

Previous studies on tabletop-based therapy (Anderson et al., 2012; Mumford et al., 2008; Annett et al., 2009) have focused solely on the movements produced by users, and have not considered the equally important aspect of user engagement. Recently, it was found that the structure of activities has more influence on participant movement than the use of technology (Anderson et al., 2012). These results emphasize that the strength of technology must be in improving motivation and compliance and demonstrate the need for the effective and informed design of activities. Not only must multi-touch therapy activities be engaging and compelling, but also the challenges such technologies present in clinical settings must also be addressed. The usefulness of direct-touch interaction and expectations that patients may have due to familiarity with similar devices (e.g., smartphones, tablets, and touch screens), are important factors that the present study investigates.

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In this paper, we examine user's subjective impressions towards tabletop-based therapy activities. We conducted an experiment in which participants were exposed to two 'traditional' therapy activities, as well as two multi-touch tabletop-based therapy activities. Participants completed questionnaires and a semi-structured interview to assess their subjective views on the therapy activities and use of technology in therapy. Overall, participants enjoyed the technology-based activities, but were unsatisfied with some aspects of the technology activities. We provide design recommendations to help mitigate the impact of these issues.

2. EXPERIMENT

2.1 Participants

As patient safety is of great concern when evaluating any new treatment, this study examined healthy participants. Although the healthy and disabled populations differ with respect to age or physical abilities, many valuable observations gathered from the healthy population should also be applicable to clinical populations. We recruited seven males and seven females (18-77 years old) to participate in the study. Each participant was right handed and had no prior experience with a multi-touch tabletop. The University of Alberta's Research Ethics Board approved the study.

2.2 Equipment

The technology-based activities in this study used a custom-built multi-touch table (Annett et al., 2009) that employed Frustrated Total Internal Reflection (FTIR) for sensing (Han, 2005). The acrylic surface of the table was approximately 80 cm above the ground and had a 91 cm x 61 cm region of interaction. The tabletop consisted of a projector, mirror, and an infrared camera. Infrared light sources were embedded around the perimeter of the acrylic display surface. The openFrameworks toolkit was used to process the raw video stream and determine when and where a user was touching the surface. Each of the technology-based therapy activities was written in Adobe Flex. Being FTIR-based, the tabletop is not as responsive or accurate as smaller-scale commercial devices that use capacitive sensing (e.g., iPhone, iPad), but is still very usable and responsive, especially when interacting with large targets, such as those used in this study.

For the traditional, non-interactive activities, a white, corrugated plastic board (91 cm x 61 cm x 0.4 cm) was placed on top of the acrylic surface of the multi-touch tabletop. The repurposing of the multi-touch tabletop in this way allowed participants to remain in the same location and use the same region of interaction across all activities.

2.3 Task

Participants stood in front of the multi-touch tabletop and completed four activities (Figure 1), two using the multi-touch tabletop (*Memory* and *Puzzle)* and two using the traditional, corrugated plastic surface (*Card Sorting* and *Grid of Stickers*). All four activities were comparable to activities currently used by patients at a local rehabilitation hospital and encouraged similar movements. For instance, the *Puzzle* activity required participants to slide rectangular images along the acrylic surface, whereas the *Card Sorting* activity required the same motions to reposition playing cards. Similarly, both the *Memory* and the *Grid of Stickers* activities required participants to reach out and touch a number of square targets. Further details about the activities can be found in Anderson et al. (2012).

Participants performed each activity for 5 minutes, with the order of activities randomized between participants. If participants finished the activity before the allotted time elapsed, the activity was reset and the participant repeated it until 5 minutes elapsed. A short 3-minute break was allowed between activities to mitigate possible fatigue effects and allow for the next activity to be set up. Similar to constraint-induced movement therapy (Kunkel et al., 1999; Taub et al., 2004), participants were restricted to use only their dominant (right) arm to complete each activity.

The Intrinsic Motivation Inventory (IMI) (McAuley et al., 1989) was used to assess participant's subjective opinions towards each of the activities using Likert-type responses to statements such as "I would describe the activities as very interesting". From the responses, scores along four separate dimensions (i.e., interest and enjoyment, effort and importance, mental tension and pressure, and perceived competency) were computed and represent the participant's subjective feelings towards the different activities. Two IMI's were administered, one assessing both of the traditional activities (*Card Sorting* and *Grid of Stickers*) and the other assessing both of the technology-based activities (*Memory* and *Puzzle*). At the conclusion of the experiment, a semi-structured exit interview was conducted. The following guiding questions were used during the

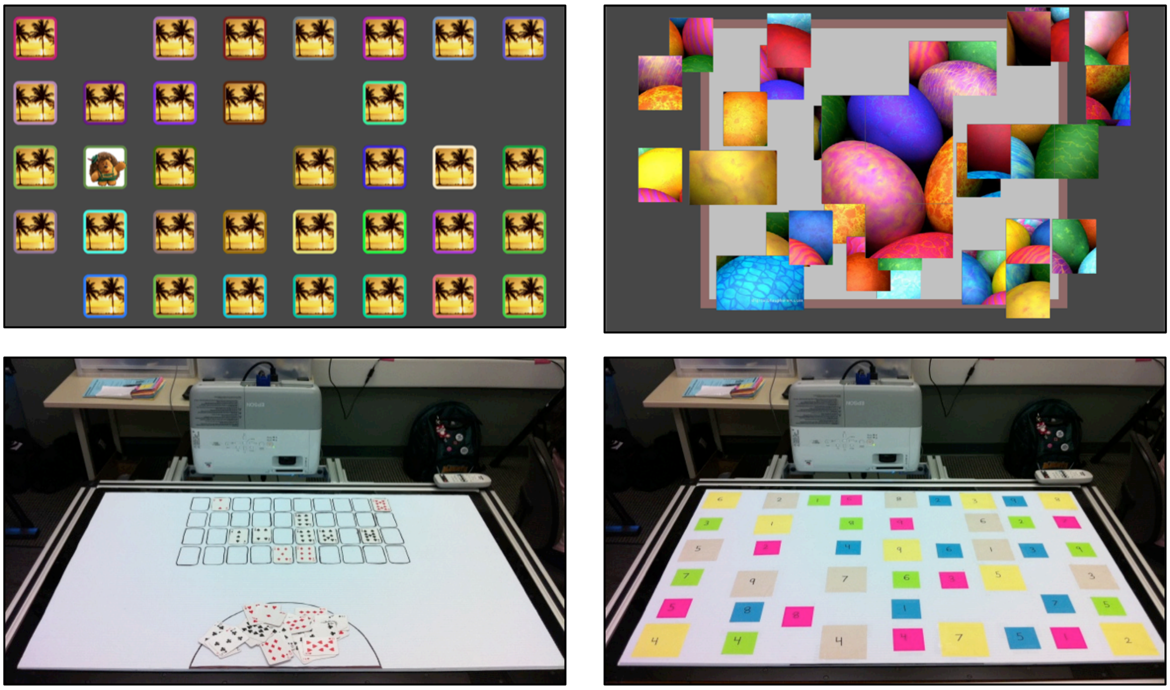

Figure 1. (Clockwise from top left) The four activities used in the study: *Memory* (in which participants touched virtual tiles to 'flip them' and reveal images underneath which they must match), *Puzzle* (in which participants had to slide tiles on the screen to assemble a large picture), *Card Sorting* (in which participants had to slide the physical cards into ascending order, by suit, into the grid) and *Grid of Stickers* (in which participants had to touch the tiles in order, by color, repeatedly).

interview and participants were encouraged to engage in open discussion:

- Which activities did you enjoy the most? Enjoy the least?
- If you could change any of activities, what would you change?
- Which category of activity (traditional or technology) did you prefer?
- Imagine you are in a therapy program. Which of the activities would you prefer to use?

3. RESULTS AND DISCUSSION

The Intrinsic Motivation Inventory responses (Figure 2) were analyzed using Bonferroni-adjusted, Wilcoxon signed-rank comparisons. Participants rated the multi-touch activities (*Memory* and *Puzzle*) as significantly more interesting and enjoyable than the traditional activities (*Card Sorting* and *Grid of Stickers;* $Z = 2.79$, $p = .0052$). There were no significant differences along the other dimensions (i.e., effort ($p = .45$), competence ($p = .71$), and tension ($p = .68$)). As all four of the activities were quite simple and participants were instructed to perform each activity at their own pace, the lack of statistical differences is unsurprising.

The semi-structured interviews help to explain the reasons behind the increased scores of enjoyment and interest. Several participants commented that they enjoyed the technology-based activities more because they contained dynamic elements and feedback about their progress: "hearing the puzzle click together and having the tiles disappear in front of me was super motivating" (P1). Although the activities were completed individually, many participants mentioned that they took a competitive stance towards completing them, "[the tech] wasn't frustrating at all! For me it was like a competition" (P10). When using the multi-touch tabletop, several participants indicated that they were motivated to accomplish a worthwhile goal: "I like the puzzle one because you're actually playing a game and trying to finish something instead of just touching stickers" (P3).

These comments suggest that technology-assisted rehabilitation might be more enjoyable because it provides meaningful, achievable challenges and real-time, dynamic feedback to users. The participant's feedback is consistent with beliefs that dynamic gaming elements lead increased enjoyment and adherence to therapy programs. When designing activities for therapy, it is not enough to simply rely on the use of

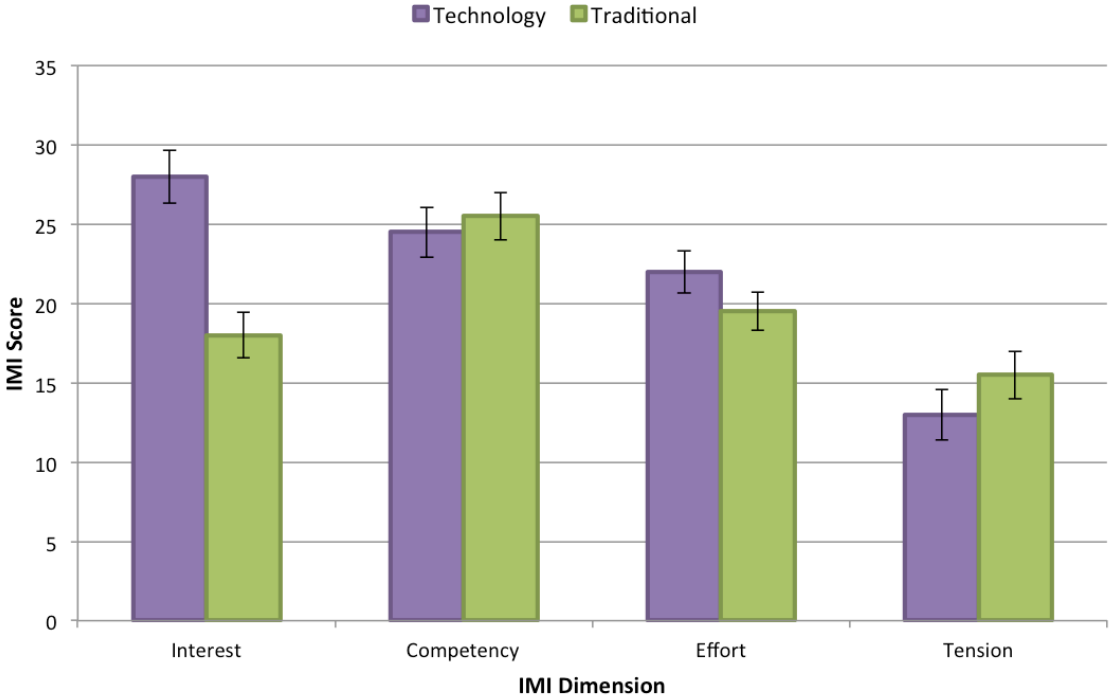

Figure 2. The median scores for each of the dimensions of the IMI. Error bars depict the standard error of the mean. The 'Interest' dimension is statistically higher with the technology-based activities (i.e., *Memory* and *Puzzle*) than with the traditional activities (i.e., *Grid of Stickers* and *Card Sorting*).

technology to increase engagement and adherence. It is important for designers to think carefully about the goals of the activities they are designing and employ feedback at the correct frequency, using the correct medium, and at an appropriate cognitive level. Designers should also work to provide engaging, and challenging (yet accomplishable) elements within their activities that are intrinsically motivating to patients.

Other comments alluded to the role that prior exposure with technology had on participants' expectations and experiences with the multi-touch tabletop. Many participants compared the multi-touch tabletop (and its activities) to commercial multi-touch devices: "if you have an iPad you can see that it registers every motion and gesture ... the design of [iPad] games are better" (P13); "I'm just so used to playing those iPhone games" (P12). Many participants expressed that they would definitely prefer to use the multi-touch tabletop in a rehabilitation setting if it was as refined as the commercial products they use every day.

As the quality of commercial technology increases but the budgets for therapy-driven software remain comparatively low, these observations become particularly relevant. The user-facing aspects of therapy software need to be improved to meet the growing expectations and familiarity patients will have with multi-touch technologies. In the near future, many patients will be intimately familiar with software products and video games released by large production studios with equally large budgets. Unfortunately, custom therapy-targeted projects will likely not have these budgets so designers will have to be creative in finding ways to meet such expectations. To create engaging, high-quality games at low costs, designers should leverage existing content and technologies where possible, and use openly available video-game engines to ensure that the rehabilitation games do not feel similar to ad-hoc prototype applications, instead appearing robust, well designed, and thoroughly tested.

Several participants were also quick to cite technology (i.e., the multi-touch tabletop) as the source of any errors that occurred rather than their own actions. As the multi-touch tabletop provides direct-touch interaction, there is a much smaller gulf of execution than with indirect-touch interfaces (Hutchins et al., 1985), causing more ambiguity with regard to the source of errors. During our experiment, the largest sources of frustration were situations in which false touches were being detected and situations where the user received little or no feedback. When this happened, many users were unsure if they were not touching the surface with enough force (even though it was not pressure sensitive) or were not touching in the right location, leading to confusion and annoyance. For example, one participant was "irritated at how the tabletop

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wasn't too responsive" (P7) and continually exerted more force on the surface. In contrast, none of the participants complained about the mechanics of the traditional activities when they made an error and one participant commented that they "felt [they] could handle the physical materials more easily than the digital ones" (P8).

To minimize user frustration during input, tabletop activities must have responsive sensing and accurate feedback, as users will otherwise become quickly irritated and feel as if they are not in control of an activity and potentially their therapy progress. While hardware is a large determinant of the responsiveness and accuracy, some steps can be taken in software to reduce the apparent effects of these parameters. For direct-touch devices with coarse sensing resolution (or noisy sensing), on-screen targets can be made larger so that pixel-level accuracy is not required. Feedback should also be used to indicate the exact location where the user's touch was registered. Such feedback will allow users to adjust their interaction to accommodate for any offsets or input warping and will help reduce the ambiguity caused by positioning errors. To mitigate latency issues, developers should ensure that feedback regarding a sensed touch is displayed as soon as possible and not delayed by complex application-specific processing. If complex processing is required, the system should first provide the feedback on where the touch was registered before processing the application-specific response.

4. CONCLUSIONS AND FUTURE WORK

Given the previous work demonstrating that technology itself is not enough to modify the movement patterns of individuals in therapy programs, it is clear that the benefit of technology lies in its ability to provide responsive, dynamic content. To that end, we have studied user attitudes towards interactive tabletops and found that while users do typically find them more engaging, there are some limitations that must be overcome before they can become truly beneficial for clinical populations.

There are several avenues along which this work can be extended. One next step is to refine our activities based on the observations gathered during the current study and perform a long-term study with a patient population. While we expect many of our conclusions and recommendations to generalize to both populations, studying the usage behavior of the actual target end users (i.e., patients) will likely produce additional insights that will be of great value. Additional future work could also involve studying those aspects of tabletop-based therapy that contribute to success and enjoyment for the end user, for instance, examining the relative importance of customization, dynamic feedback, emotional saliency, and game content.

This study has revealed important insights into multi-touch therapy activities. While direct-touch interaction offers a number of benefits when used in therapy-based activities, there are a number of drawbacks that should be addressed. Using our design recommendations, the engagement and enjoyment patients experience during therapy can be improved, leading to higher motivation and ultimately compliance with the therapeutic activities.

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