Proxemic Zones of Exhibits and their Manipulation using Floor Projection

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ABSTRACT
We investigate intimate proxemic zones of exhibits, which are zones that visitor will respect and hence not enter. In a first experiment we show that exhibits have, like humans, an intimate proxemic zone that is respected by exhibition visitors and which is 27cm. A zone around an exhibit that visitors will not enter can be increased through lines projected on the floor. In a second experiment we showed that for distances larger than 95cm, static lines will not protect the intimate zone of the exhibit anymore, but animated or color changing lines will do and allow for dynamically changing the zone size. This paper provides fundamental insight in intimate proxemic zones of exhibits and about how we can use interactive floor projections to manipulate these zones in the context of exhibitions. That might be used, for example, to increase the safety zone of exhibits if the room is crowded.

Author Keywords
Proxemic, projection, floor, exhibition, guidance.

ACM Classification Keywords
H.5.2 Information Interfaces and presentation: User Interfaces

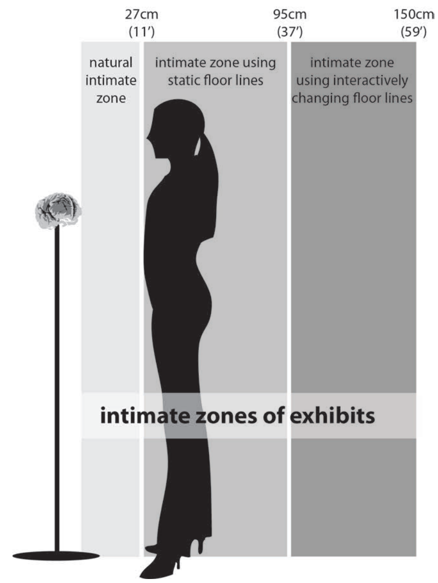

Figure 1. Intimate proxemic interaction zones of an exhibit, which is 27cm without projected line, can be increased through projecting static lines, and which can further be enlarged through interactively changing the floor projection, e.g., through color change or animated waves that suggest to in-/decrease the zone.

BACKGROUND
Proxemic theory [7] explains humans usage of space in inter-human interaction in dependence of the relationship between the people. For example, 45cm around a person's body is defined as intimate zone. That zone is usually not entered by people, and we only accept a person to come closer than 45cm if we have a close relationship to him/her. The theory of proxemics has been applied to the field of human-computer interaction through introducing Proxemic Interaction [3], and 5 proxemic dimensions (distance, orientation, movement, identity, and location) have been identified for spatial relationships between users and their ubiquitous environments [6].

Appart from studies on the influence of exhibition architecture on visitors behavior, information arrangement [2, 5] or research aiming to predict the best place for secirity control [8], the use of space and proxemics in exhibitions is not a well developed topic. An area in which the concept of proxemics has been taken up actively is the public display domain. Vogel et al. [19] introduced an interaction framework for public displays based on four zones. Michelis et al. [13] refines this approach and used the term "audience funnel" to describe the different phases in proximity of public displays and the typical behavior of users, e.g., passing by, viewing and reacting, subtle interaction and direct interaction. Each phase relates in this context to certain proximity zones from distant to close enough for direct interaction. Mueller et al. [14] suggested to extend these phases even further by including multi user scenarios and follow up actions. These multi-user situations were in particular targeted by the Ticket2Talk system [12] for academic conferences which sensed the proximity of multiple people to a display via RFID and visualized their common interest to spark conversations.

Projections in contrast to screen based systems are generally perceived as more ambient displays. This is due to their capability of turning every surface into a display and not even being noticed as display when presenting certain still pictures or being turned off completely. Many different approaches were presented that use projectors to turn spaces into display surfaces. The Everywhere projector system [16] allows to

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project on nearly every surface of a room by adding a steerable mirror to the projector. Baseballe et al. [4] use projection in the museum context to directly project onto exhibits and thus fuse projected information and static information on the object. The Illumiroom [11] project uses a projector to extend a typical TV beyond its frame and into the surrounding room and thus addresses a user's peripheral perception. The RoomAlive [10] project demonstrates how a set of ceiling mounted projectors can turn a whole room into an interactive augmented environment. For our experiment we have used a similar multi-projector approach with the difference that we only use the floor space for projection.

Previous studies investigated the effect of ambient lighting conditions on human spatial behavior. Adams and Zukerman studied the effect of bright and dim illumination conditions on personal space requirements [1]. However, in their study, they considered person-to-person interactions, while we are interested in exploring interactions with exhibits. Interactivity becomes increasingly common in exhibition spaces, for example to support the perception of the exhibits or to guide visitors through an exhibition, e.g. through motion pattern manipulation. The size of the intimate proxemic zone of exhibits represent a zone that visitors should not enter. Knowing such zone side and ways to manipulate the size would be used to adapt the intimate zone size to the situation in the room. An adaptive zone could, for example, increase if many visitors are watching an exhibit for both, providing a better view and better protecting the exhibit against damage.

Most previous work on manipulating proxemic dimensions targeted to influence motion patterns when moving through public buildings [9, 17, 15] or guiding through cities [18]. In this paper we explore the proxemic dimension distance and particularly investigate how floor projections can be used for distance manipulation in exhibitions. In a first experiment we explore the proxemic zone of an exhibit using static floor projections or no projection to identify the natural distance visitors keep to our exhibit, which is an illuminated sculpture of a human brain. In a second experiment, we investigated how we can manipulate the proxemic zones of the exhibit using interactive dynamic floor projections, such as color change and animated lines.

PROXEMIC ZONES

To explore the proxemic zone of exhibits excepted as intimate zone by visitors, we conducted an experiment within an exhibition showing media art and interactive installations.

Method

We used the opening and the closing event to run our study.

Design

Our experiment had a between-group design with the radius of lines (representing the proxemic zone size) projected around the exhibit as independent variable. As control condition we did not use any projection to identify the distance visitors intuitively keep to an exhibit. For the 3 other conditions we chose as radius 30cm, 45cm, and 95cm. The distance of 45cm is representing the proxemic border between a personal proxemic and an intimate proxemic zone [7]. That distance people usually keep to other persons if they do not have an intimate relationship. The distance of 30cm was chosen to represent a distance within the intimate zone. The distance of 95cm is still within the range of a personal proxemic zone, but it may be perceived by the visitors as too far to be able to view the exhibit. Through the experiment, we aimed to see if the projection will be accepted or ignored through crossing the line. Our dependent variable was the distance that visitors kept to the exhibit. Moreover, we wanted to understand if the projected line was accepted as border for an intimate zone and how to improve the projection design for increasing its understandability and acceptance, Thus we asked as open questions: "Did you respect the projection line as border that should not be crossed and if no, why?" and "What design would communicate better to keep distance?"

Participants were recruited through curating an interactive media exhibition. We advertised the exhibition through flyers, local newspapers, and social media. From about 200 visitors, 53 people participated in our experiment, We only considered the 36 German participants to avoid the cultural effect on proximity and human spatial behavior, which has been described by Hall [7]. Participants were aged between 18 and 45 years (M=30.8, SD=5.4) (19 males, 17 females). The participants were in sequential order assigned to one of the four groups, resulting in groups of 9 participants each. Each group saw either no projection or white lines projected in a radius 30cm, 45cm or 95cm around the exhibit.

Setup and apparatus

For our experiment we used an exhibition room that was isolated from the rest of the exhibition with a curtain and that contained just our experimental exhibit. The exhibit was an illuminated 3D printed human brain presented on a 140cm high pennant and whose filigreed surface aimed to make people wanting to view if from little distance. The exhibited object was placed on a plinth with 6 embedded IR proxemic sensors (SHARP GP2Y0A02YK0F) for measuring the distance of the participants. The sensors have range limitation of 150cm and cover only 15°) each, which results in blind spots. For capturing the entire room, we used as secondary measure device a fish eye camera mounted in the middle of the ceiling. Finally, 7 ceiling-mounted pico projectors were installed around the exhibit to project the lines that represent the proxemic zone.

Procedure

During the experiment an experimental leader was sitting in front of the experiment room and asked visitors that wanted to enter the room to do that separately one after the other. These participants were asked to view the exhibit as it was part of the exhibition. We also had a sign at the entrance that we captured the room with a camera. After the participants came out of the room, we asked them to fill in questionnaires. We compensated their effort with a drink voucher that they could use at the bar of the exhibition space.

Results

Proxemic analysis

Our IR sensors had collected distance data, and we also calculated distances applying image processing algorithms to the data captured with the ceiling mounted camera. We calculated the average of the closest distance between the visitors and the exhibit during each condition for no projection line: M=27.2cm, SE=1.3, for a projection radius of 30cm: M=45.0cm, SE=3.7, for 45cm: M=55.6cm, SE=2.3, and for 95cm: M=76.7cm, SE=2.6. A one-way ANOVA yielded a significant difference between the different conditions ($F_{3,32}$=16.184, $p<.001$). A Tukey post-hoc test revealed that the distance visitors keeps towards the exhibit was significantly the highest at the largest projection radius (95cm vs. no projection: $p<.001$, vs. 30cm: p=.001, vs. 45cm: p=.032), and without projection the distance was still lower than with a projection radius of 45cm (p=.002). There were neither a statistically significant differences between no projection and the smallest distance of 30cm (p=.088) nor between the two smallest distances (30cm vs. 45cm: p=.4.77), see Figure 2.

Design recommendations

In open questionnaires we had recorded design recommendations to improve the proxemic interaction design. Five participants assigned to the 95cm condition said that they crossed the line wanting to know what will happen if she/he passes the line as they expected some sort of interactive design. One participant said that he did not accept the projection with the radius of 95cm as that radius did not allow for viewing the exhibit well enough.

Regarding design recommendation to improve the understandability/acceptance of the projection, visitors mentioned that interactivity would have helped, for example: ”Interactive response if I pass the line.”, ”I would have understood it if the line would blink when I approach it.”, and ”One could adapt the illumination of the exhibit in dependence of the distance of the visitor, e.g. increase the illumination to tell the people to come closer.” The second trend of design recommendations was the usage of color change, mainly to red, like ”Color change to red if one passes the line.” and ”Red could serve as signal color for the border.”

Discussion

This experiment showed that visitors intuitively keep a distance to an exhibit of 27cm on average, which would be within the intimate zone for inter-personal proxemics. Projected lines can easily increase this distance to 30 and to 45cm. If lines are projected with a distance of 95cm this border is more often ignored and also not clearly understood. If the lines are very close, like 30cm, the understanding also decreases, probably because people would anyway not cross the line as the intuitive distance kept to an exhibit was measured to be already 27cm. Red lines and interactively animated projections were proposed to make the design clearer to understand or to increase its acceptance.

INTERACTIVE PROXEMIC ZONES

In the second experiment, we investigated if we can establish larger proxemic zones, which were not accepted as intimate zone using static lines in experiment 1, through an interactive design as recommended by the participants of our first experiment.

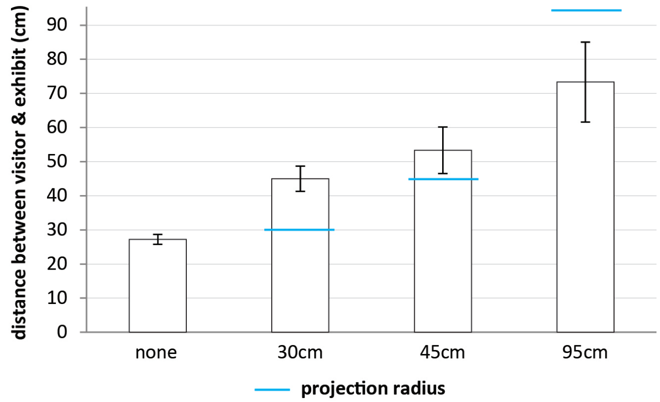

Figure 2. Distances (mean, SE) between visitors and exhibit for each projection radius (blue line).

Method

As interactivity allows for dynamic scenarios, we aimed to explore the possibility of dynamically changing the proxemic zone through interactive design. Hence, we considered intimated zones that change their size from 150cm to 95cm and back to 150cm.

Design

For that experiment, we invited 48 participants (38 males, 10 females) aged between 19 and 43 years (M=25.6, SD=4.6) through our university's mailing list. We chose again a between-group design with the projection design as independent variable. Considering the design recommendations of our first experiment, we had 4 different design condition including animation and the usage of the alarm color red: (1) As control condition we used static white lines like in the previous experiment (2) We used animated white lines (growing and shrinking waves around the exhibit) that grew to ”push” people away and ”shrunk” to invite them to come closer. (3) Static white lines changed to red color if people crossed them. (4) Animated white lines (growing to push people away and shrinking to get them closer) changed their color to red if the intimate proxemic zone was entered.

For each condition, the projection starts with a zone size of 150cm around the exhibit, followed by small radius projected at 95cm and finally, the projection has a size of again 150cm. The transition from one step to the next automatically happens after 9seconds, unless the participant enters the intimate zone. Then, depending on the applied condition, the projection (1) changed the line color from white to red if an intimate zone was entered (2) used animated waves that grow to suggest to enlarge the distance to the exhibit or that shrink to suggest to approach it. The dependent variable was the times it took the participants to adapt their position according the intimate zone radius after the floor projection suggested that.

Setup and apparatus

We used the same exhibited object as experiment 1 and simulated an exhibition situation in our lab. The light in the room was dimmed to ensure the visibility of the perception of the floor projections. To capture proxemic distances in

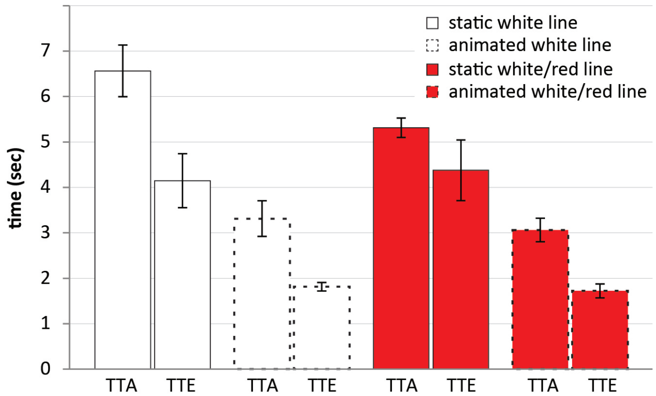

Figure 3. Reaction time per floor projection design for both, approaching (TTA) and evacuating (TTE) the exhibit.

360° around the exhibit, we used a plinth with 24 embedded IR distance sensors, covering 15° each. On the ceiling, a wide-angle projector was installed to project the intimate zone borders as well as the wave animations on the floor.

Procedure

After welcoming the participants, we asked them to view the exhibit in the simulated exhibition space. The condition order was counterbalanced. After the exhibit exploration, we asked the participants to fill in a demographic questionnaire.

Results

Reaction times

During our experiment, we had collected distance data including time stamps according to 4 different floor projection designs for the same 3 phases each: (1) a projection radius of 150cm (2) a projection radius of 95cm (3) again, a projection radius of 150cm. That allowed us to calculate the time it took the participants (after they had found their position according the first projection of a radius of 150cm) to adapt their position after a change in projection design to a distance of 95cm as well as to calculate a second time about how long it took after the third projection to again increase the distance to 150cm. We call these two reaction times: (1) time to approach (TTA) and (2) time to evacuate (TTE) the exhibit.

The average time to approach (TTA) the exhibit after an inviting cue was given by our projection design was for the static white lines 6.6sec (SE=.6), for the animated white lines 3.3sec (SE=.4), for the static white/red lines 5.3sec (SE=.5), and for the animated white/red lines 3.1sec (SE=.3). The average time to evacuate (TTE) the exhibit after an according projection was shown was for the static white lines 4.1sec (SE=.6), for the animated white lines 1.8sec (SE=.1), for the static white/red lines 4.4sec (SE=.7), and for the animated white/red lines 1.7sec (SE=.2).

An ANOVA showed a significant difference between the different conditions for the time to approach (TTA) an exhibit after the suggesting projection was displayed ($F_{3,44}$=13.672, p<.001) and for the time to evacuate (TTE) the exhibit after the third projection suggested to ($F_{3,44}$=10.040, p<.001). Tukey post-hoc test revealed that the time to approach (TTA) an exhibit after the suggesting projection was significantly shorter for the animated wave designs compared to the static designs, no matter if the color change to red or not (white animated vs. white static line: p<.001, white animated vs. white/red static line: p=.016, white/red animated vs. white static line: p<.001, white/red animated vs. white/red static line: p=.005). Tukey post-hoc test revealed similar results for the time to evacuate (TTE) the exhibit after a suggesting projection (white animated vs. white static line: p=.004, white animated vs. white/red static line: p=.001, white/red animated vs. white static line: p=.003, white/red animated vs. white/red static line: p=.001) , see Figure 3.

Discussion

We found that both interactive proxemic projections, color change and wave animation can be used to in- and decrease the proxemic zone of an exhibit, while animated waves result in faster distance changes. A possible explanation for the faster response on animations may be their better visibility when standing on the projections as the visitor sees the growing and shrinking waves even if watching the exhibit in his/her visual periphery.

CONCLUSION

This paper is targeting the topic of proxemic interaction through applying procemic theory to the domain of interactive exhibitions. We particularly explored if exhibits - similar to humans - have an intimate proxemic zone that people would not enter. Moreover, we looked at the possibility to manipulate the size of such zone using interactive floor projections. We indicated that static lines increase the natural proxemic zone of an exhibit of 27cm up to about 45cm, while trying to increase such zone to a size of 95cm fails using static lines. However, static lines are ignored for larger distances; they are understood and accepted if the color is changing to red in case a person crossed the line. Moreover, animations cannot only successfully keep persons to a large distance to an exhibit, they are also a good approach to quickly manipulate the position of people for both getting them closer or farther away from exhibits.

In summary, we indicated a natural intimate proxemic zone size for our exhibit of 27cm when no zone border visualization is used. Projecting static lines on the floor increases the intimate zone of the exhibit, but for a zone size up from 95cm static designs fail and interactively changing designs (e.g., color change or animated lines) are needed to establish such rather large intimate zone size, which remarkably is at least 3-5 times larger than the natural intimate proxemic zone of our exhibit, see Figure 1.

The intimate zones of our exhibit are empirically defined, and we think the zones we found also apply to other exhibits of same kind. However, other kinds, like extremely large exhibits, surely lead to different intimate zones sizes. Moreover, the transitions from one zone to the other are due to our experiment design rather vaguely defined. Thus, for future work we propose both, exploring the proxemic zones for other exhibit or object types as well as defining the zones more precisely through a finer grid of distances explored in user studies.

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