Fostering Large Display Engagement Through Playful Interactions

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ABSTRACT
Challenges confronting designers of public displays include display blindness, i.e. the propensity of people to ignore these displays as they become ever-more ubiquitous, and the "first click" problem, i.e. users not interacting with these displays due to being unaware of interactive content. To address the challenge of display blindness, explicit and tacit mechanisms for interacting with displays have been explored. Unfortunately, because of the short-term nature of many installations, it has been difficult both to assess the relative effects of different interventions because of limited statistical power and to assess the relative effects of different interventions due to display blindness because the short-term nature of deployment limits the onset of display blindness. We explore two simple whole body (non-touch) interactions with a public display, one a user skeleton and the second a simple game, to explore their relative efficacy at capturing passers-by attention and at keeping passers-by engaged. We demonstrate the complimentary benefits of user-shadowing and playful tasks as a mechanism to both capture and keep in the context of public deployments.

Author Keywords
Large Interactive Displays; Public Space; Field Study.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

General Terms
Large Display; Public Interaction; Gestural Input; Field Studies.

INTRODUCTION
As displays become ubiquitous, there is a risk that we develop display blindness [11, 18, 19, 20], i.e. that we fail to perceive and interact with visual content. In some cases – for example advertising – it may be that we perceive our lack of perception to be an advantage. In other situations, however, there is frequently a benefit to either the display owner or to the potential viewer in perceiving and reacting to content on a public display.

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In recent work, Cheung and others [8] have explored techniques that allow interactive public displays to capture users' attention. In particular, their work explored different on-screen awareness mechanisms such as the use of shadows of potential users and variable speed relative to potential users to attempt to attract attention. While the on-screen mechanisms were shown to have potential benefit in a short term public deployment [7], it was not possible to tease out the relative benefits of different interventions both because of the short term nature of the deployment and because of the novelty of the deployment of a new public large screen display.

The goal of this work is to explicitly build on previous work in attention capture on public displays. One challenge we note with previous work is that much of the work has been completed in laboratory settings [8]. While these laboratory studies can, through careful control, show statistically significant effects, when displays are moved to public settings it has proven difficult to replicate the significant effects of laboratory (or *in vitro*) manipulations in a deployed setting (i.e. *in situ*) [7]. This is undoubtedly due to the idiosyncrasies of deployment (e.g. novelty, the 'honey pot' effect) [6, 15] and an inability to carefully control the real world deployment such that significant effects can be measured over short durations [17]. Alongside the challenge of laboratory settings, some work in interactive public displays has assumed that these displays are touchscreens [7, 12, 17, 25]. This seems an unusual assumption given the ubiquity of smartphones, smartwatches, tablets, and other personal displays and given questions of robustness and hygiene. We would argue that public displays are at their best when they react to users to elicit subtle and tacit short-term, surrendipitous interactions [2, 25]. The simplest measure of an ability to capture visual attention for short term engagement is not proximity nor touch – we can pause and look without either of these measures; instead, the simplest measure is the *holding time* of a display [5], i.e. how long a display can capture the user. The problem then becomes one of designing interactive elements on the display that assist in capturing and sustaining the users attention for a desired duration, at a minimum sufficient time to observe content [8].

This paper describes an *in situ* deployment of a large public screen that leverages whole body interaction and two different attention mechanisms from past research, a simple 'pong' game and a skeleton representation of the user, to explore the ability of non-touch interactivity to capture users. Alongside this exploration of playful interaction, we also invest effort to foster display blindness. Specifically, a public display with ever-changing content was deployed for over one year prior to our experiment to allow frequent passers-by to habituate themselves to the presence of the display and the changing content. The display included interactive components similar to our interventions (a set of simple games, user shadows) that users could engage with alongside static content. Then, during a four week period, we explored different visual manipulations [8] designed to capture attention on the display and measure their relative holding power.

Our results demonstrate an interesting contrast between games and user skeleton representations. Games prove less effective at capturing attention upon commencing interaction, represented by the fraction of passers-by who slow down initially. However, the purposeful nature of games fosters greater holding power over longer time frames. We discuss the implications of this work to the design of attention capture mechanisms for public displays.

RELATED WORK

Public Displays

A significant body of work on large public displays exists. This work has included numerous studies of public deployments of touchscreens [17, 21] and tabletops [10, 15]. Researchers have explored how distance calibrates interaction [25], how people use space around the display [2, 22], and cognitive barriers to interacting [6, 20].

Alongside touch, other modalities of interaction exist for public displays including gaze [24] and embodiment [9, 25] to influence content. Embodied interaction [9] overcomes many of the challenges of public touch-screen displays including limitations on space around the display [2], hygiene [13], and vandalism [3]. While one option to the challenges of interaction with public displays is to use a mobile device [3, 13], this requires users to connect to the display [13], a heavyweight constraint on interaction particularly when information can be obtained from a personal device without the need for coordination with the external display. The primary role of a public display is to provide visual access to contextually relevant content of a form that is sufficiently depersonalized so as to protect the viewers privacy. We believe the primary goal should be awareness, not direct-touch interaction.

Overcoming Display Blindness and First Click Problems

Regardless of when and where displays are deployed and regardless of how one interacts, public displays are often overlooked or ignored [8, 19]. Researchers have used a few key terms in describing this phenomenon. First, display blindness [11, 18, 19, 20], which is the inability to divert passerby attention toward the display. The *first click* problem [12, 14, 19] arises after grabbing the users attention. This problem describes "interaction blindness" or the inability for the user to recognize the display as content to interact with. Reasoning behind these problems include people actively looking away from the display to avoid information overload [14], the serendipity of public displays [18], fear of social embarrassment or appearing 'silly' [6, 14, 20], or even the angle the user approaches the display from [4, 23]. Techniques to overcome these two problems include text [14, 19], gamification [19], visual effects [14] and user representations such as skeletons, silhouettes, or mirror images of the interacting user [1, 4, 8, 19, 25].

Psychological theory of kinesthetic-visual matching facilitates recognition of an abstract user representation, such as a silhouette or skeleton, through the correlation of the users' own motion and visual feedback [16, 19]. In terms of user representation, Ackad et al. [1] found that skeletons elicited longer, more playful interactions than did silhouettes.

When we look at past work, one challenge that we note in public deployments is the challenge associated with novelty effects. Cheung [7], for example, deployed a public display on a mobile stand for four hours per day over four days because of the risks of theft and damage to equipment in public venues. Morrison et al. [17] note the challenges associated with this explicitly in design, asking "What happens when the novelty wears off?" The end result of limited deployment time is that habituation cannot occur, and, without habituation, it is difficult to discriminate between different attention-seeking alternatives employed on public displays.

Measures of Interaction Success

In some environments, the form of interaction being solicited involves using a touch interface to manipulate content. When we lack the explicit feedback of a touch event to measure engagement with a public display, researchers often focus on alternative measures – holding time [5], manual encoding of videos [19], gaze detection [24], or turning of the head [4], for example – to measure their success at drawing attention.

In museum exhibits, one common measure of the success of an exhibit is holding time [5]. The advantages of this measure are that it is easy to capture automatically, but it is difficult to apply to small numbers of participants due to passers-by who may happen to stop at a specific location. The most effective way to deal with false positives that occur is through long-term deployments of exhibits or displays.

EXPERIMENTAL DESIGN

Our experimental design was a two-phase design consisting of, first, a control phase where we deployed a public window display supporting whole body interaction with playful content and allowed people to habituate themselves to the window display, followed by an experimental phase where we explored two different treatment variables to measure the ability of the display to capture attention. We first describe the deployment location. We then describe the control phase and the experimental phase.

Deployment Location

The interface was deployed in a corridor on the third floor (European second floor) of the William G. Davis Computer

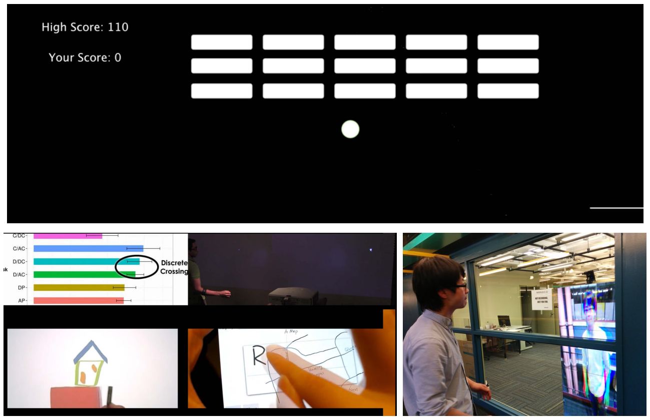

Figure 1. Interfaces used to habituate the passersby with the system. The top image is a simple breakout game with the paddle moving according to the motion of the passersby. The bottom-left, non-interactive interface shows various looping research videos. The bottom-right shows an alternate portrait configuration of the display

Figure 2. A user interacting with the display configuration used for the study in the hallway space.

Research Centre at the University of Waterloo. The corridor is shown in Figure 2. The corridor is in the common area of the building and opens onto a glass atrium that extends down to the ground floor (behind the pictured user), yielding good visibility. Because campus buildings are connected by a set of bridges and tunnels, the deployment location is moderately traveled, approximately 300 to 500 passers-by per day, as students make their way between campus buildings.

We characterize the hallway as a "semi public" space. A university campus is unique in that it shares both characteristics of a public space – an airport or a shopping mall – and a private space such as a large corporate office building. Most individuals who are present in the building are members of the university community, which might foster a greater likelihood of engagement with the technology, a sense of entitlement more common to private environments such as a corporate office. On the other hand, the 24 hour unrestricted access to the building, its proximity to a major public transit hub (just outside the entrance), and the presence of coffee vendors, food service, and a campus library make the building a major public space on campus.

The display was positioned behind a large glass wall, off-line from passers'-by walking trajectory. This allowed passers-by to see and interact (at a distance) with the display without it impeding the corridor. It also protected the hardware due to its position behind a window.

Control Phase

One challenge with any public display deployment is that the introduction of the public displays yields a novelty effect. As people habituate themselves to the existence of the display, this novelty effect wears off, i.e. display blindness sets in. One goal of our study design was to see whether and how significantly display blindness might impact user engagement.

To habituate users to our public display, we deployed a variety of display configurations of public displays in the same location for over one year prior to the experiment. These display configurations leveraged the same hardware as our experimental design (see, e.g. Figure 1) but varied the configuration and on-screen content. Many of these deployments did serve a real-world purpose, fostering interest in the work of our research group and engaging the university community.

Preparing for Deployment

Once we decided to deploy our experiment, we deployed the experimental configuration with the different visual manipulations of the current study, shown in Figure 3, for one month prior to the experiment to continue to foster habituation to the display content. The specific configuration for the deployment consisted of two main components: the window display and a Microsoft Kinect.

The window display consisted of eight Christie MicroTiles. Each tile is 408mm by 306mm, for a total screen size of 1632mm by 612mm. Each tile ran in its native resolution, 720 X 540 pixels, yielding a pixel pitch of 0.567mm with inter-tile bezels of approximately 1mm. The Microsoft Kinect was located above the display and behind the glass for optimal tracking placement. We placed the display in the lower window, near the floor, on a 10cm riser.

Experimental Data Capture

Once we had completed the pre-deployment habituation phase, we began experimental data collection. The experiment took place during the middle of an academic term at our institution. We avoided any examination periods to ensure behaviors would be similar across all weeks of the experiment.

Our experiment was a 2x2 experimental design with presence or absence of two factors as treatment variables. The two treatment variables were a simple interactive game and a user shadow. Given the two treatment variables, we ran the experiment with and without game play and with and without shadow, yielding four different experimental conditions as follows:

1. **Pong Game without Skeleton:** A simple game of *pong* where the paddle's x position is controlled by the user's center of mass, as tracked by the Kinect, and the y position

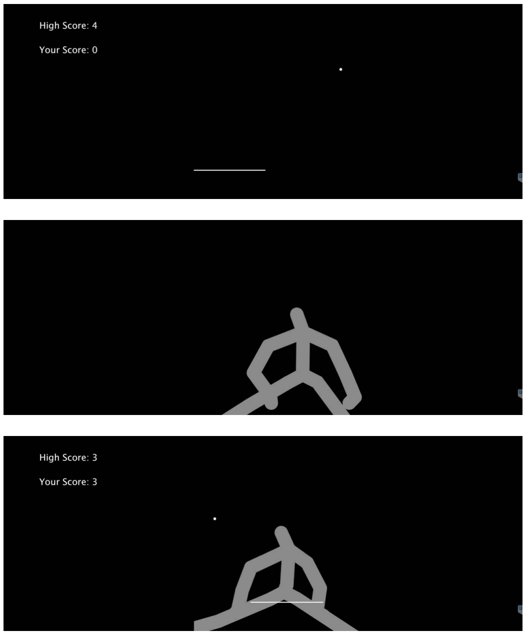

Figure 3. The screenshot of our three conditions. From top, 1.game without skeleton, 2.skeleton only and 3.game with skeleton.

is fixed. In the top left hand corner there are two scores: High Score and Current Score. The score is incremented upon every hit of the ball on the paddle. If the ball passes the paddle on the y axis, the users score is set back to 0 and the game restarts. Any time a passer-by is sensed, the paddle tracks the user's movement. The simple game is depicted in Figure 3, top.

2. **Skeleton Only:** A skeleton representation of the user, as tracked by the Kinect, is drawn on the screen. This condition is shown in Figure 3, middle.
3. **Pong Game with Skeleton:** A combination of conditions 1 and 2, where the *pong* game is played but a skeleton is also drawn, as in Figure 3, bottom.
4. **Baseline:** We also included a blank screen condition which allowed us to calculate a baseline for user behavior to determine if treatment variables were having any effect.

The graphics were designed to be simple and minimal, a conscious choice designed to limit, to the extent possible, any visual effects that could confound user behavior.

Software, Data Collection and Measures

The program for the display was written in Processing and leveraged the Kinect Library to track passers-by in front of the display. The program saved the x position of the person at 30Hz with a user ID and timestamp. Each instance of a passer-by was tracked as a unique passer-by, so if an individual walked by the display multiple times during a day, the individual would be tracked as a new passer-by at each traversal of the display. If multiple users are in the field of view of the Kinect, each user will have an individual user ID and x-position. A maximum of 6 users can be tracked simultaneously.

Tracking data obtained from the Microsoft Kinect was saved as JSON files. Each of the four configurations described above as treatment conditions was deployed for a one week period. During this period, we captured a total of 6955 discrete passers-by as follows: 1416 in the game condition, 1648 in the skeleton condition, 1667 in the game+skeleton condition, and 2224 in the baseline condition.

The primary measure we use for our data is holding time. We specifically examine holding time with respect to the number of passers-by tracked by our system. The goal is that visual manipulations increase the holding time of passers-by over the baseline condition. We are also interested in differences in holding time between the different interventions we propose.

Hypotheses

Our primary hypothesis is that we believe that statistically significant differences between baseline and visual manipulations will occur in interaction. Alongside this, it is our desire to compare interactions between skeleton and game, but we do not have strong beliefs in the direction of interaction. It may be that a game, because of its goal-oriented nature, will encourage longer interaction with a display, thus increasing holding time. However, it may be that, because of a higher commitment, or buy-in, games will encourage less overall engagement with the display. Our hypothesis about visual manipulations versus baseline allows for a one-tailed test of significance; our different enticements of skeleton versus game will be evaluated using a two-tailed test of significance.

RESULTS

Data Analysis and Cleaning

Depending on the distance between passers-by (i.e. were they part of a group, did one exit the interactive zone in front of the display just as a second entered) and lighting conditions (direct sunlight can interfere with the Kinect's ability to track), there was occasionally a delay until the Kinect captured a passer-by. To address this, we focus our analysis only on data continuously captured for more than 500ms (milliseconds). We chose the 500ms cutoff because a person walking briskly in front of the display was typically captured for at least 500ms.

Holding Time

Figure 4 and Figure 5 present two different analyses of the effect on time of the visual manipulations used on the display.

First, in Figure 4, we show the total interaction time in front of the display contrasting baseline with game, skeleton, and game+skeleton conditions.

To further analyze these interaction effects, pairwise comparisons using independent-samples t-tests with Bonferroni correction were applied to all four measures (i.e. six comparisons overall). As indicated in Figure 4, only the two game conditions did not differ. Table 1 shows descriptive statistics and significance testing results for each of these measures.

To develop a better understanding of whether differences between Skeleton and Game were a result of more people being

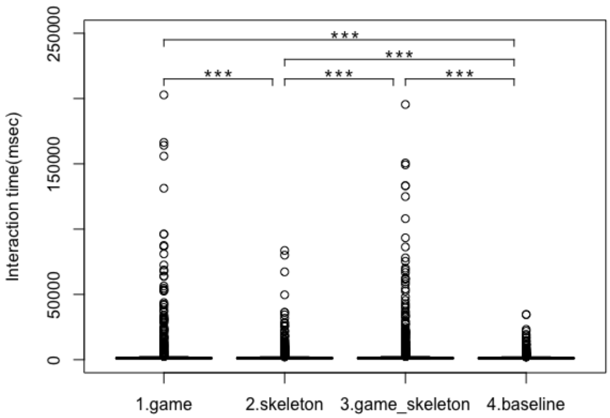

Figure 4. Overall interaction time for each condition. * indicates significance at p<.001**

Condition	t-statistic	df	p-value
1.game-2.skeleton	4.2877	1421.2	p <0.001
2.skeleton-3.game+skeleton	-4.6585	1827.2	p <0.001
3.game+skeleton-4.baseline	6.5342	1478.5	p <0.001
1.game-3.game+skeleton	0.26658	2428.3	n/s
2.skeleton-4.baseline	4.0035	1770.5	p <0.001
1.game-4.baseline	5.8021	1215.3	p <0.001

Table 1. t-test results for interaction time, with corrected p-values (p-values are corrected by multiplying by n=6

attracted to the display or of similar attraction but longer interaction, Figure 5 analyzes the fraction of users that were captured by the display during traversal. The horizontal axis of this graph depicts time in seconds. The vertical axis presents the cumulative proportion of users who were observed for *less than* the specific time. The graph, therefore, converges to 100% of passers-by.

As we note at the beginning of this analysis section, passers-by walking in front of the display with ideal acquisition and tracing consume 500ms when briskly walking. Looking at Figure 5, the first call-out highlights time values from 500ms to 1.2s (a). Looking specifically at this callout, we note the the *baseline* and the *game* only lines are higher than the *skeleton* and *skeleton+game* conditions. What this indicates is that, in both skeleton conditions, a greater fraction of passers-by stay longer than 1.2 sections than with the game or baseline condition, and that the game and baseline conditions coincide. Examining the second call-out on the graph, at times approaching three seconds, we note that the games begin to overtake the skeleton in terms of fraction of passers-by that interact for longer than three seconds(b), but that all interactions diverge from the baseline condition.

Analysis of Speed

Alongside holding time, speed in front of the display can be impacted by the presence of manipulations that seek to draw user attention. To determine whether speed was impacted, we analyzed the average speed of passers-by as they traversed the display. This result is shown in Figure 6. As shown, we see highest average speed for passers-by in the baseline condition, followed by the skeleton, with slowest average speed for the game conditions.

DISCUSSION

Combining the data from Figure 4, Figure 5 and Table 1 allows us to make the following observations:

- Both Skeleton and Game beat baseline by a highly statistically significant margin.
- Skeletons appear to attract more participants, measured as a fraction of participants that spend more than 1s in front of the display.
- Games encourage more long-term interaction, i.e. more than twice as many passers-by engaged for more than 3s with the game interface.

Based on an analysis of our data, we can reject the null hypothesis and claim that all interventions produce a statistically significant effect on holding time. We note that caution should be taken in interpreting p-values in this experiment due to the large sample size; however, this concern is counterbalanced by a strong significance signal, $p < 0.001$ in all cases. Furthermore, when one considers holding time, our initial analysis indicates a longer holding time for our game interfaces by a statistically significant margin. While our skeleton effect is significantly better than the baseline condition, it definitely does not hold passers-by as long as the game interface.

A more nuanced analysis of holding time data for game versus skeleton reveals interesting effects. Based upon a passer-by moving quickly, we found that data should include a minimum of 500ms of data. Looking beyond this point, a trend begins to emerge where the skeleton condition increases the number of participants who take additional time at the display, while the basic game condition corresponds to the baseline. Both the paddle and the shadow track the user across the display. However, because the shadow mimics user movement more reliably, there is an apparent slow down in the shadow conditions versus in the non-shadow conditions such that an additional 4% of participants spend longer than 1 second when compared to the non-shadow conditions.

As time progresses beyond 1.5s, we see the game conditions begin to converge on greater holding time, typically holding approximately 8% more participants than the baseline condition and an additional 4% of participants compared to the skeleton position. The rationale for this is, undoubtedly, the purposeful nature of the game interactions, where scoring encourages longer-term engagement.

In analyzing the above results with respect to design implications, one thing that becomes apparent is that the goal of any visual manipulation must be considered. If the goal is to hold users, then interactions with purpose or interactions that drive on-going buy-in are an important factor to consider. However, if the purpose of the display is simply to draw attention, as

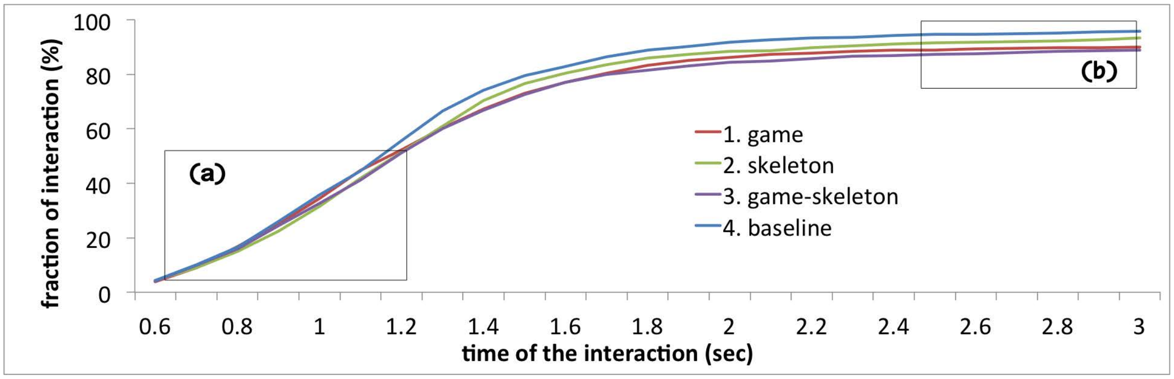

Figure 5. Fraction of the people over the time they spend in front of the display.

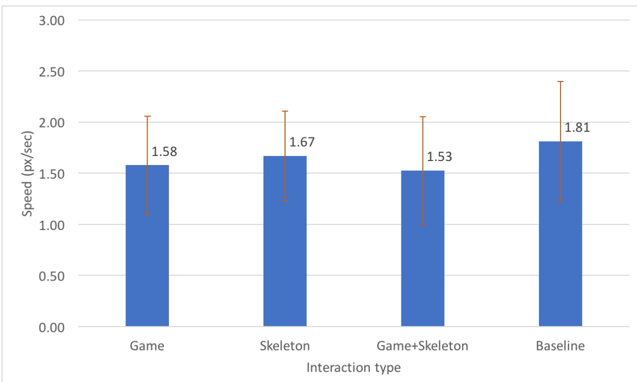

Figure 6. Average speed in front of the display for different interactions. Average speed was measured by initially segmenting the display into 10 distinct regions, and measuring the speed of the passers-by in that region. Finally, the average of the ten regions was taken for each interaction to derive the overall average trip speed across passers-by.

would be the case in non-playful public display deployments such as information displays, mirroring interactions such as skeletons or shadows merit consideration.

While we are aware that work exists that explores the efficacy of shadows in interaction with public displays [19], we are aware of no research that distinguishes between different forms of interaction such as our shadow and game distinction such that the strengths and weaknesses of these different interventions are highlighted.

LIMITATIONS

In this study, we invested some time in habituation. The purpose of habituation was to limit novelty of the display deployment. While our goal was to habituate passers-by to the display, it is undoubtedly the case that some novel passers-by trajectories would occur during the experimental period (i.e. individuals might traverse the corridor for the first time during the experimental period), and these participants may have been more motivated to interact with the display. On the other hand, one challenge with novelty of deployment is that, for regular passers-by, the deployment of a novel installation can motivate additional passers-by to stop, creating a honey-pot effect, a curiosity, which drives more interaction to the display. This, in turn, can create artificially high interaction patterns as more passers-by stop and additional distant observers are attracted to take a look. At the very least, our study designs addresses some of the challenges associated with novelty driving widespread engagement and ensures that honey-pot effects are limited.

A second limitation to our study design involves context. As we noted earlier, a university campus is a somewhat unique deployment environment. It is at once public, in that passers-by come and go freely, and private, in that members of the community feel a sense of ownership that may drive access. Any research conducted on a university campus suffers from these drawbacks, and the drawing of generalized conclusions from a specific deployment must be mindful that the context of the deployment may impact how generalizable the data collected is to other environments.

CONCLUSION

This paper explores the efficacy of different on-screen interaction effects that leverage whole body manipulations to allow public screens to capture user attention. Our deployed interactions demonstrate that a user-mimicry strategy, the use of a skeleton, fosters an increased initial observation, but that purposeful interactions such as game play foster longer-term engagement. Combining both interventions yielded the highest overall benefit, both for initial engagement and for long term capture of passers-by.

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