What People Really Remember – Understanding Cognitive Effects When Interacting with Large Displays

Philipp Panhey[1], **Tanja Döring**[1], **Stefan Schneegass**[2], **Dirk Wenig**[1], **Florian Alt**[3]

[1]University of Bremen
Research Group Digital Media
first.last@uni-bremen.de

[2]University of Stuttgart
Human-Computer Interaction Group
stefan.schneegass@vis.uni-stuttgart.de

[3]University of Munich
Media Informatics Group
florian.alt@ifi.lmu.de

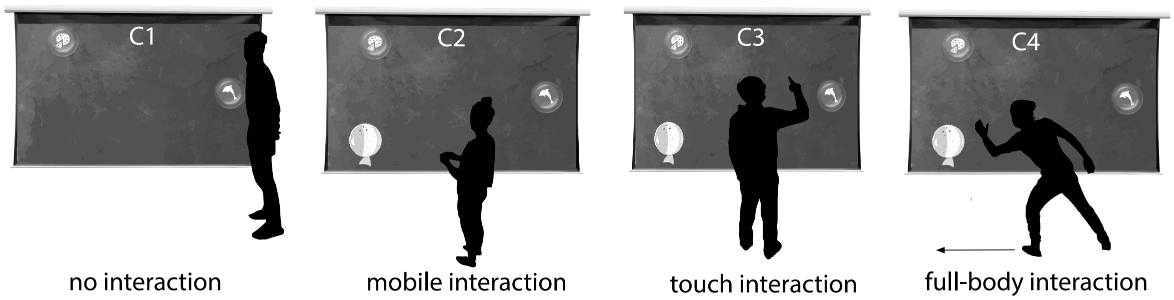

Figure 1. We investigate how different types of interaction (mobile interaction, touch interaction, and full-body interaction) impact on how well people can remember content of large screen displays. In contrast to prior work on interactive TV and the WWW, our findings reveal that more movement can negatively influence recall, hence leading to a trade-off for designers between user experience and memorable content.

ABSTRACT

This paper investigates how common interaction techniques for large displays impact on recall in learning tasks. Our work is motivated by results of prior research in different areas that attribute a positive effect of interactivity to cognition. We present findings from a controlled lab experiment with 32 participants comparing mobile phone-based interaction, touch interaction, and full-body interaction to a non-interactive baseline. In contrast to prior findings, our results reveal that more movement can negatively influence recall. In particular we show that designers are facing an immanent trade-off between designing engaging interaction through extensive movement and creating memorable content.

Author Keywords

Pervasive displays; interactivity; cognition; recall.

ACM Classification Keywords

H.5.1. Multimedia Information Systems: Evaluation / Methodology; H.5.2. User interfaces: Interaction styles

INTRODUCTION

The past years have witnessed a proliferation of our daily life with digital displays due to falling hardware prices. Particularly museums but also municipalities employ interactive displays to convey information. Though such displays have the potential to increase the experience as people can interact with the content, it is unclear as of today, whether there are benefits from a learning perspective – i.e., can we assume that users remember content shown on a screen better as they interact with it? In particular, do performative techniques, requiring a lot of movement, have a positive effect?

Prior research found interaction to positively influence cognition, particularly in the context of interactive TV [8] and on the WWW [9]. At the same time it is unclear, whether these findings hold for large interactive screens. Early work suggests a general effect on recall [1]. However, it focuses on gesture as the sole interaction technique. Our work provides the first detailed comparison of different interaction techniques, focusing on mobile phone, touch, and full-body interaction as the most popular interaction techniques for large displays. This paper contributes a detailed investigation of how these different types of interaction impact on users' ability to learn content shown on a large interactive display.

We hypothesize that, similar to prior findings, interaction leads to an increase in recall, particularly if users are required to move extensively and if interaction provokes positive emotions. To investigate our hypotheses, we built an interactive game that allows for interaction by means of mobile phones, touch, and full-body gestures and compared it to a learning task without any interaction. Results show that, in contrast to our hypothesis, recall may be negatively affected by interaction, particularly if physically demanding. Hence, designers need to decide whether to optimize for user experience through extensive movement or for cognition.

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APPROACH AND HYPOTHESES

This work explores how different interaction techniques with varying degrees of *movement* and the ability to invoke *positive emotions* impact on cognition. We designed a controlled lab experiment, that allowed us to account for any external influence that may impact on cognition. We created an interactive game where users had to destroy bubbles containing different symbols on the screen. Users controlled the game using one of three input modalities – the mobile phone, touch, and full-body gestures – thus allowing techniques that require different degrees of movement to be compared (Figure 1). After the game, we tested for recall of the symbols and assessed the different techniques through questionnaires.

Hypothesis 1. More movement results in higher recall. Prior work found positive effects on recall rates and acute cognitive performance based on motion and motor processes [1, 3, 4]. We hypothesize that similar effects occur for interaction with large displays. To address H1, we designed different interaction techniques with varying degrees of movement.

Hypothesis 2. More positive emotions while interacting result in higher recall. According to results from prior work on positive emotions (in form of positive valence) and recall [11] and on emotional arousal and memory [7], we hypothesize positive emotions (which combine positive affect with arousal, cf., [10]) during interaction with large displays to increase recall. Thus, we assess positive affect after interacting.

USER STUDY

Apparatus and Setup

We implemented an interactive display game where a blowfish on the lower border of the screen had to be moved horizontally to destroy falling bubbles. The bubbles contained different symbols that we used later to assess recall. The game design (same drop distance and speed of bubbles, bubbles bursting at the bottom of the screen) ensured that all bubbles were shown for the same amount of time (3 s), no matter if destroyed by the blowfish or not. In each game, all symbols were shown 3 times. The symbols appeared at random horizontal positions, hence minimizing any spatial memory effects. The game was deployed on a 3,5 m $\times$ 2 m screen (Figure 2).

Bubbles contained particular symbols. Each symbol belonged to one of four categories we assigned to the interaction techniques. The categories were animals (S_1), food (S_2), transport (S_3), and household (S_4) each consisting of 15 items.

Interaction Techniques

The techniques for controlling the blowfish varied in their extent of body movement necessary to perform the interaction.

- For *mobile interaction* (C_2), players stood in front of the screen and held a mobile phone horizontally in one of their hands. Tilting the phone more than 30 degrees sideways moved the blowfish while a smaller angle stopped it. The data was send to the computer connected to the display.
- For *touch interaction* (C_3), players had to directly touch the screen and, thus, move with both their arms and body. The blowfish then moved to the touched location on the screen. We used diffused illumination for finger tracking.

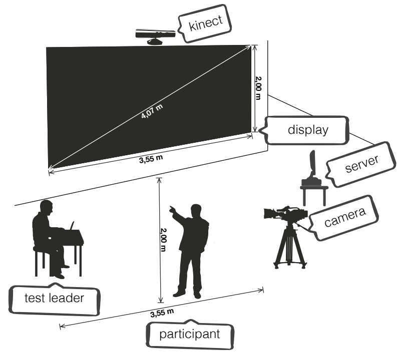

Figure 2. Study Setup. Participants interacted from a distance of 2 m with the 3.55 m $\times$ 2 m screen. The experimenter and a camera observed the players during the game.

- For *full-body interaction* (C_4), players positioned themselves in front of the screen. To control the blowfish, players simply moved horizontally in front of the screen. We used a Microsoft Kinect sensor for tracking the player's position and directly map it to the location of the fish.

A *non-interactive* baseline condition (C_1) was implemented, in which users had to stand in front of the screen, solely watching the contentpresented in the same manner as in the other conditions (e.g., falling bubbles with 15 symbols, 3 s per fall). As the participants did not interact and thus could focus completely on memorizing the symbols, the experiment is biased in favor of this condition. C_1 to C_4 are ordered by the degree of movement from least to most. In all conditions except touch, participants were to position themselves at 2 m in front of the screen with the game being shown in full-screen mode. To compensate for the closer distance during the touch interaction (0.5 m) we reduced the game size on the screen proportionally (width: 0.88 m; height: 0.5 m). Thus we ensured that bubbles appeared in constant size in all conditions.

Data Collection

During the game we logged all symbols shown on the screen as well as whether and when a bubble was destroyed by the user. All data was time-stamped. Furthermore, all blowfish destination coordinates were logged. During the study, all sessions were videotaped for post-hoc analysis.

Study Design and Metrics

The study was designed as a repeated-measures experiment where each participant played the game in each condition. The order of the four conditions and the symbol sets were counterbalanced. Participants played the game for 135 s in each condition (15 symbols were shown 3 times for 3 s each). We chose such a short time to minimize any influence of fatigue and to reproduce a typical, usually short, public display interaction [2]. Before the game we asked participants to try and remember as many items as possible. All participants were naive to the hypotheses. During the study we provided the participants different questionnaires. At the outset of the study, participants had to fill out a *demografic questionnaire*. After each condition, participants then had to complete a *recall test*; the participants had to write down the items they remembered from the previous interaction stage. In addition, we asked them to fill in a *game experience questionnaire*

(GEQ) [5] and a *user experience questionnaire* (UEQ) [6]. The GEQ quantifies tension, positive and negative affect, immersion, flow, competence, and challenge. The UEQ assesses attractiveness, design quality, and use quality. At the end, we conducted semi-structured interviews with the participants.

Procedure

We recruited participants by approaching people on campus. All participants were students or university employees but came from a wide range of subjects. As participants arrived at the lab we had them fill in the initial questionnaire and then introduced the game, the different interaction techniques, and the task. We allowed participants to practice each condition so that they could familiarize with it. Then they started to play the game in the first condition for 135 s. After that, they had to complete the recall test and the questionnaires. This procedure was repeated for all conditions.

RESULTS

We invited 32 people (16 female) with an average age of 27.5 years (SD=6.8). All participants had an academic background (25 students, 7 employees). All participants owned at least one touch device, 7 had prior experience with Kinect and 22 with Nintendo Wii. When asked about how easily they could remember things, answers were mainly neutral (5-Point Likert scale, 1=don't agree at all, 5=completely agree; M=3.09, SD=0.89). For all follow up analyses we applied a Holm-Bonferroni correction.

Game Performance

Among the three interactive conditions, participants performed best in the mobile condition, on average destroying 91.53% of the bubbles (M=41.19, SD=2.68), followed by full-body interaction with 89.51% (M=40.28, SD=2.4). In the touch condition participants on average destroyed 87.58% of the bubbles (M=39.41, SD=2.92).

Recall and Interaction Techniques

Figure 3 shows the mean recall scores per technique. Ordered by recall rate, the ranking is as follows: no interaction (76.5%), mobile interaction (69.2%), full body interaction (66.7%), and touch interaction (62.9%). A one-way repeated measured analysis of variance (ANOVA) reveals a significant effect of the interaction modality on recall, $F(3, 29)$=7.799, p<.001. Follow-up comparisons show that people could recall significantly more symbols in the non-interactive baseline condition than mobile phone (p=.009), touch (p<.001), and gestures (p=.005). Furthermore, people could recall significantly more symbols when interacting with the phone, compared to touch (p=.014). All comparisons were not statistically significant. Thus, we reject H1.

Game Experience and User Experience

Using the GEQ we investigated the impact of ”positive affect”. An ANOVA reveals a statistically significant effect of the interaction technique on ”positive affect”, $F(3, 29)$=6.142, p<.001. Mobile interaction significantly evokes more positive affect than touch (p=.008) and static interaction (p<.001). Full-body interaction significantly engenders more positive affect than static interaction (p=.004).

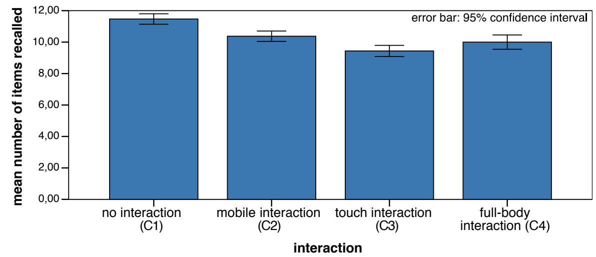

Figure 3. Mean number of items recalled for interaction techniques (out of 15 items in total). In the non-interactive baseline (C_1), participants could recall most items. The mobile phone-based interaction technique (C_2) performed significantly better than touch interaction (C_3).

Analyzing the results from the UEQ reveals a significant effect regarding attractiveness, $F(3, 29)$=16.367, p<.001. Post-hoc analysis shows that mobile interaction is significantly more attractive than touch interaction (p=.001) and the baseline (p<.001). The static condition is significantly less attractive than touch (p=.003) and full-body interaction (p<.001). Positive affect and attractiveness do not significantly correlate with recall. Therefore H2 has to be rejected in this context.

Qualitative Results

Semi-structured interviews revealed that most participants liked *mobile interaction* best (53.1%). They described it as accurate and liked the haptic element in their hand. Furthermore, they felt that it closely resembles other controller-based techniques. P5 pointed out that he liked the 'low mental effort'. With regard to *full-body interaction* participants who favored this technique (37.5%) reported to like not having to hold something in their hands. Others, however, felt that too much movement was required to accurately recall all items. They reported this technique to 'disturb' the recall process and that the task shifted into the background. Still the technique was considered to be innovative and exhilarating. *Touch interaction* (9.4%) required some familiarizing, but was in general perceived positively. Yet, participants felt to be too close to the screen to properly recall items. The fact that people could best recall items in the *static condition* is reflected in answers during the interviews. People stated that it was easier to recall items since they did not have to focus on the interaction.

DISCUSSION

There is strong evidence from prior work that interaction supports cognition. At the same time, earlier studies were conducted in situations, where (1) people are highly familiar with interaction modality and technique and (2) interaction only requires a limited amount of motion. This situation changes in front of large screens. Interaction can be designed in a way that it is physically demanding and, particularly if encountered in public space, users often need to learn the interaction.

The results of our study reveal that when designing interaction with large screens for supporting recall attention needs to be payed to the details of the interaction techniques beyond movement. The interaction technique should be highly usable, easy to learn, keep the cognitive load low, fit to the interactive content, and be engaging (e.g., through movement, but not too much of it) while letting the user keep the eyes on the content.

This is, of course, in practice not an easy task, but from our study we can derive a number of recommendations.

First of all, although our baseline condition with "no interaction" gave the best recall results, it is not an option for real settings as prior research has shown that people pay much less attention to non-interactive content [1]. In line with this, our interviews revealed that most participants found it boring.

Second, our results indicate that touch interaction may not be appropriate for recalling content on large displays due to the close distance to the screen. Although we compensated for potential effects by adjusting the screen size to the field of view and by using only the x coordinate for interaction (i.e., the users could touch at an arbitrary height on the screen), we still found the lowest recall performance, and participants gave feedback that the distance to the screen was perceived as too short. Thus, we do not recommend direct touch interaction for large screens when optimizing for recall.

Third, comparing mobile and full-body interaction, we obtained better results for mobile interaction in recall, in the subjective rankings as well as regarding mean scores for attractiveness (UEQ) and positive affect (GEQ). This shows that it was designed in a way that seemed to fit the task better. Participants pointed out that they liked its unobtrusiveness, and that they could fully concentrate on the screen. In comparison, full-body interaction was perceived as containing too much movement, which caused disturbance, especially because of moving the head changed the field of vision. Nevertheless, the participants found full-body interaction very stimulating and original. The results show that too much movement can negatively influence recall. Designers need to carefully consider whether they want to design for engaging interaction through extensive movement or to convey knowledge to the user. In our study, the mobile phone provided a good compromise that many users liked and that led to good recall rates.

LIMITATIONS & FUTURE WORK

Our study has some limitations. Participants may have had different degrees of experience with the interaction techniques. Hence, we allowed them to practice the interaction in all conditions. Also the ecologic validity of our findings is limited, since we did not conduct it in a public setting. Yet, the focus of the study was on internal validity and hence on the comparability of our study conditions. Hence, we deliberately designed the game and the interaction techniques as well as the study procedure in a way to ensure that the users kept their focus on the content and were as little as possible distracted by performing the interaction.

First of all, we did this by designing very simple interaction techniques that did not require much learning. By observing each participant we made sure that we did not start the study until his or her focus was completely on the content. In none of the conditions, the users had to look at their hands, other body parts, or at any devices to perform the interaction.

Furthermore, we focused on playful content. While we believe games to be among the most important applications for interactive displays, we cannot make any assumptions with regard to other content. This should be subject to future work.

Finally, we did not explicitly measure arousal, which was shown to impact on cognition (e.g., [7]). Future work could investigate this relationship in more detail.

CONCLUSION

In this work we investigated the effect of movement and positive emotions on recall during interaction with large displays using different modalities. In contrast to our hypotheses, neither movement nor positive emotions led to an increase. Too much movement can even negatively affect cognition. From this we learn that when deploying for interactive displays, designers need to carefully consider whether they want to design for engaging interaction through extensive movement or to convey knowledge to the user. Our findings yield that mobile phone-based interaction may be a good compromise.

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