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How can a tour guide robot's orientation influence visitors' orientation and formations?

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Abstract. In this paper, we describe a field study with a tour guide robot that guided visitors through a historical site. Our focus was to determine how a robot's orientation behaviour influenced visitors' orientation and the formations groups of visitors formed around the robot. During the study a remote-controlled robot gave short guided tours and explained some points of interest in the hall of Festivities in the Royal Alcázar in Seville (Spain). To get insight into visitors' reactions to the robot's non-verbal orientation behaviour, two orientations of the robot were tested; either the robot was oriented with its front towards the visitors, or the robot was oriented with its front towards the point of interest. From the study we learned that people reacted strongly to the orientation of the robot. We found that visitors tended to follow the robot tour guide from a greater distance (more than 3 meters away from the robot) more frequently when the robot was oriented towards the visitors than when it was oriented towards the point of interest. Further, when the robot was oriented towards the point of interest, people knew where to look and walked towards the robot more often. On the other hand, people also lost interest in the robot more often when it was oriented towards the point of interest. The analysis of visitors' orientation and formations led to design guidelines for effective robot guide behaviour.

1 INTRODUCTION

Several robots have been developed to give guided tours in a museum-like setting (some examples are described in [1]–[4]). These previously developed robotic tour guides did good jobs in their navigation and localization tasks, such as avoiding collisions with visitors or objects, and showing they were aware of the visitors' presence. While giving the tours, these robots captured the attention of visitors, had interactions with visitors and guided the visitors through smaller or larger parts of exhibitions. Studies reported some information about the visitors' reactions to the robot's actions which has led to knowledge on specific reactions of people to the modalities of these robots and behaviour shown by these robot designs.

Within the EU FP7 FROG project we were, among other innovations and application areas, interested in effective tour guide behaviour and personality for a robot guide. To find effective behaviours we started to examine the effect of single modalities on robot behaviour and visitor reactions to those behaviours. The question we wanted to answer with this study is: how does the robot orientation behaviour influence the orientations of the visitors, as well as the type of formations that (groups of) visitors form around the robot? The findings of the study we present in this paper led to guidelines to design behaviours (for FROG and other robots) that will influence visitors' reactions, such as orientation and group formations.

One way of creating robot behaviour is to copy human behaviour to a robot. A limitation of copying human tour guide behaviour to robots is that robots in general, and the FROG robot specifically, do not have the same modalities to perform actions that human tour guides perform. On the other hand, robots might have modalities to perform actions that human tour guides cannot perform. Therefore, we need to carefully study how and which robot modalities can effectively be used in interaction.

In previous studies, the reactions of the visitors were assumed to be similar to visitor reactions to human tour guides, but it turned out that these were different. For example, people often crowded around the robots [1], [2], [4], [5] or started to search for its boundaries by blocking the path [1] or pushing the emergency button [2], [6]. On the other hand, people often used their known human-human interaction rules to interact with the robots [2], even if the robots were not humanoid and people were informed that not all cues could be understood by the robot. Similar to robots that have been used in other studies, our FROG robot is not humanoid. We know that human tour guides influence visitor reactions of a group of visitors by using gaze behaviour and orientation [7]. Therefore, we are interested in visitors' reactions to a basic tour guide robot with limited interaction modalities. Also, we wanted to find out whether these reactions are similar to or different from visitor reactions to a human tour guide.

In this paper we will focus on the formation and orientation of visitors as a reaction to the robot orientation behaviour. We use the term formation to indicate the group structure, distance and orientation of the visitors who showed interest in the robot and/or the point of interest the robot described. In human guided tours, people generally stand in a common-focus gathering, a formation in which people give each other space to focus on the same point of interest, often a semi-circle [8]. For robot guided tours, we expected to find similar formations. However, from previous research we learned that single persons or pairs of visitors also joined the tour [9], [2]. Therefore, we considered the combination of distance and orientation of these individuals or pairs as formations as well. We assumed that people would be engaged with the robot or the explanation, when they were oriented towards the robot or the point of interest for a longer period of time. Hence, we also use the terms formation, orientation and engagement separately from each other in order to be specific in the description of the results.

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In this paper, we first will discuss the related work on effects of robot body orientation, gaze behaviour and the use of several modalities in tour guide robots. Then we will present a field study where we aimed to find how robot orientation behaviour influences the group formations and orientations of the visitors. Next, we present will the results and discuss them. Finally, we will present design guidelines for non-verbal robot behaviour. The paper will end with a conclusion, in which we give directions for future research.

2 RELATED WORK

A tour guide robot for instance engages visitors and directs their attention to points of interest. This is similar to what human tour guides do intuitively. Human tour guides use their (body) orientation and give gaze cues to direct visitors' attention. However, most important are their subtle reactions to visitors' actions [7]. Kuzuoka et al. showed that a robot could effectively reshape the orientation of a visitor by changing its own orientation with a full body movement [10]. Also, human-like gaze cues can be successfully copied to robots, as shown by Yamazaki et al. They found that visitors showed higher engagement to a robot tour guide that used human-like gaze cues and its story than when the robot was not using these human-like gaze cues [11]. Sidner et al. found that head movements (and thus gaze cues) of the robot helped to keep people engaged during interaction [12]. Subtle gaze cues of robots can also be understood by people, as was shown by Mutlu et al. who let a robot describe an object among several other objects that were placed on a table. When the robot was "gazing" at the object it described, people found it easier to select the corresponding item [13].

The previously described body of work has focussed on copying two important types of cues that human guides use. However, robots are often able to apply a more diverse set of cues than body orientation and gaze cues alone. Different types of robots can use alternative modalities to give cues about their intentions. For example, if a robot uses a screen to convey information, visitors will stand close and orient themselves so that they can see the screen. However, when a robot uses arms to point and has no screen, visitors will probably orient themselves so they can easily see the robot and the exhibit the robot is pointing at.

Researchers have tried different modalities for museum robots to communicate intentions to their users. In the next paragraphs some examples of behaviour will be given to illustrate the effects of specific behaviours. The robot Rhino as developed by Burgard et al. blew a horn to ask visitors to get out of the way, which often had the opposite effect and made visitors stand in front of the robot until the horn sounded again [1]. Thrun et al. developed Minerva, the successor of Rhino. This robot did not have the problem that people clustered around when it wanted to pass, because it used several emotions and moods using its face and tone of voice. First, the robot asked in a happy and friendly state to get out of the way and if people did not react, the robot became angry after a while. With this behaviour Minerva was able to indicate its intentions and internal states successfully to the visitors [2]. However, the design of emotions and moods should be done carefully, as Nourbakhsh et al. found in the development of their robots. The robots Chips and Sweetlips showed moods based on their experiences that day. Visitors who only had a short interaction timeframe with the robots did not always understand these moods [4]. Touch screens and buttons have also been used for interaction purposes. These were found to make people stand closer to the robot, inviting them to interact with the buttons. This was for example found for the eleven Robox at the Expo.02 that were developed by Siegwart et al. [3]. However, buttons also can ruin the intended interaction. For example, Nourbakhsh et al. found that for the robot Sage [14] and Graf et al. for their robots in the museum of Kommunikation in Berlin (Germany) [6], people liked to push the emergency stop button and unintentionally stopped the robot from functioning.

All robots mentioned so far, had some interactive and social behaviour. However, specific guide behaviours - to engage multiple visitors and give information about exhibits - have still received little attention. To make a guided tour given by a robot a success, a smooth interaction between the robot guide and the visitors is essential, and therefore, interaction cues should be designed carefully.

Another challenge for museum robots is that they often have to interact with groups of people rather than with just one person. Research on group dynamics and behaviour of visitors gathering around a (dynamic) object in a museum setting or following a tour guide has revealed that visitors often stand in a specific formation (so-called F-formation) and react to each other and the (dynamic) exhibit (e.g. [7], [8], [15], [16]). For example, when a small group gathers around one person giving them information, they usually form a sort of (semi-) circle. In that way all group members can listen to the person who has the word [15]. Of course, the type of formation depends on the size of the group. However, the previously described formation is also recognizable when a human tour guide is guiding a (small) group of visitors and when people gather around a point of interest to all have the chance to see it [7]. When gathering around a museum object there are differences between gathering around interactive objects and static objects. When gathering around static objects, a lot of visitors get a chance to see the object at the same time. However, when gathering around interactive objects (often including a screen), fewer people can see the object at the same time [16], because people tend to stand closer to see the details shown on the screen or to directly interact with the (touch) screen. Museum exhibit designers tend to make the exhibits more interactive in order to keep the attention of the visitors, which also is effective for tour guide robots to attract visitors [4]. While these exhibits introduce more interactivity to the exhibition, it decreases the social interactions and collaborations between visitors [16]. Therefore, interactivity of robots should be designed for a larger group and other modalities than a screen/buttons should be used to shape the visitors' orientations and formations.

Our question is, can we design robots that have robot specific and intuitively understandable behaviour? To answer this question, robot designers have often resorted to directly copying human behaviour. In the design of other product categories, designers have often used anthropomorphism, (copying human forms and/or behaviour) in an abstract way rather than by directly copying. Subtly copying human forms or behaviour might likewise give cues about a product's intention and help people to understand the function of a product intuitively [17]. For robots, this implies that a robot does not have to directly resemble a human being, while it can still be capable of clearly communicating its intentions. Creating a robot with some anthropomorphic features does not necessarily mean that the robot needs to be human-like. However, to smooth the interaction human-like cues or features can be used in the design of robots [18]. Another question is, what should be designed first; the behaviour or the appearance of the robot. In most research on robots and their behaviour, the visual design for the robot was made first, and afterwards accompanying behaviour was designed. We decided to start from the other end. In this study, we used a very basic robot that showed some anthropomorphic behaviour in its body orientation. We were interested to find if and how people react to this behaviour while the appearance of the robot is far from human-like. In this way we expected to find some general guidelines for robot behaviour to influence people's reactions to the robot, while the options for the design of the robot are still multiple.

3 STUDY DESIGN

The goal of this study was to determine how orientation behaviour of a very basic robot influenced visitors' orientation and the formations groups of visitors formed around the robot. The orientation behaviour of the robot was manipulated, while other interaction features were limited. To evaluate how visitors reacted to the robot, we performed a study in the Royal Alcázar in Seville (Spain). The robot gave short tours with four stops in the Hall of Festivities of in the Royal Alcázar.

Participants

Participants of the study were visitors of the Royal Alcázar. At both entrances of the room, all visitors were informed with signs that a study was going on. By entering the room, visitors gave consent to participate in the study. It was up to them if they wanted to join the short tour given by the robot or not. Approximately 500 people (alone or in groups ranging from 2 to 7 visitors) interacted with the robot during the study.

Robot

The robot used for the field study was a four-wheeled data collection platform (see Figure 1). The body of the robot was covered with black fabric to hide the computers inside. A bumblebee stereo camera was visible at the top of the robot, as well as a Kinect below the bumblebee camera. The robot was remotely operated. The operator was present in the room, but he was not in the area where the robot gave tours. The robot was operated using a laptop. The laptop screen was used to check the status of the robot, while the keyboard was used to actually steer the robot. The interaction modalities of the robot were limited; the robot was able to drive through the hall, change its orientation and play pre-recorded utterances. The instruction "follow me" was visible on the front of the robot, and signs informing people about the research (in English and Spanish) were fixed to the sides of the robot.

The robot used for this study was very basic. We chose this particular robot to be able to determine the effects of body orientation on visitors' reactions without being influenced by other factors in robot design and behaviour (such as aesthetics of the robot, pointing mechanisms, visualisations on a (touch-) screen or active face modifications).

During the study we used a user-centred iterative design approach [19] for the behaviour of the robot. When the robot charged in between sessions, we discussed robot behaviours that had the intended effect and behaviours that did not work well. During the study we modified the explanation of the robot after session one, because it became clear that visitors did not understand where to look. A total of three iterations were performed. In all iterations only changes to the explanation of the robot were made, however the content about the points of interest remained the same.

Procedure

The tour given by the robot took about 3 minutes and 10 seconds. The points of interest chosen were all visible on the walls of the room (no exhibits were placed anywhere in the room), however the position of the points of interest on the walls differed in height. During a tour the distance to drive in between the points of interest also differed, from approximately two meters up to approximately five meters. This was done so we could see if there were different visitor behaviours when following the robot. However in this paper we will not focus on the results on following the robot.

When visitors entered in the Hall of Festivities, the robot stood at the starting place (1) (see Figure 2) and began the tour by welcoming the visitors and giving some general information about the room. When the robot finished this explanation, it drove to the next stop (about 3.5 meters away), asking the visitors to follow. At the next stop (2) the robot told the visitors about the design of the figures on the wall that were all made with tiles, after which it drove the short distance (about 2 meters) to the next exhibit. At the third stop (3) the robot told the visitors about the banner that hung high above an open door. At the end of this story the robot asked the visitors to follow after which it drove the long distance to the last stop (about 5 meters). Here (at point 4) it gave information about the faces visible on the tiles on the wall. Before ending the tour the robot drove back to the starting point (about 3.5 meters), informed the visitors the tour had finished and wished them a nice day.

After a while, when new visitors had entered the room, the robot started the tour again. During the study the robot tried to persuade visitors to follow it with the sentences "please follow me" and "don't be afraid", when visitors were hesitant. In all cases it was up to the visitors to decide whether they followed the robot or not. Visitors were never instructed to follow the robot by researchers present in the room.

As the study was performed in a real life setting, with uninformed naïve visitors, we sometimes had to deviate a bit from the procedure. The robot had defined places for stops. However, sometimes the robot had to stop close to the defined place, because people walked or stood in front of the robot.

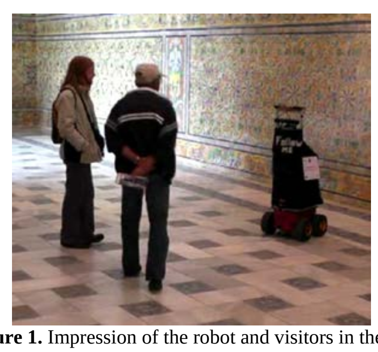

Figure 1. Impression of the robot and visitors in the site

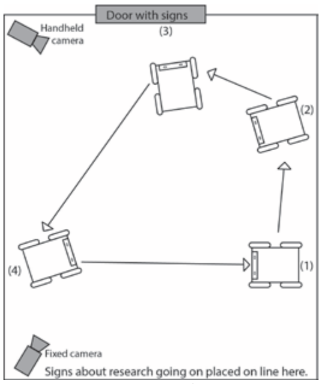

Figure 2. Layout of the tour

Another reason to deviate was when the robot lost the attention of all people who were following the tour. Then, it drove back to the starting place and started over again. If some visitors lost interest and left, but other visitors remained listening to the robot, it continued the tour.

When all visitors left the hall, or did not show any attention towards the robot, the trail was aborted, and restarted when new visitors entered the hall. Therefore the number of times the robot was presenting at each of the four exhibits was decreasing. The robot started the tour 87 times at the first exhibit, continued 70 times at the second exhibit. At the third exhibit the robot started its presentation 63 times and it finished the story only 58 times at the fourth exhibit. A total of 278 complete explanations at points of interest were performed (see table 1 for a specification of the actions per point of interest).

Manipulations

During the study, we manipulated the robot's orientation behaviour. Either the robot was orientated towards the point of interest or the robot was orientated towards the visitors. When it was orientated towards the point of interest, the front of the robot was in the direction of the point of interest. The points of interest were all located a few meters apart from each other. When the robot was oriented towards the visitors, its front was directed towards a single visitor or towards the middle of the group of visitors. See table 1 for a specification of the orientation of the robot per iteration and per point of interest.

In between the three iterations, some changes were made to the explanation by the robot. The explanations for the robot were developed in such a way that they could be used for both orientations of the robot. During the first iteration we observed that these explanation worked fine when the robot was oriented towards the points of interest. However, we found that it seemed unclear where to look when the robot was oriented towards the visitors. Therefore, for the second iteration, the explanations of the robot when oriented towards the visitors at points of interest two, three and four were modified. Information about where visitors had to look exactly to find the point of interest the robot explained about was added. As a result, the robot explained more clearly to the visitors "to look behind it" when it was orientated to the visitors and "to look here" when it was oriented towards the point of interest. Also, the sentences "please follow me" and "don't be afraid" were added to try to convince people to follow the robot to the next point.

Table 1: **Specification of manipulations**

	Robot actions	Point 1	Point 2	Point 3	Point 4
Iteration 1	**109**	**38**	**26**	**23**	**22**
To exhibit	*66*	*4*	*23*	*20*	*19*
To people	*27*	*27*	*0*	*0*	*0*
Excluded	*16*	*7*	*3*	*3*	*3*
Iteration 2	**90**	**25**	**24**	**22**	**19**
To exhibit	*42*	*0*	*10*	*17*	*15*
To people	*35*	*20*	*11*	*0*	*4*
Excluded	*13*	*5*	*3*	*5*	*0*
Iteration 3	**79**	**24**	**20**	**18**	**17**
To exhibit	*1*	*0*	*0*	*1*	*0*
To people	*65*	*16*	*18*	*16*	*15*
Excluded	*13*	*8*	*2*	*1*	*2*
Total	**278**	**87**	**70**	**63**	**58**
To exhibit	*109*	*4*	*33*	*38*	*34*
To people	*127*	*63*	*29*	*16*	*19*
Excluded	*42*	*20*	*8*	*9*	*5*

In the third iteration another modification was made to the explanation of the robot when it was oriented towards the visitors. The sentences were ordered in such a way that the robot would capture the attention of the visitors with something trivial, so people would not miss important parts of the explanations. All iterative sessions took about 1 hour and 40 minutes.

Data collection

During the study, the visitors were recorded with two cameras: a fixed camera that recorded the whole tour and a handheld camera that was used to record the facial expressions of the visitors close to the robot. Also, several visitors who followed (a part of) the tour were interviewed about their experiences. The interviews were sound recorded.

For this study only the data collected with the fixed camera was used, because the data from this camera gave a good overview of the room and the actions, orientation and formations of the visitors. We decided to not to use recordings from the cameras that were fixed on the robot, because their angle of view was limited to only the front of the robot. Using these recordings would not give us opportunities to study the behaviour of visitors who were next to or behind the robot (for example when the robot was oriented towards the exhibit), which in this study would lead to the loss of a lot of information on visitor orientation and formations. The proximity of the visitors was measured based on the number of tiles they stood away from the robot. Data collected through the short interviews was also not used in this analysis, because in this case we were only interested in how robot orientation influenced the actual orientation of visitors and their formations and less in their experience with the robot.

Data analysis

For the analysis, 236 robot actions of a total of 278 robot actions were used. Forty-two cases were excluded from analysis because no visitors were in the room or no robot was visible, because it was out of the angle of view of the camera, or the view was blocked by large numbers of visitors (for example a group with a human tour guide that did not show any interest in the robot). This resulted in 236 robot actions (278-42=236) in 3 iterations that were left for the analysis. The robot was oriented towards the exhibit while it explained 127 times, and the robot was oriented towards the visitors while it presented 109 times.

We were interested in the reactions of the visitors that might be influenced by the robot orientation during each if these 278 complete explanations at the points of interest. However, exact visitor behaviour to search for was not defined before the study. We performed a content analysis of the recordings from the fixed camera. We isolated robot actions -the moments that the robot stood close to a point of interest and presented about it- in the data for coding purposes. Coding of the data was done by using a Grounded Theory Method [20] and use of an affinity diagram [21] for the open coding stage. No exact codes were defined before the start of the analysis. We defined the codes based on the actions of the visitors found in the video recordings. Some examples of found codes are: “standing very close to the robot and oriented towards each other,” “visitors standing in a semi-circle and robot oriented towards the exhibit,” “visitors losing interest during the robot story and robot oriented towards the visitors,” “visitors walking towards the robot and robot oriented towards exhibit.” We used a count method to compare the reactions of the visitors during the robot actions between the different robot orientations and the different points of interest.

10 % of the data was double coded and we found an overall inter-rater reliability of a=0.662 (Cohen’s Kappa), which indicates a substantial agreement between the coders. Hence, one coder finished the coding of the dataset that was used for analysis.

4 RESULTS

We found that visitors stood far away more often when the robot was oriented towards the visitors (31 times, 24.4% of all cases in this condition) than when the robot was oriented towards the point of interest (17 times, 15.6% of all cases in this condition). Further, no differences were found in formations of the visitors between both conditions. However, when the robot was oriented towards the visitors, just 18 times (14.2% of all cases in this condition) visitors walked towards the robot, while when the robot was oriented towards the point of interest visitors walked towards the robot 25 times (22.9 % of all cases in this condition). In both conditions and at all stops, a lot of people (78% of all cases) were just walking by, showing no attention for the robot at all. However, most of the time one or a few visitors had already joined the robot by then. A few times we observed that visitors waited until the robot was free again and then followed the tour. Also, when some of the visitors left the robot, others stayed to hear the rest of the explanation about the point of interest.

We found more differences between visitor formations when we focussed our analysis on the interactions in stops two, three and four, while excluding stop one. We decided to exclude stop one from our analysis, because at that stop the robot was always oriented towards the visitors and it was not explaining about a specific point in the room. We found that when the robot provided information about points of interest two, three and four, more people lost interest when the robot was oriented towards the point of interest (22 times, 21% of all cases in this condition) than when the robot was oriented towards the visitors (8 times, 12.5 % of all cases in this condition). Also, 6 times (9.4 % of all cases in this condition) visitors did not have a clue where to look when oriented towards the visitors. This was never the case (0% of all cases in this condition) when the robot was oriented towards the point of interest.

The number of visitors standing close to the robot was comparable between both conditions (5 times, 3.9% of all cases with orientation towards the visitors and 6 times, 5.5% of all cases with orientation towards the exhibit). However a difference was found between the exhibits. Only at stops one and two, did visitors stand really close to the robot when the robot was oriented towards the visitors. However, in the condition where the robot was oriented towards the point of interest people stood close to the robot at all stops. From reviewing the video, we observed that when people stood very close to the robot and the robot was oriented towards them, visitors only seemed to focus on the robot, while visitors focussed on the point of interest when the robot was oriented towards the point of interest.

Also we found some differences in visitor reactions between the different stops. Fewest visitors walked towards the robot at stop three (5 times; 9.3% of the cases in this condition), most did at stop four (16 times, 30.2% of the cases in this condition). Visitors lost interest in the story and the robot most often at stop three (14 times; 25.9% of all cases in this condition) and least often in stop four (6 times; 11.3% of all cases in this condition).

Looking only at the differences between the stops over both conditions, we found that many more single visitors and pairs joined the robot for at least one stop (86 times, 36.4% of all cases) than that people gathered around the robot in any group formation (38 times, 16.1% of all cases). We found that during 11 robot actions (4.7% of all cases) visitors stood less than 30 cm away from the robot. During 48 robot actions (20.3% of all cases) people stood more than 3 meters away from the robot. In 131 robot actions (55.5% of all cases) visitors stood between the 30 cm and 3 meters from the robot. Note that these cases can overlap, because there could be more than one visitor at the same time. In the rest of the cases no visitors or no robot were in the field of view or the visitors did not join the robot tour.

5 DISCUSSION

Influences of robot orientation

We found that visitors stood far away from the robot more often when the robot was oriented towards the visitors than when it was oriented towards the point of interest. Furthermore, we found that visitors tended to walk towards the robot more often when the robot was oriented towards the point of interest than when the robot was oriented towards the visitors. One possible explanation for this visitor reaction might be that visitors could not hear the robot well enough. However, we do not consider this a valid explanation in all cases, since people generally in both conditions followed the robot from a distance and they were able to hear the explanations of the robot. Therefore, we argue that it might be that the visitors felt that a distance was created by this specific orientation of the robot. This may have caused that people felt safer to approach the robot when it was oriented towards the point of interest. Perhaps, the robot kept people at a distance with its “eyes” when it was oriented towards the visitors. This finding is in line with findings from other studies that people walked closer to a robot that was not following them with gaze than when the robot was following them with gaze, as shown by Mumm and Mutlu [22]. Remarkable was that more people lost interest when the robot was oriented towards the point of interest than when the robot was oriented towards the visitors. As we argued before, the orientation of the robot towards the point of interest might have felt safer for people, at the same time, it might also have given them the feeling of being excluded, which made them leave the robot.

In stops one and two, several people were walking towards the robot, because the robot captured their attention and they were curious to see what it was for. Fewest visitors walked towards the robot at stop three, most did at stop four. Visitors probably did not have to walk to the robot in stop three, because it was really close to stop two. From stop three to stop four was the longest walk. Visitors who walked towards the robot in stop four were probably a bit reserved following the robot and therefore just walked to the robot when it had already started the next explanation. Apart from that, stop three was close to an open door, the entrance to the next room, therefore people who lost interest could easily walk away from the robot into the next room. When visitors followed to stop four, the last stop of the tour, they were likely to follow the robot the whole tour. We assume these visitors liked to hear the explanations of the robot and stayed with the robot until the final explanation, therefore fewer of them left the robot in stop four.

Visitor actions that were coded with “losing interest” showed that most of the time not all visitors lost their interest at the same moment. When one visitor of a pair or group walked away, the other(s) either followed the leaving person directly, stayed until the end of the explanation at that point or stayed until the end of the tour. This indicates that visitors of pairs or groups gave each other the time to do what they liked and that they did not have to leave together at the same moment. An advantage was that for most people it was clear that the robot just gave a short tour, so the people who left did not have to wait for a long time if the others stayed. In some cases we observed visitors discussing if they would follow the robot and in the end they decided that one would follow the tour, and that the other would wait outside the research area. It was important for the robot that when one visitor lost interest, most of the time the robot had other visitors (either close or far) who were still interested in the robot and the story, so it went on with the story.

We found a difference in the distance people kept from the robot and the orientation of the robot. Only at stops one and two, did visitors stand really close to the robot when the robot was oriented towards the visitors. However, when the robot was oriented towards the point of interest, visitors stood very close in all four stops. It seemed that when visitors stood very close to the robot and the robot was oriented towards them, visitors only had interest in the robot as an object and they tried to make contact with the robot (by waving at the robot or bringing their eyes on the same height as the lenses of the camera of the robot). We think this visitor behaviour mainly occurred at points one and two, because at these moments the robot captured people’s attention. In stop three and four only visitors who were already following the tour seemed to be present and people who were only interested in the robot as an object did not disturb the robot guide and its visitors in these points. When visitors stood close and the robot was oriented towards the point of interest, the visitors probably could not hear the voice of the robot well enough to follow the story in the crowded area, while they were interested in the point of interest the robot presented about and wanted to hear the explanation.

Visitors who were interacting with the robot oriented towards them, sometimes appeared to have no clue where to look. This indicates that visitors were sensitive for the orientation of the robot. More verbal cues were added to the explanation of the robot in iterations 2 and 3. However, during these iterations, we still observed that when the robot was oriented towards them visitors got the clue where to look later than they expected. So, even though we changed the explanation of the robot to make more clear where to look and started with something trivial, just as human tour guides do [23], visitors did not readily understand where to look. This might be due to the length of the explanations of the robot. These were much shorter than explanations given by a human tour guide at a point of interest usually are. So, in general visitors had less time to focus again before they would miss something. The robot orientation towards the point of interest avoided this problem.

Visitor reactions to the “eyes” of the robot

Our observations showed that visitors were aware of the lenses of the camera on the robot and responded to them as if they were the eyes of the robot. This can for example be seen from the observation that some visitors waved at the camera when they arrived or when they left the robot. People also stood in front of the camera when they wanted to make contact with the robot. The observation that people are sensitive to the camera of a robot and orient in front of it was also made by Walters et al. [24]. These examples make clear that visitors react to the orientation of the robot and probably see the lenses of the camera as the eyes of the robot. Another observation that strengthens these conclusions is that visitors most often lost their interest in stop three. In this stop the explanation was difficult to understand because the story was about a banner that hung high in the room, above an open door. When the robot was oriented towards the exhibit, it seemed as if it was “looking” at a point in the other room because it was not able to tilt its orientation upwards. This confused the visitors, even when the robot was clear in its explanation about where to look.

Differences between robot guide and human tour guide

We found that visitors reacted differently to the robot tour guide than we would expect from observed reactions to a human tour guide. First of all fewer groups and more individual visitors or pairs of visitors joined the robot tour guide. Also, visitors seemed not prone to join strangers, but rather waited till the tour was finished and they could join a new tour.

Most visitors stood between 30 cm and 3 meters from the robot. When there were visitors standing very close or far away from the robot, there also could be visitors who stood at average distance (between 30 cm and 3 m) from the robot. While most visitors stood at an average distance, standing really close or staying at a distance differs from visitor behaviour shown when they follow a human tour guide. Most of the time visitors of a group of a human tour guide does not show that large difference in proxemics to a guide and often stand in a semi-circle to give everyone a chance to see the guide [7]. Also, Walters et al. [25] and Joosse et al. [26] showed in controlled experiments that people allowed different approach distances and appropriate proxemics for a robot than they allow for confederates. This leads to the conclusion that we cannot assume that people react the same to robot tour guides as to human tour guides.

Implications of study set-up

The study was performed in the wild which influenced the execution of the study and the manner of analysis. One disadvantage was that the situations of guiding could not be controlled. Also, less information of the visitors could be obtained. For example, we could not have extended questionnaires because people did not want to spend their time to filling these in.

We performed the study in several iterations in which we modified the explanation of the robot. Without these modifications to the explanations, we would not have been able to perform the manipulation of the orientation of the robot, because with the original explanation visitors did not seem to know where to find the point of interest when the robot was oriented towards them. This led to the following differences between the iterations. In iteration one the robot was mainly oriented towards the point of interest. In iteration two the modification of the explanation seemed insufficient, so the robot was mainly oriented towards the points of interest. In iteration three the robot was mainly oriented towards the visitors.

An advantage of the in-the-wild set-up of this study was that we observed the reactions of the visitors the way they would probably be if an autonomous tour guide robot were to be installed in the Royal Alcázar. The findings of this research were an important step for the development of FROG, because with in-the-lab studies with small groups of users, it would be difficult to create a similar environment including people who are acquaintances and strangers. Probably, we would also not have found how people react when the robot is already occupied by strangers, while in this set-up we did find interesting reactions of visitors in the real-world context.

Also, we used a very basic robot with limited interaction modalities. Nevertheless, the influence of body orientation and was largely observable in the visitor reactions. We expect that these factors will keep influencing visitor reactions when more robot modalities (such as arms to point, or a screen to show information) are added to the robot.

6 DESIGN IMPLICATIONS FOR ROBOT BEHAVIOUR

Findings described in the previous section led to the following set of design guidelines for the design of the non-verbal behaviour of a tour guide robot, that can be used irrespective of the visual design of the robot.

1) *Check for visitors standing far away when people close-by leave the robot during the explanation.*

The robot did not only catch the attention of people who were standing close such as we would expect with human tour guides. Visitors who chose to stay at a distance also followed the robot tour. Although these visitors were interested in the story and the robot, they did not want to be close. The tour guide robot should therefore not only focus on visitors nearby, but scan the surrounding once in a while and go on with the story or tour if it detects visitors who are not standing close, but show an orientation towards the robot and stay there during explanation. This behaviour of scanning the environment is even more important when visitors who are standing close all leave. Also, the robot should not rely solely on its detection of visitors by gaze (cameras directed to the front-side of the robot) to determine whether it should go on or stop the explanations, because in some situations the visitors tend to stand next to or behind the robot, while they are still interested in its story. The robot should be aware of these visitors and continue the explanation at the exhibit.

2) *Define behaviour of people standing close-by to decide whether to stop or to continue the story.*

For visitors who are standing close, the robot should make a distinction between people standing very close that are following the tour and people standing very close that show interest in the robot only. When people are still following the story, the robot should go on giving information. However, when people only show interest in the robot, the robot can decide to play with them a bit and show it is aware of the visitors being there. Possibly the robot can catch their attention for the story and change the playful or disturbing interaction to a guide-visitors interaction.

3) *Ask people to join the tour when they are hesitant to join strangers.*

The robot mainly attracted individuals and pairs who did not join other people who had started following the tour before them. People preferred to wait until others had left before they decided to join the tour. In other cases they just followed the tour from a distance, when other people were already close. This fits the purpose of the robot, however it would be nice if the small groups joined in order to all have an even better experience of the robot, because the robot cannot focus on all visitors close-by and far away. To do so, the robot can at certain moments in the story decide to scan for visitors and invite them to join.

4) *When camera lenses are clearly visible in the design of the robot, use them as eyes*

In our field study, a stereo bumblebee camera and a Kinect were clearly visible on the robot. Our experience in this study taught us that visitors see the stereo camera on top of the robot as the eyes of the robot. Therefore, when the camera cannot be hidden, the camera should be designed as eyes, including the design of gaze cues and gaze direction. Using these cues, especially when people expect them already, will probably smoothen the human-robot interaction. In our case, the FROG robot is not a humanoid robot, while the camera is visible. Therefore, we argue that a visible camera should be used as eyes of a robot, because this will support the mental model users will create of the robot.

7 CONCLUSION AND FUTURE WORK

To conclude, the orientation of the robot is important to shape the visitors' reactions. When it was clear to the visitors what to look at (mostly when the robot was oriented towards the exhibit), they became engaged more easily in the robot guided tour. However more people became interested in the robot when it was oriented towards the exhibit. Also, more people lost interest in the robot and the story when it was oriented towards the exhibit than when it was oriented towards the visitors. Therefore, keeping the attention should be done in a different way than capturing the attention of the visitors.

With this research we focused on visitors' orientation and group formations that visitors formed around the tour guide robot. However, in order to design robot behaviours for giving an effective tour, visitors' reactions when the robot is guiding them from one point of interest to the next should also be analysed, and guidelines about how to shape these should be developed. We will further use the recording from this study to analyse the visitor reactions to the robot guiding behaviour (e.g. following the robot from a distance or really close to the robot, hesitating to follow the robot) as well as visitor reaction at stops at points of interest while following the robot.

The present study has given us insight into how robot orientation and behaviour can influence people's formations and reactions. A future research question, is to find how the combined effects of robot behaviour and visual design of a robot will influence the number of people who stop to see the robot and eventually join the robot guided tour. In the future we will perform more elaborate evaluations including more robot modalities and behaviours.

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