Quantifying the Attention Potential of Pervasive Display Placements

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Abstract: Being able to quantify the attention potential of pervasive display placements holds promise in selecting suitable placements, scoping expectations of impact, informing display designs and calibrating engagement data against placement-related factors when evaluating display designs. This paper contributes a first version of an instrument to quantify the attention potential of display placements, focusing in particular on small interactive displays in museum environments. It reports on an empirical evaluation revealing strong and significant correlations between quantified attention potential and measured attention and engagement. The paper describes the methodology of the evaluation, discusses its findings and their limitations, and concludes with a call for more research into quantifying the attention potential of display placements.

1 INTRODUCTION

Attention and engagement are key aspects in the design and evaluation of public displays. The former, characterised by Mack and Rock (1998, p.25) as "the process that brings a stimulus into consciousness" relates to the problem of making people aware of a pervasive display in the first place. The latter, commonly used to mean both the act of making initial contact and the state of being occupied with the object of attention (Peters et al., 2009), relates to the problem of making people read a display and possibly interact with it once they are aware of it.

The HCI literature is rich in empirical studies about attention and engagement with public displays, offering various models and heuristics to conceptualise, capture and manage attention, to communicate the interactivity and affordances of public displays and to support peoples' transition from attention to engagement. One important aspects under discussion in this context is the physical placement of displays, which has been identified as a key factor determining whether people notice and engage with them (Huang et al., 2008).

Various guidelines on how to increase attention and engagement with public displays offer placement-related recommendations (e.g. Brignull and Rogers, 2003; Kules et al., 2004; Hardy et al., 2010; Huang, Koster and Borchers, 2008), however, these are typically simple heuristics that aim to maximise attention or to address specific problems related to attention and engagement.

By contrast, a more elaborate approach that combines multiple heuristics and allows to quantify the attention potential of display placements might be useful in many ways. For instance, quantification could help to select display placements among possible alternatives and scope expectations of the attention and engagement they receive; it could inform design aspects such as display size, type, content and casing as well as supporting measures advertising, framing and explaining display use to mitigate for a low or high attention potential of the placement; and it could help to calibrate evaluation results by isolating placement-related factors of attention and engagement from factors related to display design and supporting measures.

In this paper we tentatively propose an instrument to quantify the attention potential of display placements, focusing in particular on *inch scale* (Weiser, 1991) interactive displays. The approach emerged from research around Social Object Labels as a specific instance of this display class, designed to support situated commenting and feedback in museums (Winter, 2014a). Reflecting this context, the instrument uses a subset of placement-related criteria found to affect visitors' attention to exhibits and labels in gallery environments (Bitgood 2009a; 2009b). As these placement-related criteria are fundamentally domain agnostic, the model might also be useful in other environments.

The following sections briefly discuss literature on attention and engagement with public displays, and describe a first version of the proposed instrument to quantify the attention potential of display placements. The paper then reports on an empirical evaluation at Science Gallery Dublin, where the proposed model was used to quantify the attention potential of display placements before deployment while actual attention and engagement were recorded through observations and technical logs. The paper concludes with a discussion of findings, including limitations of both the instrument and its preliminary evaluation, and a call for further development and evaluation towards quantifying the attention potential of display placements.

2 BACKGROUND

There is a broad range of literature on ambient information systems and interactive public displays discussing attention and engagement. While the former is strongly influenced by Weiser and Seely Brown's (1996) vision of calm computing and seeks minimise the cognitive costs of monitoring information, the latter is not encumbered by an aspiration to minimise cognitive load. An important question in this field is simply how to attract the attention of audiences and, for interactive displays, how to communicate interactivity and encourage engagement. Besides engagement models, this field also provides heuristics on how placement in the physical environment affects attention and engagement.

In addition to largely domain agnostic HCI perspectives, the field of museum studies offers detailed insights into attention and engagement in museums. While some guidelines in this field can be mapped to placement heuristics in public display research, others provide additional aspects that might be equally useful outside a museum context.

2.1 Attention and Ambient Displays

Reflecting the more differentiated approach to attention in ambient display research, this field offers various models breaking down attention into pre-attention, in-attention, divided attention and focused attention (Matthews et al., 2003), primary, secondary and tertiary realms of attention (Hazlewood and Coyle, 2009) or simply peripheral and focused attention (Matthews et al., 2007). Common to all these notions is that attention can be voluntary or involuntary (Mack and Rock, 1998), and that display designers should address multiple forms of attention as well as transition between them, for instance targeting peripheral attention by default but supporting escalation to focused attention through appropriate notifications when an exception occurs.

2.2 Attention and Engagement Models for Public Displays

In contrast to ambient information displays, which typically have limited affordances for explicit interaction and consequently focus on attention management rather than user engagement, research into interactive public displays sees attention as the first stage in a sequence of stages leading up to users' engagement and eventual disengagement.

The literature in this field offers several models of engagement with public displays, which have been classified by Michelis and Müller (2011) into ad-hoc models describing how displays react to users, and observational models describing how visitors engage with displays. Ad-hoc models use concepts of proxemic interaction (Greenberg, 2011; Wang et al., 2012) and are typically employed to support specific stages in observational engagement models such as attracting attention and communicating interactivity.

One of the best known observational models of engagement with interactive public displays is the audience funnel (Michelis and Müller, 2011), which differentiates between six distinct phases including (i) passing by, (ii) viewing and reacting, (iii) subtle interaction, (iv) direct interaction, (v) multiple interaction and (vi) follow-up action.

An earlier observational model by Brignull and Rogers (2003) describes only three levels, including (i) peripheral awareness, (ii) focal awareness and (iii) direct interaction, but crucially also offers advice on how to help users to transition between these stages.

Finke et al.'s (2008) model of engagement, originally developed for game design on large public displays, defines seven distinct interaction states including (i) enter, (ii) glance, (iii) decode, (iv) observe, (v) input, (vi) feedback and (vii) result, and the authors discuss relevant design aspects relating to each of these states.

Casting the net wider to include earlier literature on public access systems, Kearsley (1994) identifies four stages of audience engagement including (i) attraction, (ii) learning, (iii) engagement and (iv) disengagement. Kules et al. (2004) offer guidelines for each of these four stages based on the concept of immediate usability (ibid).

2.3 Placement-Related Factors Influencing Attention and Engagement

While many of the recommendations around attention and engagement relate to display design and content (e.g. content type and representation, information design, learnability, usability) or to supporting measures framing and explaining the purpose and use of displays in a specific context (e.g. appropriate signage, calls to action, facilitation), some explicitly refer to the physical placement of displays:

a. Cheverst et al., (2003) point out that interactive displays should be installed at an appropriate height to be accessible to wheelchair users.
b. Brignull and Rogers (2003) and Kules et al., (2004) suggest there should be enough space around displays in which interaction can take place.
c. Kules et al., (2004) suggest that interactive installations should be placed in locations with a sustained flow of people.
d. Huang et al., (2008) found that displays installed at eye height and close to other eye-catching objects receive more attention.
e. Huang et al., (2008) suggest to consider the direction of people’s movement within a space when placing displays.
f. Ten Koppel at al., (2012) found that flat spatial configurations of displays emphasise the honeypot effect and foster social learning, and that hexagonal configurations are most inviting for strangers to join in and interact with adjacent screens, while concave configurations are less conductive to people interacting simultaneously.
g. Brignull and Rogers (2003), Riekki et al., (2006) and Finke et al., (2008) all discuss social embarrassment as a barrier to engagement with public displays and in this context suggest to avoid display placements that would expose users or involve awkward body positions during interaction.

These heuristics help researchers to avoid pitfalls when placing displays in the environment and to identify suitable locations. However, they typically focus on a single characteristic (a-e), relate to spatial configurations rather than placement locations (f) or leave considerable room for interpretation (g).

The only effort towards quantification is described by Dalton et al., (2010), who found that the visual complexity of a space influences attention and reading of displays. Drawing on the architectural concept of an isovist, defined by Benedikt (1979) as the set of all points visible from a given vantage point in space, they quantify visual complexity by calculating the Area-Perimeter Ratio (APR = Area ÷ Perimeter) of a display location's isovist. Using this concept in empirical studies, they found significant correlations between APR and how people notice displays and perceive different types of information on them.

2.4 Attention and Engagement in Museums

Looking outside the fields of ambient information systems and public displays, there is a rich seam of research into attention and engagement in museums (e.g. Screven, 1969; 1992; Serrell, 1996; Bitgood, 1991; 2000; 2009a; 2009b), which offers useful heuristics on the design and placement of interpretive resources and exhibits to improve communication and increase visitor engagement. While many of these heuristics are based on experiences with (static) print labels and tangible information displays, such as multi-layer labels and multiple-choice flip questions, some researchers in this field explicitly widen their scope to digital displays and interactives. For instance, Screven (1992, p.1) refers to "all type of media [including] print, audio and graphics" and presentation formats including "interactivity, sound, graphics, video, computers", while Bitgood (2009a; 2009b) examines attention for both interactive interpretation resources and exhibits.

Some placement-related heuristics in this domain have clear equivalents in public display research, e.g. Bitgood's (1991, p.120) recommendation to place labels "within line of sight so that visitors do not have to turn, look up high, or down low" can be directly related to Huang, Koster and Borchers' (2008) finding that displays installed at eye-height and in the direction of people's movement receive more attention. Others demonstrate a more holistic perspective that takes into account people's overall visiting experience. For instance, Bitgood (2009a; 2009b) considers satiation and fatigue when visitors progress through a exhibition as critical factors affecting attention and engagement. While this consideration is clearly informed by experiences in museum environments, it might also be relevant to other contexts where passers-by encounter multiple displays over a period of time.

Overall, research into ambient information systems and public displays, as well as museum studies exploring attention and engagement with exhibits and interpretive labels, offer useful models and heuristics that can inform the placement of displays in the physical environment. However, apart from Dalton et al. (2010), who introduce the APR of a display location's isovist as a quantifiable measure influencing attention and reading of displays, the literature offers little in terms of quantifying the attention potential of display placements.

3 TOWARDS QUANTIFYING ATTENTION POTENTIAL

Being able to quantify the attention potential of display locations might be useful in many ways. For instance, it might help to scope expectations when deploying displays; it might inform specific display designs and configurations before deployment to mitigate for a low or high attention potential of its placement; and it can help to calibrate measured attention and engagement rates against placement-related factors when evaluating display designs during and after deployment.

3.1 Instrument

In order to test the viability of quantification, we developed a first version of an instrument to quantify the attention potential of display placements in museums. Considering the specific environment, it draws on Stephen Bitgood's (2009a; 2009b) research into factors impacting on attention and engagement with exhibits and interpretive labels during a museum visit. While Bitgood's (ibid) original research describes a wide range of factors, the developed instrument limits itself to four factors that can be related to placement either in a local context (placement in relation to close-by exhibits and interactives) or in a global context (placement in the gallery space). These include:

- *Distraction* - how many other stimuli are close by that add to a visitor's cognitive load.
- *Competition* - whether there is competition from other interaction opportunities.
- *Satiation* - how often a visitor has encountered a similar object before (boredom).
- *Fatigue*: at what stage during a visit a visitor encounters an object (physical exertion).

For each of these criteria, potential placements are assessed along a simple rating scale reflecting the number of displays deployed, which simplifies ratings along the *Satiation* and *Fatigue* criteria. Individual ratings are then added up to a total score for a specific placement, which, together with maximum and minimum possible scores, is used to express the attention potential as a percentage value:

$$attention\ potential\ = \frac{maximum\ score - total\ score}{maximum\ score - minimum\ score}$$

Higher attention potentials indicate conditions that are more conductive for displays to be noticed and engaged with, while lower attention potentials indicate conditions that are less conductive to displays being noticed and engaged with.

3.2 Limitations

An obvious limitation of the instrument in its current form is that it contains only four criteria drawn from museum studies. Other versions of the instrument could include a larger number of criteria to cover more aspects and increase precision. These could include additional or entirely different criteria, for instance drawing on heuristics from public display research, to make them more suitable for their specific context.

Another limitation is that two of the criteria used in the current version make certain assumptions about the context in which displays are deployed. Specifically, the *Satiation* and *Fatigue* criteria assume that displays are encountered in a certain order, which might not apply, or might not be easily predicted, in other contexts.

Lastly, measuring *Distraction* and *Competition* for placements might be problematic due to a lack of suitable approaches and metrics. While highly relevant, rating placements along these criteria necessarily introduces some level of subjectivity. While subjectivity could be mitigated to some degree by employing multiple raters, this might not always be an option due to practical constraints.

4 EVALUATION

In order to evaluate the instrument in a realistic gallery environment, it was used to quantify the attention potential of four display placements in the *Home\Sick* exhibition at Science Gallery Dublin (SGD, 2015). The evaluation formed part of a wider research effort to develop design guidelines for Social Object Labels as a platform for social interpretation in museums (Winter, 2013; 2014a; 2014b; 2015).

4.1 Display Type and Content

The deployed displays were *inch scale* (Weiser, 1991) interactive screens affording both direct touch interaction and mobile interaction via a related web application for visitors to submit and browse comments for specific exhibits (Figure 1).

Figure 1: Deployed displays consisting of a 6 inch e-ink screen and black casing to fit in with gallery environment.

Reflecting their particular purpose and gallery environment, the displays are designed to strike a balance between attracting enough attention to be noticed and encouraging engagement on the one hand, but not detracting visitors' attention from the exhibit as the primary object of interest on the other hand. Given these opposing requirements, the displays use small, 6 inch, monochrome, passive-light e-ink screens and black casings that integrate with the gallery environment.

Each display is associated with a specific exhibit and can be configured to show different types of content (e.g. exhibit specific question or generic prompt) and representations (e.g. exhibit specific icon or generic icon) and to expose different interaction capabilities (e.g. allow content browsing on touch screen or not) reflecting curators' specific requirements and preferences (Winter, 2014b).

In order to answer research questions in the wider study, displays were set up to automatically switch between seven possible configurations at specific times. Switches between configurations were synchronised so that all displays ran the same user interface at any given time, i.e. while there was some content variation between placements, these were limited to different icons or questions, whereas all displays at the same time either showed a generic icon or an exhibit specific icon and a generic prompt or an exhibit specific questions. Figure 2 shows minimum and maximum display variations between placements under these conditions.

Figure 2: Minimum (a-d) and maximum (e-f) content variation between displays at different exhibits.

4.2 Display Placement

The selection of exhibits and related placements was guided by the idea of social objects (Engeström, 2005; Simon, 2010), which provoke a reaction from visitors and stimulate debate, however, faced with realities on the ground, actual object selection was equally influenced by more pragmatic aspects such as availability of a mains power socket and artists' agreement to have a display installed next to their exhibit.

Figure 3 shows the four display installations in the order in which visitors would typically encounter them when making their way through the exhibition.

In the ground floor gallery, one display was integrated with an exhibit called *Parasite Farm*, which explores how agricultural practices can become part of urban living. The display was placed on an empty shelf in a book case holding the plant boxes, occupying a central position and affording convenient access for direct interaction (Figure 3a).

Also in the ground floor gallery, one display was installed next to *LillyBot 2.0*, a personal microalgae farm that produces oxygen and Chlorella algae while binding carbon dioxide in the air. The display was placed on the right side of the plinth supporting the installation, in a peripheral position that required visitors to slightly bend down for direct interaction (Figure 3b).

In the first floor gallery, one display was integrated with *Ritual Machines*, which explores how technology can help to connect with family members away from home. The display was slightly set back from an interactive installation involving two iPod devices, in a peripheral position but within easy reach of visitors operating the iPod on the left side of the installation (Figure 3c).

Also in the first floor gallery, a display as installed next to *Dust Matter(s)*, which conceptualises domestic dust in the home as an indicator of the occupants' outdoor activities. The display was placed in a prominent position below a large video screen and within easy reach for direct interaction (Figure 3d).

4.3 Attention Potential

Table 1 rates all four display placements with the developed instrument to quantify their attention potential. To make ratings for specific placement criteria more transparent, the table provides brief descriptions explaining the reasoning behind each rating and includes image references to the related display installations.

The quantified attention potential of individual display installations varies considerably, ranging from a maximum of 92% for the placement at *Parasite Farm* to a minimum of 17% for the placement at *Dust Matter(s)*. While this information could have been used to compensate for low or high attention potentials by adjusting relevant design aspects, such as the luminosity of the display or the design of the casing, no mitigating measures were taken in this case to avoid compromising the experimental setup.

Figure 3: Displays (circled red) integrated with exhibits Parasite Farm (a) and LillyBot 2.0 (b) in the ground-floor gallery space, and with exhibits Ritual Machines (c) and Dust Matter(s) (d) in the first-floor gallery space.

4.4 Data Collection and Analysis

The displays were deployed for 20 days, during which time actual attention and engagement was recorded through observations, analytics data and content contributions.

Observations were carried out covert in order to not disturb visitors' natural behaviour. Observation notes were recorded in a coding template and then transferred into a spreadsheet for analysis with standard statistical methods discussed in Sauro and Lewis (2012). The observations were carried out in two blocks of four days each, with a combined observation time of 28 hours and 56 minutes, during which a total of 812 encounters were observed. Encounters are conceptualised as situations where visitors have a clear chance to notice and engage with a display. As a minimum, this involves a visitor stopping at an exhibit. Visitors might then look at the exhibit, read the object label, look at and engage with the display in various ways.

Analytics data was collected for mobile and touchscreen interaction with displays. The data was prepared for analysis by excluding touchscreen interactions involving admin tasks (e.g. display configuration, initial screen activation) and mobile interactions from demonstrations (e.g. to show visitors how NFC works). Analytics data is structured into sessions, with a key difference between mobile and touchscreen sessions being that the former relate to specific users, while the latter are anonymous and can involve multiple visitors, e.g. when a visitor initiating a session abandons the display and another visitor engages before the screen times out. In order to approximate the number of visitors engaging with touchscreens, Jenks' (1967) natural breaks classification was used to segment the time intervals between interactions into two clusters,

Table 1: Quantifying the attention potential of display placements in the gallery.

	Parasite Farm	LillyBot 2.0	Ritual Machines	Dust Matter(s)
Distraction	Display placed prominently on empty shelf with little distraction apart from pot-plant above (Figure 3a). Rating: **1** 2 3 4 (Low–High)	Display placed peripherally at foot of sensor-driven exhibit that dominates the scene (Figure 3b). Rating: 1 2 **3** 4 (Low–High)	Display placed peripherally next to interactive flip-dot matrix and two iPods to control matrix (Figure 3c). Rating: 1 2 3 **4** (Low–High)	Display placed prominently to the right of the exhibit below a large video screen (Figure 3d) Rating: 1 2 **3** 4 (Low–High)
Competition	There is an option to use a little spatula to dig in the plant box on the shelf below but this is often not noticed by visitors. Rating: 1 **2** 3 4 (Low–High)	Another exhibit just five feet away invites visitors to control a blender by voice, which is very popular with visitors Rating: 1 2 **3** 4 (Low–High)	Visitors are invited to use two iPods in front of the exhibit to control an interactive flip-dot display, which is very popular Rating: 1 2 3 **4** (Low–High)	There are no interaction possibilities at the exhibit (video screen can't be controlled) or at other close-by exhibits. Rating: **1** 2 3 4 (Low–High)
Satiation	1st display encountered in a typical gallery tour. Rating: **1** 2 3 4 (Low–High)	2nd display encountered in a typical gallery tour. Rating: 1 **2** 3 4 (Low–High)	3rd display encountered in a typical gallery tour. Rating: 1 2 **3** 4 (Low–High)	4th display encountered in a typical gallery tour. Rating: 1 2 3 **4** (Low–High)
Fatigue	Display installed in ground-floor gallery at 3rd exhibit in a typical gallery tour Rating: **1** 2 3 4 (Low–High)	Display installed in ground-floor gallery at 4th exhibit in a typical gallery tour. Rating: 1 **2** 3 4 (Low–High)	Display installed in first-floor gallery at 6th exhibit in a typical gallery tour. Rating: 1 2 **3** 4 (Low–High)	Display installed in first-floor gallery at 10th exhibit in a typical gallery tour. Rating: 1 2 3 **4** (Low–High)
Attention potential	$\frac{16-5}{16-4} = 92\%$	$\frac{16-10}{16-4} = 50\%$	$\frac{16-14}{16-4} = 17\%$	$\frac{16-12}{16-4} = 33\%$

Table 2: Correlation between attention potential and measured attention and engagement.

	Attention potential	Attention (observed)	Direct Eng. (observed)	Direct Eng. (analytics)	Mobile Eng. (analytics)	Contribution (comments)
Parasite Farm	91.7%	86.6%	31.4%	23.7%	1.28%	0.25%
LillyBot 2.0	50.0%	60.8%	10.5%	10.0%	0.97%	0.17%
Ritual Machines	16.7%	47.0%	4.3%	5.4%	0.38%	0.05%
Dust Matter(s)	33.3%	61.7%	10.9%	7.9%	0.38%	0.12%
Correlation r	-	0.97	0.97	0.98	0.93	0.98
t-value	-	5.80	5.39	6.68	3.76	7.32
p-value	-	0.0011	0.0017	0.0005	0.0094	0.0003

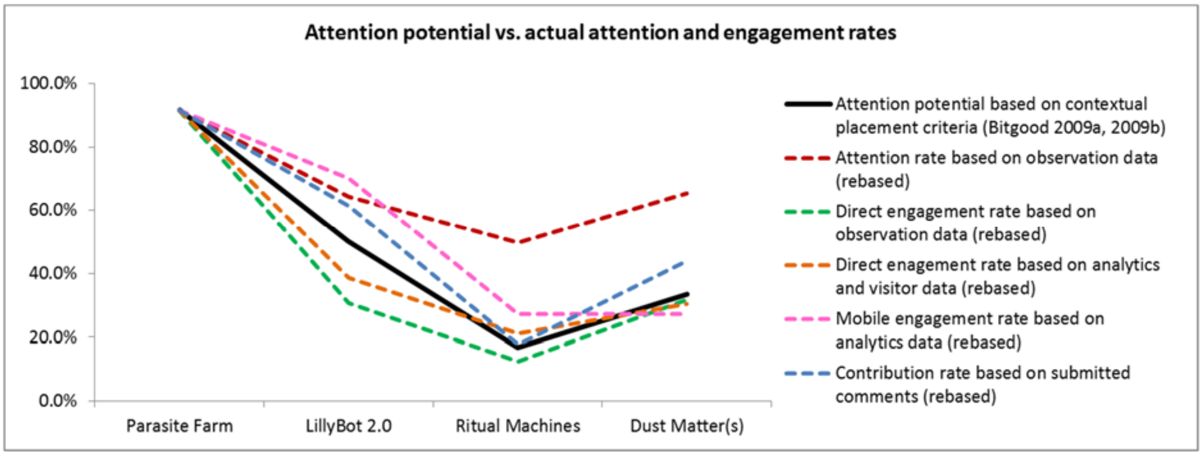

Figure 4: Correlation between attention potential and measured attention and engagement. The diagram shows values proportionally rebased to the attention potential of Parasite Farm.

representing touches during and between individual user sessions. The resulting disengagement threshold was then used to estimate the number of individual users engaging through touchscreen interaction. Total numbers based on 1,921 analytics data logs (excluding logs relating to admin and demonstration activities) include 2,031 touchscreen user sessions and 109 mobile interaction sessions.

Content contributions were measured as comments submitted to displays by visitors. The small number of contributions during the evaluation period (n=21, excluding seed comments) does not support a meaningful analysis but shall be included nonetheless as an additional indicator of visitor engagement with displays.

Finally, a baseline of 15,446 possible encounters with displays during the evaluation period was established based on Science Gallery Dublin's in-house visitor numbers and display uptimes. As visitor numbers are based on automatic counters installed in the gallery and therefore include false positives caused by double entries, trade and staff, they represent a theoretical maximum rather than verified visitor numbers. For the purpose of this study, however, they are taken at face value in order to arrive at defendable minimum values when using them to calculate attention and engagement rates from analytics data.

4.5 Results

Attention rates per display were calculated by dividing the number of people observed to look at a display by the total number of encounters observed for that exhibit. There are marked differences in attention rates between exhibits despite all displays using the same design at any given time, with observed attention being highest at Parasite Farm (86.6%), decreasing at LillyBot 2.0 (60.8%), reaching its lowest at Ritual Machines (47.0%) and picking up again for Dust Matter(s) (61.7%).

Observed direct engagement rates per display were calculated by dividing the number of people observed to touch the display screen by the total number of encounters observed for that exhibit. Similar to observed attention, there are clear differences in observed engagement rates between exhibits, being highest at Parasite Farm (31.4%), decreasing sharply at LillyBot 2.0 (10.5%), reaching its lowest point at Ritual Machines (4.3%) and picking up at Dust Matter(s) (10.9%).

Direct engagement from analytics data was calculated by dividing the number of individual user sessions for each display by the number of potential encounters per display based on visitor numbers and display uptime. The data shows marked differences in engagement rates between exhibits, with engagement being highest at Parasite Farm (23.7%), decreasing considerably at Lillybot 2.0 (10.0%), reaching its lowest at Ritual Machines (5.4%) and picking up again for Dust Matter(s) (7.9%).

Mobile engagement rates per exhibit were calculated from analytics data and visitor numbers by dividing the number of mobile interaction sessions with a display by the number of potential encounters with that display and its uptime. The mobile engagement rate is highest at Parasite Farm (1.28%), decreases at LillyBot 2.0 (0.97%), reaches its lowest point at Ritual Machines (0.38%) and stays at this level for Dust Matter(s) (0.38%).

Contribution rates per exhibit were calculated by dividing the number of submitted comments per exhibit by the number of potential encounters for that exhibit and its uptime. The contribution rate is highest at Parasite Farm (0.25%), decreases at LillyBot 2.0 (0.17%), reaches its lowest point at Ritual Machines (0.05%) and increases again for Dust Matter(s) (0.12%).

4.6 Findings

The data reflects visitors' contingent progression from attention to engagement to contribution, with large numbers failing to progress at each stage. Regardless of absolute numbers, the different data sets reveal a consistent pattern (Figure 4) suggesting they are influenced by similar factors. There are strong and significant correlations between observed attention and observed direct engagement ($r = 0.99$, $t = 8.69$, $p < 0.01$), engagement rates from analytics data ($r = 0.97$, $t = 5.52$, $p < 0.01$) and contribution rates ($r = 0.96$, $t = 4.56$, $p < 0.01$). The only data set not strongly and significantly correlating to observed attention is mobile engagement ($r = 0.83$, $t = 2.08$, $p = 0.08$), which remains flat between Ritual Machines and Dust Matter(s). While this might be attributed to the small sample, an alternative interpretation is that the additional physical and cognitive effort associated with connecting a mobile device to the display becomes more relevant in the later stages of a visit when museum fatigue (Davey, 2005; Bitgood, 2009a; 2009b) sets in.

Regarding the predictive power of the developed instrument, the data shows strong and significant correlations (Table 2) not only between quantified attention potential and observed attention rates but also between attention potential and observed direct engagement, direct engagement from analytics data, mobile engagement and contributions. While these correlations do not imply causality, they suggests that placement-related factors are a good indicator of how much attention and engagement a display receives.

5 DISCUSSION

We introduced a first version of an instrument to quantify the attention potential of pervasive display placements. The instrument is based on the idea that combining multiple placement criteria evens out inaccuracies and gives a better overall representation of attention potential. Reflecting the wider context in which the research took place, we used placement-related criteria relevant in museum environments (Bitgood, 2009a; 2009b) and evaluated the instrument in a gallery setting.

The results show significant differences in attention and engagement rates between individual display installations that far outweigh the small and mostly insignificant differences between design variations involved in the evaluation. Comparing the attention and engagement rates for specific display installations with their quantified attention potential reveals strong and significant correlations.

While the correlations do not imply causality, they suggests that the attention potential of display placements is indicative of the relative levels of attention and engagement the displays receive. As such, the evaluation suggests that the developed instrument might be a useful tool to inform placement- and design-related decision leading up to display deployments.

Several limitations of both the instrument and the evaluation study must be considered with regard to validity, reliability and generalisability. The instrument uses only four criteria in its current form, two of which make specific assumptions about the order in which placements are encountered. While the small number of criteria might impact on accuracy, the implied order in two of the criteria impacts on generalisability as it only applies to environments where that order can be predicted. A limitation of the evaluation study is that it is based on only four display placements, which considerably weakens the substantiation of found correlations and thereby impacts on the validity and reliability of the results.

Considering these limitations, the findings are presented only as indicative of warranting further investigation.

6 CONCLUSIONS

Being able to quantify the attention potential of display placements could help to scope expectations when deploying displays, inform design decisions mitigating low or high attention potentials, and calibrate measured attention and engagement against placement-related factors when evaluating display designs. While the literature offers a number of insights and heuristics for the placement of displays in order to maximise attention and engagement, there are so far no attempts to combine multiple heuristics into a single instrument as a way to cover a range of relevant aspects and even out inaccuracies when quantifying the attention potential of display placements.

The main contribution of this paper is a first version of an instrument to quantify the attention potential of display placements, focusing in particular on small interactive displays in a museum environment. An empirical evaluation of the instrument involving displays deployed in a real gallery environment found strong and significant correlations between quantified attention potential and measured attention and engagement with displays.

Acknowledging limitations of both the instrument and the evaluation study, no claims are made towards the reliability and generalisability of findings. The aim at this stage is rather to flag up the surprising correlation between predicted attention potential and measured attention and engagement, and to encourage others to adapt and evaluate the instrument with a view to developing alternative versions of the instrument and a more robust evidence base for its predictive qualities. As such, the paper presents a starting point rather than a solution to quantifying the attention potential of display placements.

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