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The Use of Situated Visualized Data to Nudge Visitor's Paths: a Case Study at the Detmold Design Week 2023

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1 ABSTRACT

In light of the rising importance of data transparency and open data guidelines (e.g. OGP Local[1]), Open Data Portals became standard in Smart City strategies (Van Oosterhout et al. 2020). While it is clear that these tools can serve as a valuable way for internal administration processes, at the same time it is critical that data is not only openly available following standard formats limited to computer-readability but above all also largely understandable for average citizens. For this reason, it is researched how open data can not only be made available but also visualized in an accessible way to all citizens. Moreover, the aim is to simultaneously boost private behavior changes which are inevitable to achieve locally-set goals in sustainability (Barr et al. 2011, TWI 2050 2018). To do so, we draw on the principle of nudging. Following the tradition of behavioral economics, nudging is defined as a positive intervention that induces a voluntary change in behavior without resulting in external (negative) consequences (Thaler & Sunstein 2008) and thus contrasting interventions like commands or bans because freedom of choice is maintained (Mongin & Cozic 2020, Ranchordás 2020).

This paper discusses an installation that explored the potential of combining nudging and situated visualization to improve data transparency and support individual decision-making in urban public spaces. During the Detmold Design Week 2023, an event showcasing creative works in various locations, the visitor numbers at nine locations were captured using computer vision. Visitors then received on-site suggestions in real-time for the next place to visit based on the occupancy. A survey was conducted to evaluate visitors' willingness to follow these data-informed suggestions. Findings highlight the importance of balancing between simplicity, relevance and privacy in data visualization. The results of the field test provide the foundation for the installation of interactive interfaces in Detmold's public spaces in the next years, in particular for communicating smart city topics focusing on mobility and urban climate protection.

Keywords: Situated Visualisation, Nudging, Planning, Computer Vision, Human-computer interaction

2 INTRODUCTION

In urban development policy, getting all stakeholders to behave in accordance with goals that are widely accepted in the population e.g. in climate protection presents a significant obstacle (Klementschitz et al. 2020). Opposed to commands or bans, the principle of nudging consists in inducing a voluntary change in behavior while maintaining freedom of choice (Thaler & Sunstein 2008, Mongin & Cozic 2020, Ranchordás 2020). Nudging is widely used to incentivize more sustainable choices in various fields like mobility, traffic safety, management of public spaces, energy consumption (Bandsma et al. 2021, Ranchordás 2020) etc. Behavior Change Techniques are mainly based on the assumption that public policies cannot rely on rational responses by individuals if the decisions contradict their inner beliefs, needs etc. (Loidl et al. 2023, Mongin & Cozic 2020, Thaler & Sunstein 2008). Klementschitz and colleagues describe four pathways for nudging: "1. simplification and framing of information, 2. changes to the physical environment, 3. changes to the default policy and 4. the use of social norms" (Klementschitz et al. 2020). With the shift to a digital society, improved affordability of sensors and therefore the constant collection and analysis of data, the application area is expanding to include digital nudging (Loidl et al. 2023, Weinmann et al. 2016).

Current debates discuss data protection challenges and ethical guidelines for an approach to nudging that addresses the potential paternalistic tendencies in influencing people's behavior (Huber et al. 2023, Klieber at al. 2020, Mongin & Cozic 2020, Ranchordás 2020, Santos Silva 2022). Research has also explored the implementation of nudging in contexts of circular economy, e.g. in the project Antwerp Circular South which combined sending app-messages with weekly reports, group challenges, competitions, rewards and

[1] www.opengovpartnership.org/ogp-local/

emotion-provoking images regarding energy use in peak hours, garbage reduction and water consumption and sensors to control the results (Hofman & Van de Mosselaer 2021, Smets & Lievens 2018). Others have utilized the concept to nudge travelers to use socially favorable routes by trialing modified design of cartographic symbolization based on scenarios for traffic and air quality (Fuest et al. 2023).

Although these studies show the application of nudging in Smart City contexts, it is apparent that most solutions rely on smartphone-applications as a tool for visualization. Online Open Data Portals are also standard in Smart City strategies (Van Oosterhout et al. 2020) when conforming to the current data transparency and open data guidelines (e.g. OGP Local). According to these guidelines, data must be openly available in computer-readable formats, but the question of how to visualize the data in a human-readable format for the average citizen is left to researchers (Ansari et al. 2022). Moreover, when available online, the data reaches only those citizens that actively look for it. When trying to nudge citizens in the direction of more sustainable choices, data can be used to inform and back-up such choices, if visualized in an understandable way and reachable where the citizen can see it passively. Insights into other types of visualization for nudging are limited and we aim to identify how on-site display of information and nudges can be combined in the later-presented case study and therefore contribute to this incomplete body of research.

Previous research in human-computer interaction (HCI) has already explored the concept of so-called situated visualization. According to White & Feiner, this term refers to "a visualization that is related to and displayed in its environment" (White & Feiner 2009). Other authors expand the definition by taking into account that the place of visualization must have relevance for people (Bressa et al. 2022). Situatedness incorporates the contextual, local and social environment (Huber et al. 2023). Projects using situated visualizations use a variety of technologies, data sets, methods and visualization styles (e.g. artistic, physical) (Bressa et al. 2022). While situated visualizations are at their core displays of information (e.g. Vande Moere & Hill 2012, De Macêdo Morais et al. 2019, Wiethoff & Hoggenmueller 2017), related projects often provide additional functionalities such as voting (Behrens et al. 2014, Claes et al. 2018, Koeman et al. 2014, Steinberger et al. 2014, Valkanova et al. 2014) or facilitating user-created content (Claes et al. 2018, Fischer & Hornecker 2012). Situated visualizations are considered to be highly relevant in dealing with digital information, as they provide users of urban (digital) services with a detailed overview and, as a result, enable better decisions (Martins et al. 2023).

Several projects have meaningfully deployed the concept of situated visualization. Nuage Vert in Helsinki, Finland, visualized the energy consumption of the inhabitants through a low-energy laser light which lit up the projection surface of a cloud caused by emissions of an electricity plant chimney and automatically adjusted according to the consumption rate (Vande Moere & Hill 2012). "Data on Site" combined several wirelessly networked e-ink displays installed on street-facing windows, which visualized data-sets and diagrams regarding topics like air quality or local shopping habits (Claes et al. 2018). Our research is based on the current leading discussion in situated visualizations, namely, achieving high interaction rates with the physical installations and attaining high effectiveness in communicating information, while also ensuring inclusiveness for the majority of inhabitants (Caldwell et al. 2016, Letondal et al. 2023, Steinberger et al. 2014, Wiethoff & Hoggenmueller 2017).

In the installation "Where to go next?", we tested the use of situated data visualization in public spaces to nudge users' decision-making based on the number of visitors in different event locations. In this case study we conducted an experiment to evaluate citizens' willingness to follow computer-generated data-based recommendations presented directly on site. In presenting this field test, we wish to bring attention to the opportunity to connect nudging with situated visualization to, on the one hand, improve transparency for citizens regarding data collection in Smart Cities and on the other hand encouraging favorable behavior through interaction and information. One main task was to explore how data can be visualized in such a way that the associated relevance can also be communicated through the design. To do so we build on the theoretical and applicatory insights from the earlier presented case study examples.

3 CASE STUDY SETTING

The installation took place during the Detmold Design Week (DDW) 2023 (detmolderdesignwoche.de), an event that occupies vacant stores and abandoned industrial buildings in the city for a week to showcase independent designers' and artists' works. The first event in 2022 had more than 1500 visitors and was received very positively by the population. With 30 different exhibition locations, the second year week presented a good opportunity to test the concept of a decentralized data-supported nudging system. The number of visitors at selected exhibition sites was collected and visualized in real-time on-site (see Figure 1). The nudging was tested in the form of suggestions for the next location to visit based on the occupancy of surrounding locations. In order to be able to give suggestions on which location to visit next, the visitors were counted to determine the occupancy of each location, using a computer vision algorithm.

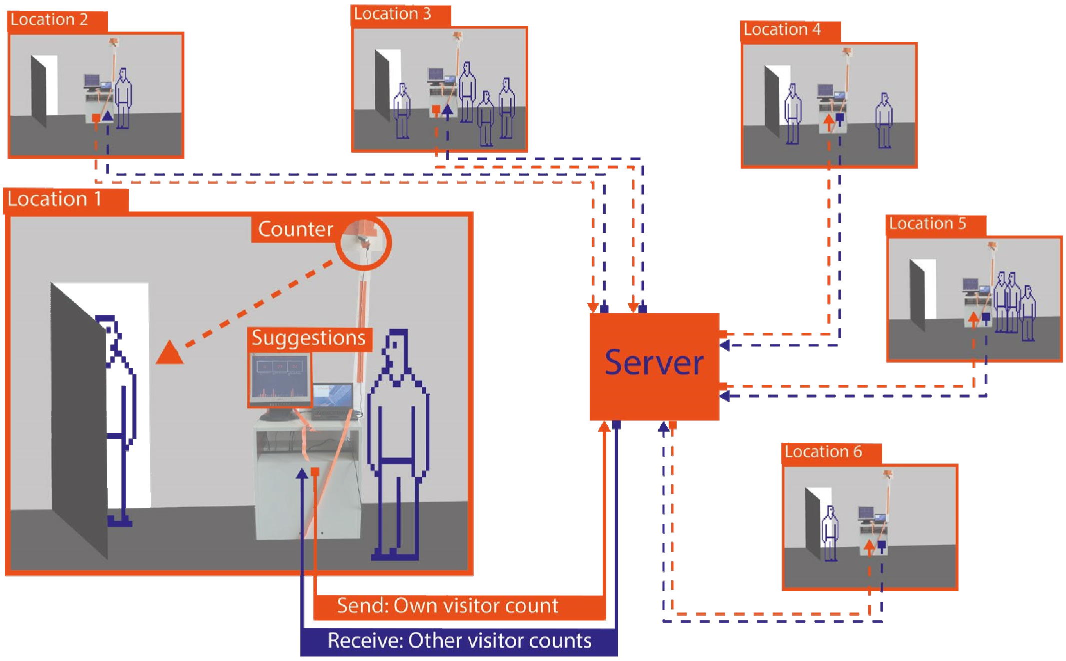

Figure 1: General setup of the case study in different locations with data exchange through server.

4 CASE STUDY DESIGN

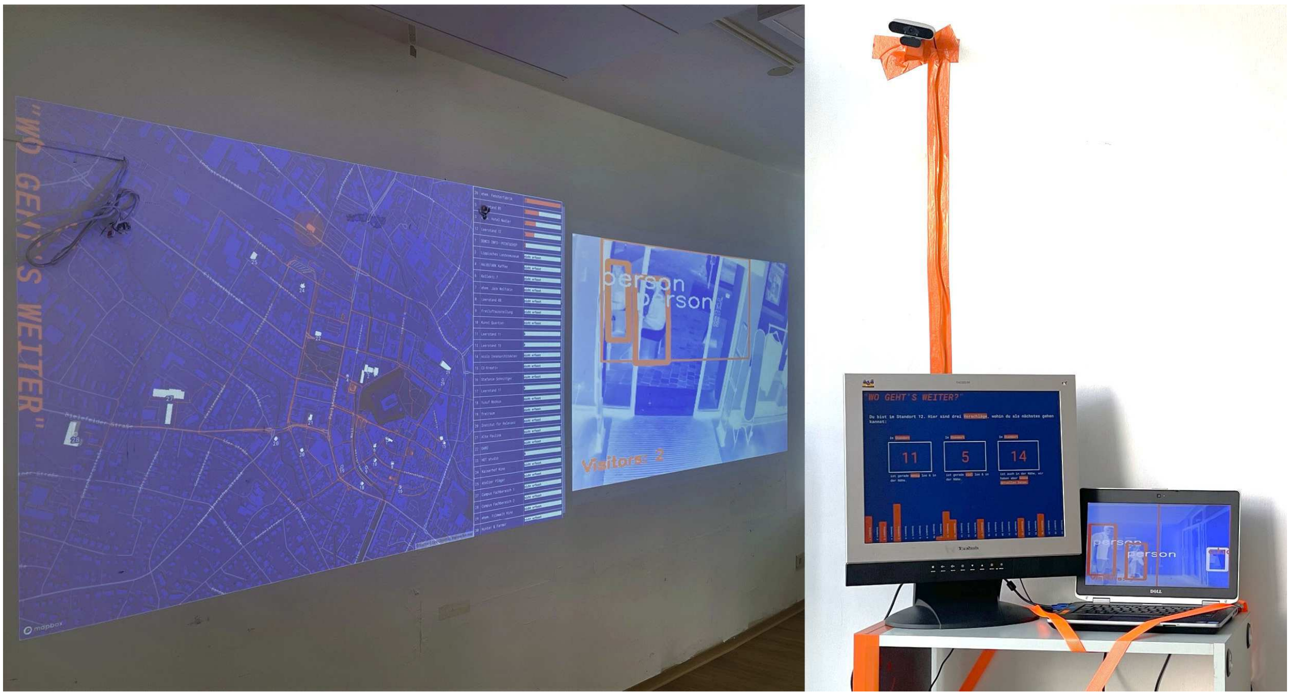

Figure 2: Projections at the DDW info point and data collection and on-site visualization setup.

The DDW's info point was chosen as the central point for the installation, where all information was visualized and visitors could find a team member for questions at all times. It was equipped with two projections (see Figure 2), one showing the map of all locations (described in 3.2.1), the other streaming the video of the people counter (described in 3.2.2). The projections were run by a standard laptop (12 years old/intel i5 processor/4gb RAM, no dedicated GPU), which also hosted the computer vision algorithm (described in 3.1) using the connected webcam (FHD, 120-degree wide angle).

Besides the central information point, 8 other locations were selected for data collection and on-site visualization. In each entrance area, the same type of laptop and webcam as described above and an additional second screen were installed (see Figure 2). The laptop screen showed the live stream (as described in 3.2.2), on the second screen suggestions where to go next (as described in 3.2.3) were visualized.

In all locations, posters explained the idea of the installation and the technology behind it, especially focusing on privacy concerns and transparency in the whole data collection process. Furthermore, a QR code directed the visitors to the survey (described in 3.3) and an Instagram account, where more information was available. In the following, the setup is explained in detail, divided in the data collection process, the data visualization and the survey structure.

4.1 Data collection: computer vision algorithm

The fast development of machine learning and deep learning helped bringing many recent advances in the field of computer vision (Cob-Parro et al. 2021). Most relevant is the introduction of the algorithms R-CNN, fast R-CNN, faster R-CNN, SSD (single shot detection) and YOLO (you only look once) (ibid.). For this case study, a SSD algorithm was used for object detection.

Unlike other methods, which analyze the video in a server or cloud solution, shifting it towards the location (so called edge computing) reduces network traffic (Herelia & Barros-Gavilanes 2019) and helps reducing privacy concerns. Since computational power at each location was limited though, the algorithm had to be as light as possible. It is based on Adrian Rosebrock's OpenCV People Counter (Rosebrock 2021) but was modified as explained in the following. First the video is analyzed locally in real-time to detect people and other objects. After detection, the algorithm is able to track the object through the image.

For object detection, mobilenet-ssd, a Single-Shot multibox Detection (SSD) network was used, as presented by Liu et al. In 2016 (Liu et al. 2016). The network uses the deep learning framework Caffe (Convolutional Architecture for Fast Feature Embedding) to store and represent trained neural network models and is available on Github (https://github.com/chuanqi305/MobileNet-SSD) with pre-trained weights on Pascal VOC (Visual Object Class) 2007 and 2012, which is a widely used benchmark dataset in computer vision. It combines two editions of the dataset, namely VOC2007 and VOC2012, which were released as part of the Pascal VOC challenges. The available pre-trained network contains 20 different object classes, including common objects such as people, cars, animals, and household items. The mean average precision is mAP=0.727 (https://github.com/chuanqi305/MobileNet-SSD). In the case of this project, only objects identified as people are relevant. Every frame of the live video is sent through the SSD network, using Open CV's deep neural network module. Objects with the class people are further processed.

After successfully detecting the visitor, the dlib correlation tracker is activated in order to keep track of it, as done by Rosebrock (Rosebrock 2021). In his approach, the visitor is counted after crossing a predefined line (LOI: line of interest) as an entry or exit, depending on the direction. This is useful for an installation in a clear entry situation with one opening and a clear walking direction towards it through the given floorplan. In other approaches (Kowcika & Seshadri 2015) the number of people inside a certain area (ROI: region of interest) is counted. This can be done, if the camera is able to face the whole location and count all current visitors. In our case, it was needed to come up with a new approach, which is also based on a region, but where not only people inside the region are counted, but also the direction is relevant, meaning it makes a difference if the object appears first in the region and leaves it, or in the opposite direction (see Figure 3).

The door or opening is marked as polygon, and the counter is activated if an object left or entered this region. This approach brings benefits for locations, where it is not possible to use LOI, because of the given floorplan. For calculating the direction of the objects' movement, Rosebrock calculates the average of all its previous locations and the latest location, to create a vector (Rosebrock 2021). For this case, the first location, where the object appeared, and the current location was taken into account instead, which showed better results in testing. Moreover, the code was modified in such a way, that also visitors that entered the polygon but then reentered the room, would be taken into account properly. Every 15 seconds, the current number of visitors is sent to the database using a request.

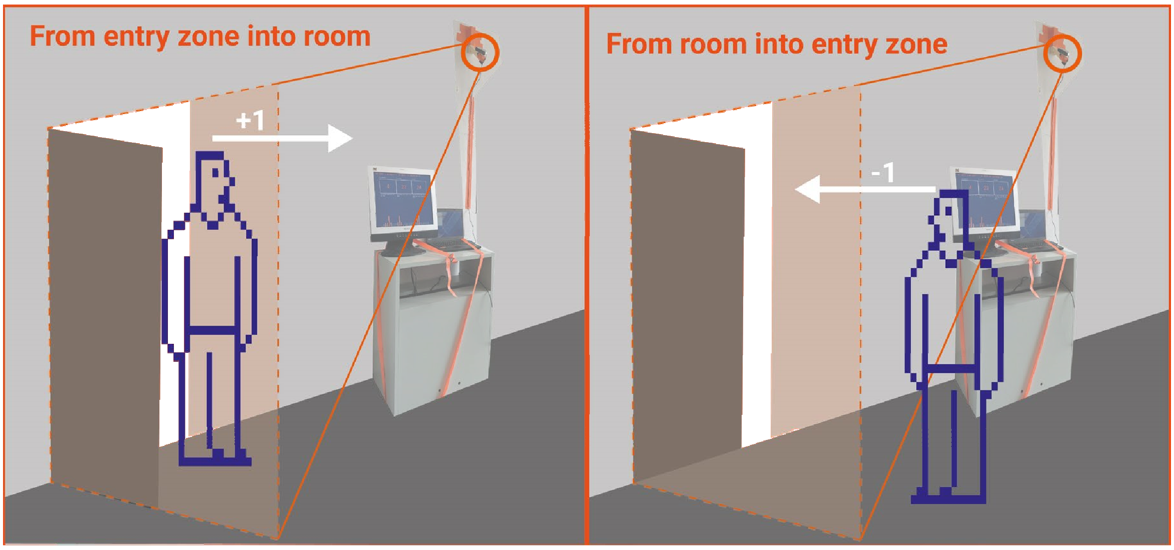

Figure 3: Region of interest (ROI) principle for counting algorithm.

4.2 Data visualization

The collected data was visualized in three different ways throughout the exhibition, described in detail below: map, camera view and suggestions.

4.2.1 Map

The map (see Figure 2) shows an overview of all the data being collected at all 9 monitored locations of the DDW. The larger the dot on the map, the more visitors were currently at that location. Despite not being tracked, the remaining 21 locations were marked with a white dot, so visitors would still be aware of them as options to visit. The list on the right side of the map was updated in real-time, with the most visited location always at the top. The orange network displayed showed the shortest routes between the 30 locations, where it was likely to encounter many DDW visitors. In the online interactive map, available on a tablet at location 1 and also shared on social media, the user could click on a location and see the number of people there, the time of the last update and the name and number of the location. Some visitors later informed us that they actually used the map at home to check which locations were more eventful. In the final days of the week spontaneous finissages were happening in some locations, which were not mentioned on the event's agenda and were being spontaneously shared on social media. The map could then assist the visitors to find these unscheduled events.

4.2.2 Camera view

Besides showing the resulting data, a main concept was also the visualization of the technological principles behind it, in this case the object detection via webcam. By doing so, the mistrust over cameras was supposed to be reduced and data transparency maximized, the understanding towards the technology enhanced and interaction engaged. In each location, the live stream was therefore visualized in real time. The detected objects were then marked as such and given a matching tag, e.g. person or cat, depending on the algorithm (see Figure 2). Using a real time filter from Open CV, the stream was modified into a more abstract picture, which made individuals almost unrecognizable, while still being identified as object.

4.2.3 Suggestion/Nudging Algorithm

For suggestions, all locations within a radius of 300 m were considered. Visitors were given a suggestion for the location with the fewest visitors, the one with the most, and a randomly selected location where we did not conduct measurements. The goal of the nudging was not to favor some locations over others, but instead to motivate the visitors to always move to a next close location, instead of finishing their visit at the present one or moving to a further location while missing others that were close by. For this reason, the locations with no data were also included as an option, while the other two options backed with data were given to test if the data itself played a role in the decision-making. All options were visualized on the second screen in each location (see Figure 2), together with an abstract overview on visitor numbers of all locations.

4.3 Survey

Visitors were invited at the locations to scan a QR Code and take part in an online survey to evaluate their willingness to accept data-informed suggestions in public places. The survey contained 11 questions (7 close-ended and 4 open-ended) and explored the following three themes: 1. willingness to follow data-informed suggestions, 2. feelings and trust towards the technology and 3. willingness to share their own data. It was advertised through QR codes in the exhibition and also online on social media (Instagram). Visitors were also actively recruited in person by our team to take part in the survey. Since the participation in the survey (n=38) was too low to give representative results, it is only possible to get first insights on the topic and also test the survey for comprehensibility. With this in mind, the results are listed in the following.

With the first question, which asked if the suggestions shown in the locations impacted their way through the event, 11 users had to be filtered out, since they were not aware of any suggestions. From the remaining 19 users, ten reported that yes, the recommendations impacted their way through the exhibition and nine responded that no, they did not have an impact.

When asked why the recommendations impacted their way through the event, four respondents answered that the information helped them to orient themselves, but sometimes they didn't follow them anyway. Another four answered that they wanted to go where less or more people were, and the suggestions helped them with that. And two respondents liked that they didn't have to think where to go next.

Among those who were not impacted by the recommendations, four answered that they would rather follow their own way and four thought that the recommendations were not relevant for them. We also asked if the visitors could imagine using publicly visualized data, like it was done with the visitor numbers, for daily decisions. One visitor responded in the free text field that it would depend on each situation, four visitors responded no and 14 responded yes.

Besides whether or not the visitors were impacted by the recommendations, we were also interested in exploring how they felt about their data being collected and used in this manner. When asked how the presence of the camera made them feel, 13 respondents reported being interested, three were indifferent and another three felt insecure. From those respondents that felt indifferent as well as from those who felt insecure, two out of three responded that their feeling towards the camera changed for the better after understanding how the data is anonymously processed and not saved.

5 DISCUSSION

The survey showed that visitors principally react to nudging-based situated visualizations and also that the questionnaire was suitably designed to provide results for the targeted topics. In general, the importance and meaningfulness of the survey is relatively low though, since only a small percentage of visitors participated. A stronger presence of interviewers at the locations and visual promotion of the survey through posters etc. could increase the number of respondents in the future. The implications and questions deriving from the survey, but also conversations and observations during the test, are summarized in the following.

Does transparent data collection and processes motivate participants? The survey hinted on that by focusing on transparency during data collection and visualization, people can be motivated to participate. This was also reflected in several conversations with visitors. Based on observations, the transparent visualization of the data collection process helped to motivate people to come closer, read the recommendations and get informed about the study.

Are people open to follow suggestions informed by situated data visualization? The received results are not representative for giving a conclusive answer to this. Out of 19 visitors, 14 answered that they could imagine using situated data visualizations for daily decision making. 10 out of 19 answered that the suggestions had an impact on their way through the exhibition. In conversations, visitors acknowledged the relevance of this type of interfaces for the urban space and showed willingness to use them and contribute with data.

How does the data have to be visualized and contextualized? Three visitors stated that they would also like to have a map showing them where to go next. The researchers' focus on keeping the data visualization simple ended up leaving out an important piece of information that would have been relevant for the visitors and eased their experience following the suggestions. For the maps, the work of Fuest et al. 2023 could be valuable since they focused on ways of visualizing maps and directing people. Some visitors were not even aware of the suggestions, indicating that the visualization and/or the posters explaining the experiment failed partially in transmitting the message clearly to all. This shows that a balance between choosing the right information to be shown and keeping it direct, simple and clear is necessary.

How can engagement be generated? Based on observations and conversations with visitors the playful visualization of the live stream (see Figure 2) helped in getting visitors engaged. Some would recognize themselves and move around the camera picture to see if the classification and tracking would keep up with their movements. Some would try to change their classification by changing posture or raising their arms, imitating a dog or a cat. Through this, awareness for the field study was created and also conversations about it started. In the further development, tangible elements are planned as well in order to attract people and engage them, as done by Claes & Vande Moere 2018. According to them, "especially in the context of the visualization of data in the public realm, offering tangible interaction modalities might actively attract and engage passers-by, and lead to increased information discovery" (ibid.).

Technical challenges. While not being the focus of the field test, the algorithm for counting visitors was not as accurate during the week as during testing before. This was mainly due to the different entry situations in each location, with some better suited and some less suited, as well as due to the lack of computational power. Another challenge was ensuring a steady internet connection for all locations. Public Wi-Fi networks turned out to be too unstable for the study, while individual sim cards for each location were too expensive. In the future, a city-wide LoRaWAN network would be helpful for the data exchange.

6 CONCLUSION

In this study, we explored the use of situated visualization in nudging users' decision-making. Using the visitor count of several locations at the DDW as example, our focus was mainly on running a first test on the general acceptance of situated visualizations and the visitors' willingness to use such interfaces. The installation during the Detmold Design Week showed great potential for nudging through data visualization, even though problems and challenges appeared during the execution, which we identified through the survey, observations and conversations. In conclusion, a good balance between choosing the right amount of information to be shown while still keeping it as simple as possible and also balancing between privacy concerns and personal relevance has to be found. The interactive and playful character of the installation proved to be very helpful for engagement.

As part of an ongoing research project with the city of Detmold, the concept of a situated visualization based nudging system is going to be further developed with the goal of integrating it in the urban public space (streets, squares, etc.). This first test gave valuable insights, even though the survey answers were not representative for giving a conclusive answer yet. With more tests using the same survey, this will be improved. In an iterative research through design process, the next steps are to develop suiting interfaces which incorporate tangible elements for enhanced engagement as done by Claes & Vande Moere in 2015 and Claes et al. in 2018. A connection to the future open data platform of the city is planned to be implemented, thus making it a universal tool for visualizing a variety of urban datasets.

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