Readability in Multi-User Large-Screen Scenarios

Andrea Nutsi, Michael Koch
Bundeswehr University Munich
Werner-Heisenberg-Weg 39, D-85577 Neubiberg
{andrea.nutsi | michael.koch} @unibw.de

ABSTRACT
Large interactive wall displays for multi-user interaction are readily available today. However, little is known about the specific aspects influencing usability for applications supporting several users interacting simultaneously and co-located with wall displays. Especially for large screen information applications in public or semi-public places, the ease of noticing and reading text is very important. In this study we are focusing on determining readability in such single-user and multi-user scenarios. Participants in our laboratory study are presented with four different text moving directions in different settings. The evaluation of the results shows that the typical text moving direction (right to left) is not always the optimal choice. When just one user is standing in front of the screen our results showed a preference for a vertical text movement. For reading while walking we found it to be optimal if the text moves with the reader.

ACM Classification Keywords
H.5.2 Information Interfaces and Presentation (e.g. HCI): User Interfaces

Author Keywords
Multi-User; Readability; Large Screen; Public Display; Wall Display.

INTRODUCTION
Today interactive wall displays are quite common in (semi-) public spaces. Due to their size, wall displays offer the possibility for several users to interact co-located and simultaneously at the same screen [10, 3]. In such multi-user scenarios the interaction of the multiple users often is not linked, however they influence each other in different interaction zones from peripheral awareness to actively interacting with the content [9]. Closely related to our work is the concept of proxemic interaction which refers to people and devices reacting on each others presence. The reaction may depend on (among others) distance, orientation or movement of the user [5].

NordiCHI'16,, October 23-27, 2016, Gothenburg, Sweden.

DOI: http://dx.doi.org/10.1145/2971485.2971491

Our main research interest are large screen information applications. For the consumption of textual information readability and legibility are important requirements. According to [1] readability is defined as

> "characteristics of a text presentation on a display that affect performance when groups of characters are to be easily discriminated, recognized and interpreted".

In this work we focus on readability of dynamic text on large screens. In the past, studies about dynamic text display focused mainly on small screens but not on (large) LED displays [12]. Today, however, large displays are commonly used for displaying information, for example news headlines at train stations, news and lunch menu at a campus or project information in a business context. If focusing on non-critical information, users have to be attracted towards the display. Among several recommendations, Huang et al. [6], suggest to use dynamic content in order to prolong the user's attention. In our research we focus on short textual information, using leading as display method. Leading is defined as moving a sequence of words from right to left (eg. [12]). But is the typical text moving direction, from right to left, always the optimal choice? We compare four different text moving directions (right to left, left to right, top to bottom and bottom to top) in different settings: single vs. multi-user (with partly occlusion of the screen by a user), standing vs. walking past the screen as well as three different distances to the screen.

RELATED WORK
Studies on the readability of dynamic text on large screens are mainly found in Asian countries, where some languages are not written from left to right as in the Latin alphabet. Chen & Chen [2] studied vertical and horizontal scanning directions of Chinese and found reading for both directions equally efficient. Similarly, Hwang et al. [7] identified no significant influence of the display format (vertical or horizontal) on reading speed or comprehension for Chinese university students.

Schmidt et al. [11] evaluated the reading while passing by a very large screen (5x2.5m). They translated, rotated and zoomed the text according to the reader's movement in order to ensure optimal reading. In a field study even novice users were able to read while walking, but only remembered few words. In our study, we use a smaller display (65 inch) and do not adjust the text, but also evaluate walking by the screen while reading. Schmidt et al. also observed that passers-by did not slow down in order to read, consequently we asked our participants to walk with constant speed while reading.

STUDY OF TEXT MOVING DIRECTIONS

The research questions guiding our study were the following: Are there differences in the preferences for a text moving direction between a single user and a multi-user setting? Does it influence the preferences for a text moving direction whether a person stands in front of the screen or walks past the screen? Does the distance to the screen matter? Which text moving direction is preferred for which scenario? As can be seen from the research questions, we focused on subjective preferences of the user, rather than using objective measures.

Hypotheses

Based on our previously stated research questions we formulated the following hypotheses:

H1 Subjective readability is better in a single user setting than in a multi-user setting (where parts of the screen are hidden from view by another user).

H2 Subjective readability is better in case a person stands in front of the screen than he/she is walking past the screen.

H3 Standing directly in front (0.5m) of the large screen, a vertical text moving direction is preferred over a horizontal text moving direction.

H4 Walking past the screen, a horizontal text moving direction matching the walking direction is preferred.

H1 is based on the assumption that occlusion that occurs in a multi-user setting will negatively influence the readability. For H2 we assume that the movement during walking distracts the user and therefore he/she has difficulties in reading the text. Standing in a distance of 0.5m in front of a 65 inch screen, a person's vision field does not cover the whole screen which leads us to the assumption that in this case vertical text moving directions are preferred (H3) as this involves less head movement. For H4 we assume that it is easier to read a text that moves with the reader, ideally in a similar speed.

Thus, the independent variables of this experiment are the text moving direction, the distance to the screen, occlusion and a person's movement. The dependent variable is the subjective readability.

Design & Method

The experiment was conducted as a controlled lab study using a between-subject design. The study was divided into four sub-experiments which were organized by four different student groups. A supervisor coordinated the groups in order to ensure comparability. The sub-experiments represent the different conditions: single vs. multi-user and standing vs. walking:

1. One participant is standing in front of the screen.
2. Two participants are standing in different distances in front of the screen.
3. One participant walks past the screen.

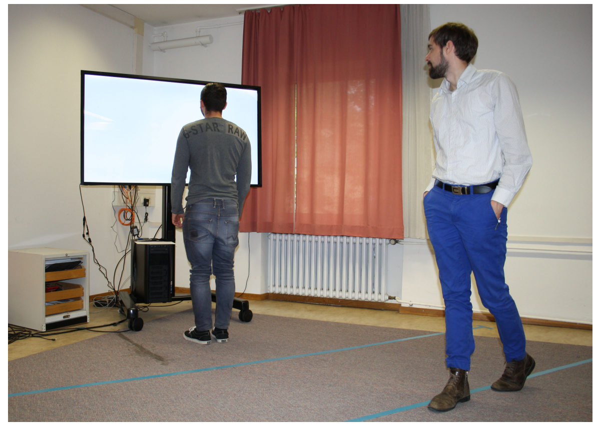

Figure 1. Photo of the fourth sub-experiment.

4. One participant walks past the screen while a second person is standing in front of the screen and partially occludes it (cf. Figure 1).

In all sub-experiments four different text moving directions were evaluated: right to left, left to right, top to bottom and bottom to top. The text was either moving in the horizontal or vertical centre. The distance to the screen was also varied, the used distances are listed in Table 1. We started with 0.5m for standing in front of the screen as this is approximately one arm length which is a typical distance for touch interaction. For walking past the screen, we started with 1.5m, as people naturally keep a distance when walking past something. We chose different distances in order to match the three interaction zones presented in [9]. For each interaction zone we added 1m. All four sub-experiments were conducted at a 65 inch 4k wall display. During the experiment the curtains were closed and a light source from the ceiling was switched on.

	Standing	Walking
Interaction Zone	0,5m	1,5m
Communication Zone	1,5m	2,5m
Notification Zone	2,5m	3,5m

Table 1. Distances used for the readability studies.

For the font type, we chose Verdana due to its optimization for high readability [13]. Based on the formula by [4] we calculated optimal font sizes for the different distances and the chosen font type. The following parameters were applied for the calculation: a = 500 | 1500 | 2500 | 3500 mm; β = 20'; n_{Av} = 2160 px; h_A = 833mm; p_{OS} = 96ppi = 3,78 pt/mm; f_R = 2048; h_{xt}= 1117. The calculation resulted in the following font sizes: 11.5pt (0.5m), 34.4pt (1.5m), 57.5pt (2.5m) and 80.5pt (3.5m).

We used a high contrast, with black text color on a white background. The experiment was realized with Microsoft PowerPoint using animation for the text movement. Start- and endpoint of the text was outside of the slide and therefore not visible. Text was displayed in two lines. Text length and text varied slightly between the groups. For the first two sub-experiments (standing) text length was between 13-22 words (using the standardized word length of five characters) and text speed was 130wpm (based on the recommendation by Meyer [8]) whereas for the third and fourth experiment (walking) it was 6-8 words at 120wpm (calculating with a slow walking speed of 1m/s and having a walking distance of 3.5m in the lab). We chose shorter text for the walking scenario as [11] found that people who read while walking remember only few words. If content catches a users attention he/she might stop and read more text. Thus we used longer text for our standing in front of the screen scenario.

Participants started in one interaction zone (clearly marked on the floor) and one after another text was presented from the four different directions. The text had to be read aloud and after each text the participant had to judge the readability on a scale from 1 (best) to 4 (worst). This was verbally done and the experiment supervisor noted down the number. In the multi-user scenario participants had to write down their judgment in order to eliminate mutual influence. After the experiment the participants were asked to answer a socio-demographic questionnaire. Prior to the experiment, participants were inquired whether their (corrected) vision is impaired. All of them declined and were therefore allowed to take part in the study.

Participants

In total 42 persons participated in the experiments. They were aged between 21 and 32 years (mean = 25.6, sd = 2.6), with 33 male and 9 female. Their first language matched the language of the experiment and the text. All of them were either university students or staff members, therefore all of them had at least A levels which ensures literacy. Due to different groups working on the four sub-experiments participants were not equally distributed among the groups: ten for Sub-experiment 1, twenty for Sub-experiment 2 (conducted in pairs), six for Sub-experiment 3 and six for Sub-experiment 4.

Results

In this section the four hypotheses will be answered. One-way analysis of variance is used for statistical analysis.

H1

In order to answer H1 we have to compare different settings. We start with standing in a distance of 1.5m. With a mean of 1.73 for single users and a mean of 2.43 for multi-user we found a significant difference ($F(1,78) = 19.23$, $p < .0001$). For the distance of 2.5m (cf. Figure 2) the difference is also statistically significant ($F(2,117) = 5.90$, $p < .01$), with means of M1 = 1.6, M2 = 2.23 and M3 = 2.05. Therefore, we accept the hypotheses for participants standing in front of the screen. This is not the case for walking past the screen: for 1.5m, the mean for single user (1.69) is better than for multi-user (1.88) but the difference is not significant ($F(1,94) = 1.60$, n.s.). The same is found for the 2.5m distance ($F(1,94) = 3.94$, n.s.), with a mean of 1.54 for single-user and a mean of 1.85 for multi-user. This changes for 3.5m where the mean for multi-user (2.42) decreases whereas for single user it remains similar (1.60). This difference is significant ($F(1,94) = 22.86$, $p < .0001$). Summing up the results of all three distance, the difference in readability between single and multi-user (with occlusion) is also significant ($F(1,286) = 21.79$, $p < .000005$) for walking and based on our data we accept H1.

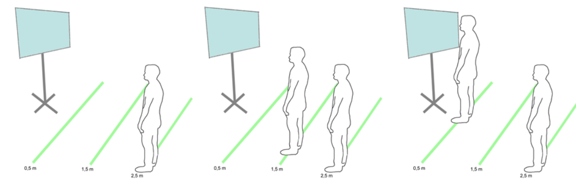

Figure 2. Tested settings for standing 2.5m in front of the screen.

H2

Summing up the results of the different scenarios we got a mean of 2.09 for standing in front of the screen and a mean of 1.83 for walking past the screen, this difference is significant ($F(1,646) = 14.36$, $p < .0005$) and we therefore have to reject H2: subjective readability is not better in case a person stands in front of the screen than he/she is walking past the screen.

H3

For H3 we analyze the data for standing in front of the screen at a distance of 0.5m. Detailed data for the different directions can be found in Table 2. Vertical text moving directions were significantly rated better than horizontal directions ($F(1,38) = 25.69$, $p < .00005$). Therefore, we accept H3.

Direction	Mean	Variance
from left	3.4	0.49
from right	2.8	1.07
from below	1.8	0.62
from top	1.8	0.40

Table 2. Mean and variance when standing at 0.5m in front of the screen.

H4

In order to accept or reject H4 we analyze data of the walking scenario, summing up multi-user and single-user as well as the different distances and just considering horizontal text moving directions. This resulted in a mean of 1.47 (variance of 0.42) if the walking direction matches the text moving direction and a mean of 2.04 (variance of 0.66) if these do not match. This difference is significant ($F(1,142) = 21.58$, $p < .00005$) and we therefore accept H4: walking past the screen, a horizontal text moving direction matching the walking direction is preferred.

DISCUSSION

Due to four different students groups working on the four different sub-experiments our study has several limitations. First of all the number of participants is not equally distributed among the groups and are rather low for the third and fourth sub-experiment. Furthermore, despite being a between-subject design, different texts were used for the four sub-experiments. But as we only asked for a subjective rating, this might have had only little influence on the results. If future studies include an objective rating, the used texts have to be comparable.

In the following we elaborate on the results and answer our research questions. In Table 3 we summarized the results on

	Single-User		Multi-User	
Zone	Standing	Walking	Standing	Walking
Interaction	b→ t, t→ b	b→ t	r→ l	l→ r
Communication	b→ t	r→ l* or l→ r*	r→ l	r→ l* or l→ r*
Notification	b→ t, r→ l	r→ l	r→ l	r→ l* or l→ r*

Table 3. Summary of preferred text moving directions. *=matching walking direction.

the preferred text moving directions, based on the mean of the subjective judgment by our participants. For the setting 'standing single user' two directions are given for two interaction zones, as these obtained the same mean. For walking the walking direction is relevant and therefore also two directions are given. It has to be noted, that for 'standing multi-user' in interaction zone, no occlusion occurred whereas for the other two zones the screen was partly covered by a second user.

The replies show a preference for horizontal text moving directions in a multi-user setting (either right to left, or left to right if walking in this direction) whereas for single-user also vertical text moving directions are preferred, especially if the user is standing in front of the screen. Therefore, if using dynamic text on a wall display a thoroughly context analysis needs to be done in order to determine whether the display is most often used by single users or by groups of people with possible occlusions. Table 3 also provides an answer to our second research question, users do prefer different text moving directions in case they are standing or walking. If possible the text moving direction should match the walking direction, for standing the preferred choice depends on the scenario: for single-user we would recommend bottom to top and for multi-user right to left. Looking at the tested distances, only little influence was found. For both walking scenarios a different preference was discovered for the interaction zone than for the other two. Otherwise, the preferred text moving directions are consistent over the different tested interaction zones. Finally, Table 3 provides an answer to our last research question, which text moving direction is preferred for which scenario.

CONCLUSION AND FUTURE WORK

In this work we showed that the typical text moving direction (right to left) for leading is not always the optimal choice. Especially when just one user is standing in front of the screen our results revealed a preference for a vertical text movement (bottom to top). For reading while walking we found it to be optimal if the text moves with the reader. Future work has to include how to achieve this in a multi-user scenario when several people walk past simultaneously from different directions. We plan to test the combination of different text moving directions, for example both horizontal directions at once. Future work has to include an objective rating of the readability, which could be done by testing the recall.

ACKNOWLEDGMENTS

We would like to thank all students who conducted the studies as well as all participants.

REFERENCES

1. 9241, I. Ergonomics of human-system interaction - part 302: Terminology for electronic visual displays, 2008.
2. Chen, H., and Chen, M. Directional scanning in chinese reading. *Cognitive aspects of the Chinese language 1* (1988), 15–26.
3. Coutrix, C., Kuikkaniemi, K., Kurvinen, E., Jacucci, G., Avdouevski, I., and Mäkelä, R. Fizzyvis: designing for playful information browsing on a multitouch public display. In *Proc. DPPI 2011*, ACM (New York, NY, USA, 2011), 27:1–27:8.
4. Domhardt, M., and Schmidt, L. Ergonomischer schriftgrad für elektronische anzeigen. In *Mensch & Computer 2013*, Oldenbourg Verlag (München, 2013), 231–240.
5. Greenberg, S., Marquardt, N., Ballendat, T., Diaz-Marino, R., and Wang, M. Proxemic interactions: the new ubicomp? *interactions 18*, 1 (2011), 42–50.
6. Huang, E. M., Koster, A., and Borchers, J. Overcoming assumptions and uncovering practices: When does the public really look at public displays? In *Proc. Pervasive 2008*, Springer (Berlin, 2008), 228–243.
7. Hwang, S.-L., Wang, M.-Y., and Her, C.-C. An experimental study of chinese information displays on vdts. *Human Factors: The Journal of the Human Factors and Ergonomics Society 30*, 4 (1988), 461–471.
8. Meyer, B. J. F. Importance of text structure in everyday reading. In *Understanding language understanding*, A. Ram and K. Moorman, Eds., Language, speech, and communication. MIT Press, Cambridge, Mass., 1999, 227–252.
9. Ott, F., and Koch, M. Social software beyond the desktop — ambient awareness and ubiquitous activity streaming. *it - Information Technology 54*, 5 (2012), 243–252.
10. Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., Oulasvirta, A., and Saarikko, P. "it's mine, don't touch!": Interactions at a large multi-touch display in a city centre. In *Proc. CHI 2008*, ACM (New York, NY, USA, 2008), 1285–1294.
11. Schmidt, C., Müller, J., and Bailly, G. Screenfinity: extending the perception area of content on very large public displays. In *Proc. CHI 2013*, ACM (New York, NY, USA, 2013), 1719–1728.
12. So, Joey C. Y., and Chan, Alan H. S. Design factors on dynamic text display. *Engineering Letters 16*, 3 (2008), 368–371.
13. Vinot, J.-L., and Athenes, S. Legible, are you sure? an experimentation-based typographical design in safety-critical context. In *Proc. CHI 2012*, ACM (New York, NY, USA, 2012), 2287–2296.