FROG - Fun Robotic Outdoor Guide

Deliverable: **D4.1 part c**

Identification, evaluation and design of guide robot personality and behaviors: Design Guidelines for Effective Robot Guide Behavior

Consortium

UNIVERSITEIT VAN AMSTERDAM (UVA)

YDREAMS - INFORMATICA S.A. (YD)

IDMIND - ENGENHARIA DE SISTEMAS LDA (IDM)

UNIVERSIDAD PABLO DE OLAVIDE (UPO)

IMPERIAL COLLEGE OF SCIENCE, TECHNOLOGY AND MEDICINE (ICL)

UNIVERSITEIT TWENTE (UT)

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Authors:	D.E. Karreman, E.M.A.G. van Dijk, V. Evers (UT)
Reviewers:	G. Ludden (Industrial Design, University of Twente), expert in "multisensory design and product experience"
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D4.1 c: Design guidelines for effective robot behavior

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1. SUMMARY

Guidelines for robot behavior were developed based on the behavior and strategies of human tour guides (see D4.1b). These behaviors are transformations, reductions and abstractions of the behavior of human tour guides. As the robot is not human-like, and will carry devices such as a screen and a projector, effective human tour guide behavior cannot just be copied, because the robot has different means of communication. Therefore, specific robot behaviors need to be designed. It is very important not only to understand human tour guides' behaviors, but also the interactional outcomes of their behaviors. The interactional outcomes of the robot behavior should increase the visitor engagement and visitor experience just as human tour guides aim to do.

Several studies were performed to come to a set of design guidelines for robot effective guide behavior. For all studies performed we used different, very basic robots. None of the robots had arms and all had digital eyes or camera lenses as eyes at the top. From a controlled experiment on robot expressive gaze behavior we found that people liked human-like gaze behavior and expressions of the robot, but that the human-like movements of the robot distracted the visitors. Therefore, a more static robot with a pointing device will be used in future studies.

Visitors of the Royal Alcázar reacted strongly to the lenses of a stereo camera at the top of the robot. They treated them as if they were the eyes of the robot; therefore we propose to use and design the lenses as the eyes of the robot and also to add communication cues that people expect from the eyes of the robot.

In a controlled setting we found that visitors liked to be approached by the robot within their field of view. Also, the robot should not lock them in. In a semi-public space the robot should always approach the closest visitor within their field of view. When this is not possible, because visitors are standing in a circle-formation, the robot should wait.

Surprisingly, we found in a real-life setting that visitors were not always orienting around the robot, which was influenced by the pose and orientation of the robot. Sometimes people oriented themselves in a semi-circle around the robot. However, we also observed people standing very close or staying far away. While standing very close, the robot should recognize if the visitors are still interested in the story (then go on with the story), or if they are only interested in the robot (then try to divert the interaction to a visitor-guide interaction). Also, when all visitors nearby the robot leave, the robot should first scan the environment to see whether there are visitors standing further away that are still engaged in the story. Only if there are none should the robot stop explaining.

The proposed behaviors will influence work of the partners involved in the navigation and localization of the robot, the content of the robot, and the engagement of visitors. In a visual and a schematic approach the specific behaviors of the robot at specific moments are described, based on the guide scenario for the FROG robot.

Design guidelines for effective robot behavior

2. Introduction

In this deliverable, we will describe several studies that were performed to define a set of design guidelines for the guide behavior of the FROG robot, such as movement, pose and expression. The robot to be developed for the FROG project will not be a human-like robot, but might have some anthropomorphic aspects (in appearance as well as in behavior) to make the interaction between human and robot intuitively understandable for visitors. The tours given by the FROG robot will be short and in predefined sections of the tourist site only, so visitors will still get a chance to explore the site on their own as well. The robot will not have arms (due to safety issues) and will have a height of 1.20-1.50 meters. The robot will have four wheels and will navigate autonomously through the tourist sites. For communicative abilities of the FROG robot the focus is on non-verbal behaviors, communication cues and expressions. The robot will not be able to interact with visitors by natural speech. Instead, a screen at the front will enable the visitors to interact with the robot. The robot will be able to 'see' the visitors and their poses, facial expressions, gestures and movements. People also use several means to communicate, such as speech, gestures, facial expressions, so, for the robot, using several (redundant) means might be useful too. A screen and recognition of gestures and facial expressions are just two options to interact. Further research should point out which communication means should be implemented.

To be able to function as a tour guide the robot needs to show some social skills and intuitively understandable behavior, as well as fun and engaging behavior and personality. The robot will not replace human tour guides; instead, it will offer short novel interactive experiences for small groups that are exploring the site by themselves. We have good indications that robot tour guide behavior should be different from human tour guide behavior. First, because of the differences in appearance between robots and people. The robot will not point, but will use a screen to show pictures or videos, and it will use a projector to project pictures or videos on the wall. These devices (projector and screen) can make the robot tour more lively and interesting to join. But also, it forces a design of the robot that differs from the human body. Furthermore, the robot will have visible camera lenses at or near the top. Based on future studies and previous research on human robot interaction, other modalities for interaction might be added.

It is important that robot behavior, personality and appearance match (Duffy 2003). The robot can have the perfect nice and gentle behavior, but if the shell of the robot looks aggressive, many people may judge from the shell that the robot will not be nice to interact with in the first place. For the design of the robot behavior, we argue that iterative design and continuous user testing will help find the best solutions. The human form or human behavioral patterns can be a starting point in designing robot behaviors, however we argue that the (intended) effects and outcomes of the human behavior should be studied and, consequently, robot behavior should be carefully designed to evoke the desired communication goals in human-robot interaction.

Previous research already indicates that people react differently to robots than to human interlocutors. For example, people accept robots to come closer than they would allow a person when they are focused on something in the room (Sardar et al. 2012). Also, a robot will probably not have the same modalities as people to communicate, which means that a person needs to adjust the 'form' of communication when interacting with a robot, and people have the ability to do so (Weiss et al. 2010). Last, people intuitively guess that the robot can interact with one user at a time, therefore, when in groups, people take turns in interacting with the robot (Sabanovic, Michalowski, and Simmons 2006).

As we argued before, it is not useful to just copy human tour guide behavior to a robotic tour guide; however, human behavior can be a source of inspiration for the design of robot behavior. In this deliverable, we will first give the design guidelines that were derived from the observation of human tour guides. Next, these guidelines were implemented in a robot and evaluated in controlled lab settings and real life settings. The studies performed will be described and design new guidelines will be given that can be used when designing behavior for tour guide robots. Finally, we will discuss how these design guidelines affect the work of the other project partners in the FROG project.

In section 3, the guidelines for robot behavior based on the observations of human tour guide behavior will be given (the extended description of effective human tour guide behavior can be found in D4.1b). Section 4 will be about a study on gaze behavior and expression of a tour guide robot, and guidelines for robot gaze behavior will be given. In section 5 a quasi-experiment will be described and the effects of a robot approaching a pair of people will be described. The previously found guidelines were used for a study with a basic robot to guide visitors through a hall in the Royal Alcázar. This study yielded some surprising results, which will be described in section 6. In section 7 we will describe the guidelines collected in a bullet list, to give a simple and quick overview that can be used when designing robot behavior. In section 8 we will describe how these guidelines affect the work of other partners in the project. Also, a detailed scenario for robot guide behavior in touristic sites will be given. Conclusions and directions for future work will be given in section 9. Studies that were published in conference proceedings or submitted and presented at workshops are marked as such throughout this document. Parts of the content of the papers were copied into this deliverable, to give a clear overview of the work done.

3. Human Tour Guide Behavior

In Deliverable 4.1b the effective behaviors of human tour guides were described. In this section, the observed effective guide behaviors shown by human tour guides are the start for the development of robot tour guide behavior. The behaviors of human tour guides will be examined and abstracted, reduced or transformed to come to guidelines for specific robot guide behavior. As described in D4.1b, the human tour guides followed in the tourist sites (2x at the Lisbon city Zoo, Lisbon, Portugal and 2x at the Royal Alcázar, Seville, Spain), were people with different personalities, however, they showed similar behavior for obtaining and keeping the visitors' attention. These behaviors can be split into explicit behavior (strategies), that guides use consciously, and implicit behavior, that influence the interaction, but that the guides use unconsciously.

Implicit and explicit behaviors of human tour guides partly overlap and influence each other. It is important to study these behaviors for developing guidelines on how a robotic guide can engage visitors. The strategies a human tour guide uses can serve as inspiration for the behavior of the robot. The strong cues in human-human interaction have to be transformed, reduced or abstracted to fit the robot appearance and personality. So, strategies human tour guide use might not have to be copied one-on-one to the robot. However, the results in visitor behavior and visitor experience should be comparable (or improved). The behavior that the guides show subconsciously can inspire the design of robot intuitive tour guide behavior. The robot is a machine; therefore, mainly the interactional outcomes will inspire the behavior that will be specific for the robot. The main areas to focus on for the robot specific guide behavior are described below. All proposed robot behaviors are non-verbal, and all are meant to support the story or to make interaction patterns clear and easy to understand for visitors. The behaviors presented below will be tested with a robot and visitors to verify whether they have functional interactional outcomes.

For a detailed description of the research done on human tour guide behavior, please see Deliverable 4.1 b.

GUIDELINES:

INTERACTION

When human tour guides guide visitors, they try to encourage the visitors to interact with them, they use speech to do so. For the FROG robot this will be more difficult, because the robot will not use natural speech. However, the robot will have other means to initiate interaction, such as a screen and projections on the wall or on the floor. Also, the robot will recognize groups of visitors, their facial expressions and the gestures they make, which can be used as input to start human-robot interaction. This means that the interaction between person and robot will become different from that between two people. A specific human-robot interaction will be formed, in which all means of the robot should be used to establish interaction.

DIFFERENCES IN TOURS

Human tour guides constantly adapt their tours. As the robot will be able to recognize facial expressions of close visitors, the robot can use these expressions to examine the visitors' interest and adapt the content of the tour to the interest level of the visitors; for example, by enhancing or shortening the information at an exhibit based on that information.

For children, listening to a guide can become boring; human tour guides have strategies to keep their attention. The robot should be careful when guiding groups with children, it could give less scientific information, use analogies to explain difficult concepts and propose games to keep their attention. The games human tour guides use can also be used by the robots (for example: jump like a kangaroo). Human tour guides can react very flexible to the reactions of the visitors, while the robot will be more static. However, if the robot has enough different preprogrammed options to react to visitors, the visitors will not recognize this during the short interactions of a tour.

INFORMATION

The robot should have several levels of information. On a basic level, the robot will give the main information to understand what is visible in the exhibit. However, when visitors want to know more the robot should have deeper levels of information to inform visitors more fully. Also, a distinction between the subjects of the explanation can be made. For example, when visitors like historic information more than architectural information, the robot should go into more depth on the history. This means that, except for in-depth levels, the levels should cover broad areas of information. Furthermore, curiosities should always be part of the story.

Human tour guides sometimes used visuals to clarify the story; the robot can use many more visuals to make history or animal care much more vivid. As the robot can show pictures, movies, augmented reality visuals, or projections on the wall or on the floor to show how some of the zoo animals live in the wild and how things were at the Royal Alcázar in time gone by.

STARTING AND ENDING THE STORY

The performance of the guiding task will differ between the human tour guide and the robot. For example, a human tour guide starts talking at an exhibit with some words or sentences that are not important for the story, just to get the attention of the visitors. The robot is not able to use natural speech, therefore it needs to obtain the visitor attention in another, robot specific way. This can be done, for example, by making some noise, flashing a light or making some movements to ask for attention again. Alternatively, the robot can ask visitors to press a button when they are ready for the next part of the story. However, the robot can also just start (like human tour guides do) and assume all visitors are there and ready to listen. In any case, the pre-recorded animation should always start with trivial information, so visitors are triggered to focus on the robot again. Human tour guides often start with a louder voice when they start with something important. The robot will have one sound level to explain with, and the groups the robot will guide should be small, so the robot can assume that if one or two people of the group are close, the rest is also close or not interested anymore. The options described for robot behavior at the start of an exhibit clearly indicate that the behavior of the robot cannot be directly copied from the human tour guide, because its means of communication means are different.

While moving, the robot has to be slightly in front of the group, because then the robot can guide the visitors, check if the exhibit is free and keep pace in the tour, just as human tour guides do. When the robot is going from exhibit to exhibit, it should give feedback on the task it is performing, because otherwise visitors cannot be sure what the robot is doing and whether or not it is still carrying out the task (Norman 1990), in this case guiding. The feedback can be given by projecting an arrow on the ground while driving, making a sound, using a pointer in the drive direction or using light cues. In previous research with the Rackham robotic guide, Clodic et al. found that showing the visitors on the screen what the robot saw was important feedback, especially while driving to the next exhibit, because visitors were able to see that the robot was still aware of them (Clodic et al. 2006). So, the robot should give both feedback on performing the task and feedback on being aware of the visitors.

When the robot stops at an exhibit, the feedback (of performing the task and being aware of the visitors) should change, but not stop. At the exhibit the robot should turn the screen towards the visitors. To indicate that the robot is stopping at the area of the exhibit, the previously proposed driving feedback should change. Visitors will then recognize the robot has arrived at the right spot and will wait until it has turned the screen towards them. The eyes of the robot could look briefly at all people, indicating that the robot notices they are there. At the end of a story at the exhibit the robot can break "eye-contact," and during the last sentence the robot should already indicate the direction to the next exhibit. When the robot finishes the explanation, it is ready to start driving, so, the feedback that indicates guiding should turn on and the robot can go to the next exhibit.

The study described in section 6 will give more details on guidelines for robot behavior at the start and at the end of the story at an exhibit.

Gaze behavior

Gaze is the main non-verbal feature human tour guides use. Human tour guides use gaze to look at the visitors to get feedback about their engagement, to make eye-contact with them, to look at the exhibit and make the visitors look at the exhibit as well (Best 2012) and to express their own intentions and feelings. The guides also give lots of communication cues with their eye-gaze only, such as breaking eye-contact when the explanation at an exhibit is finished.

In general, people give a lot of non-verbal information and these cues can be imitated by robots (Mutlu et al. 2009). From Mutlu et al. we know that listeners that the robot looked at had a better recall of the story (Mutlu, Forlizzi, and Hodgins 2006), therefore making eye-contact with the visitors is likely to increase their recall of the knowledge transferred. Also, gaze can have the function of pointing. People start to look at the exhibit when the guide looks towards the point of interest (Best 2012). A robot with eyes that start to look at the point of interest, which people will recognize from human-human interaction, can also prompt visitors to look at the point of interest.

The robot will have cameras to detect the visitors far off and the facial expressions of visitors close by. This camera will be visible for the visitors, which will give the visitors the feeling that the robot looks at them. Apart from detecting the visitors, the cameras can also be used to communicate gaze cues, such as gaze at them and alternate gaze between them. The robot will not have eyes that can convey as much information as human eyes do, but for the robot the effect of eyes can be mimicked. The robot will have eyes that can be pointed towards the visitors or at the point of interest. However, the cameras are in use for detecting the visitors' attention, and there is no use to focus on the point of interest. So, non-functional eyes next to the camera lenses, just to enhance the intuitive interaction, can be used to create the feeling of eye-contact with the visitors, alternating gaze between them, looking at the visitor that is talking, or looking at the exhibit to create mutual gaze.

Further research should point out which kind of gaze or combination of gaze-functions can be best used for the robot. The studies in section 4 and 6 describe more about preferred robot gaze behavior and will provide more detailed guidelines on development of robot gaze.

Gestures and movements

People make many gestures during speech. All human tour guides made hand gestures during their talks. The function of depicting and pointing is easy to understand: these are to give meaning to the story. For the robot without arms, showing pictures on a screen or a projection on the ground or the wall when the guide would depict something will help visitors understand the robot's story. Depicting can be done by showing pictures, movies, but also, single words or important numbers that help visitors understand or remember the story can be shown. Pointing will be of importance for the robot as well. The robot can point using a pointing device such as a laser or a spot light, arrows on the screen pointing in the direction the visitors should look, a picture of the point of interest on the screen with an indication where to look exactly, or a projection on the wall that can show arrows to the right point or the point of interest itself.

All tour guides also make a lot of supporting gestures. These gestures do help them with telling the story, and having listeners does influence the number of gestures made which suggests that these gestures are communicative too (Alibali, Heath, and Myers 2001). To engage visitors with the FROG robot it can be helpful to use these supporting gestures, so the visitors will understand the robot even better. These gestures need to be transformed to armless robot specific behavior, for example by using the screen to put emphasis on words or to show dates to remember, such as presenters often do in their power point presentations. People always show some movements (e.g. blinking, swallowing, breathing etc.), however, further movements should not be made with the FROG robot, as it will influence the opportunities to have a clear view of the screen or it will interfere with the quality of the recordings. Effects of using the screen for “supporting gestures” need to be researched in more detail.

Orientation and pose

A human tour guide will walk in front of a group, to keep pace in the tour. A robot guiding a small group to a point of their interest may show different behavior. Also the proxemics of the robot and the group need to be examined. As Sardar et al. found, the comfortable proxemics and trust in confederate between a person and a robot, differs from that between two people (Sardar et al. 2012). For the FROG robot appropriate proxemics and movements need to be determined.

When the robot arrives at an exhibit it will turn its screen towards the visitors. The pose of the robot towards the visitors should be such that the visitors can easily watch the screen and the point of interest that the robot is giving information about. As the robot will only be 1.20 to 1.50 meters high, the robot can stand between the visitors and the exhibit, because adults will be able to look over the robot’s top. This also is an advantage when the robot wants to project something on the wall, since it has to stand right in front of the wall in this case. If the robot would block the view when standing between the exhibit and the visitors, the robot can stand next to the exhibit, as a human tour guide often does. Visitors can see the robot and the exhibit by alternating their looking direction over a small angle.

A human tour guide influences the visitor behavior and the behavior of the robot will influence it too. It is still uncertain in what way. By copying the guide pose and orientation towards the visitor and towards the exhibit and by the method of starting and ending at an exhibit, the visitors’ formations can be shaped. Tests with the robot should confirm if this will work in the same way. Results and guidelines for this behavior will be given in section 6.

Conclusion

To conclude, the FROG robot guiding visitors around the tourist site should increase the visitor experience, just as human tour guides try to do. However, the robot has different qualities than the human tour guides. As opposed to human tour guides, we expect the FROG robot to guide small groups of visitors (e.g. a family) for a short amount of time through just a part of the site. The robot will base the information it conveys on the interests of a few visitors that are closeby, while the human tour guide has to interest a larger group. Therefore, the robot can shorten, lengthen or skip the story at an exhibit, which the human tour guide cannot.

Explicit behavior and strategies of human tour guides can be used to inspire the behavior of the robot, however they have to be adapted to specific robot guide behaviors. The strategies, such as breaking eye-contact at the end of the exhibit, starting to walk in the new direction during the last sentence, walking in front of the group to lead the visitors, looking at the point of interest and the like, can be copied and transformed, reduced or abstracted to robot specific behaviors. In follow-up studies (described in this deliverable) this proposed set of behaviors will be tested with visitors on effectiveness and efficiency. The implicit behavior of tour guides contains cues that are important in communication, but as guides are not consciously aware of them the exact behavior is difficult to determine and to copy. However, the interactional outcomes of the behavior of the robot should be the same as the outcomes of the behaviors shown by the human tour guide.

4. Tour guide robot gaze behavior

The final FROG robot will have visible lenses of a stereo camera, and will not have arms to point. Therefore, we carried out a study on the effects of gaze behavior of a basic robot. From a previous study on human tour guide behavior, we knew that guides often point to the exhibit to steer the visitors' attention towards the exhibit. With the study reported here, we tested whether a robot is able to direct the attention of visitors with gaze only. Also, as the robot already used its gaze, we tested what the effect is when a robot looked more at one person than at a group looking at an artwork. The gaze behavior we implemented was directly inspired by the study on human tour guide behavior, which was described in the previous section.

The experiment described here has been published as Late Breaking Result for HRI 2013 conference (Karreman, Sepúlveda Bradford, et al. 2013b) and extended as full paper for IROS 2013 conference (Karreman, Sepúlveda Bradford, et al. 2013a). Large parts of the description of this study are taken from these papers.

Effects of a robot that gazes

(This section is copied from: (Karreman, G. U. Sepúlveda Bradford, et al. 2013a, 2013b)**):**

Experiment design

We conducted a 2 (object-oriented vs. person-oriented gaze) x 2 ('favored' vs. 'not favored' by the robot) mixed factorial design study, where a robot guide presented two artworks to groups of three participants.

Fifty seven participants, students and staff members of the university, took part in the experiment (mean age was 25.6 (sd = 7.585); 41 male, 16 female). Of the participants 78.9% studied or worked in IT. 91.2% of the participants reported having little or no experience with robots. Slightly more than half (56.1%) of the participants had some previous knowledge about one or both artworks.

The platform used in the experiment was a Magabot-robot (www.magabot.cc). It came with a table-structure and a custom-made shell was used. The custom-made shell was very basic and had no anthropomorphic features. A laptop showing anthropomorphic eyes was placed on top of the structure of the platform. The robot turned its front toward the point it was looking at and moved its eyes to that side to indicate it was looking at a specific participant or at one of the artworks. See Figure 1 for an impression of the robot. During each session of the experiment, the guide robot stood in front of two posters of famous artworks; the Mona Lisa and the Girl with the Pearl Earring. The robot told a story about both artworks to groups of three participants.

Manipulations

Favored vs. not-favored condition: While giving information about the artworks, the robot looked toward each of the participants and alternated its gaze between them. However, the robot focused on the person on the left, and alternated its attention at eight moments during the story to the people in the middle and on the right for 1 to 2 seconds.

Person-oriented vs. object-oriented gaze condition: In the person-oriented gaze condition, the robot alternated its gaze between the three participants, as described above. In the object-oriented gaze condition, the robot also turned toward ("gazed at") the artwork it was talking about. The duration of the gaze was 2 to 6 seconds. The robot looked toward the artworks at moments when a human tour guide would point at the object. When the robot looked at the objects, it asked participants explicitly to look at the artwork ('please take a look at her hands'), or it was implicit about looking at the artwork ('the Mona Lisa is perhaps the most famous artwork in western art history').

Thirty Participants interacted with the robot in the object-oriented condition, 27 participants interacted with the robot in the person-oriented condition.

FIGURE 1: THE ROBOT IN FRONT OF THE TWO ARTWORKS

PROCEDURE

The experiment was performed in a lab at the University of Twente. The participants were welcomed in groups of three persons and informed about the study. All participants signed a consent form before entering the experiment room. The participants were asked to position themselves on one of the three lines. The position of the participants was partly predefined, as they had to stand on a line drawn on the floor. However, the participants were able to choose their proximity to the robot. Also the lines were designed to place participants around the (robot) tour guide as they would be in real exhibition areas where they would stand in "common-focus gathering:" in small groups a slight difference between speaker and group (oriented in semi-circle) becomes visible (Marshall, Rogers, and Pantidi 2011). The robot was remote controlled by one of the experimenters in a Wizard-of-Oz setting. After listening to the robot's story about the two artworks, the participants filled out an online questionnaire individually on laptops provided to them. Each session took approximately 30 minutes. All sessions were video recorded.

RESULTS

The manipulation of 'favoritism' was checked with one survey item that asked who the robot had looked at most. The majority of the participants indeed noticed that the robot looked more at one of the participants, indicating that the manipulation was successful. Forty four of 57 people (77.2%) responded correctly that the participant on the line at the side of the Girl with the Pearl Earring was favored. Only

4 of 57 (7%) responded that the participant on the line in the middle was favored, and the remaining 9 (15.8%) responded that they did not know. None of the participants responded that the participant in front of the Mona Lisa was favored.

The manipulation check for 'gaze condition' was done by analyzing the video data. We expected that when the robot looked at the artwork, participants would also look at the artwork and thus engage in shared attention. However, we did not find this. Instead, we found that participants in the object-oriented mode paid more attention to the robot at explicit compliance moments ($F[1,35] = 25.395$ $p = 0.000$) and at implicit compliance moments ($F[1,35] = 21.902$, $p = 0.000$) than participants in the person-oriented mode. Instead of directing attention to the object, it seems that the robot's (gaze) movement grasped attention to the robot. This means we successfully drew people's attention with the object-oriented gaze behavior but were not successful in creating shared attention toward the art object.

Hypothesis 1 concerned the expectation that participants in the object-oriented gaze condition (the robot looked at the participants and also at the artwork) would pay more attention to the object and the robot, would remember more about the object and the story, and would have a more positive attitude toward the robot.

In fact, participants interacting with the robot in the object-oriented gaze condition tended to perceive the robot as more human-like ($F[1,53] = 3.844$, $p = 0.055$) than participants that were exposed to the robot looking at participants only. Also, these participants ($M = 1.39$m) stood significantly closer to the robot halfway through the interaction ($F[1,53] = 4.167$, $p = 0.046$) than participants in person-oriented gaze condition ($M = 1.58$m). Overall, during the story, the difference in proximity between participants in object-oriented mode ($M = 1.39$m) and person-oriented mode ($M = 1.58$m) was marginally significant. The participants in the object-oriented mode tended to stand closer to the robot ($F[1,53] = 3.595$, $p = 0.063$). No differences in recall of story or artwork details were found between groups. Also, no differences in general attention between groups were found. With these results hypothesis 1 is partly supported.

Hypothesis 2 concerned the effect of a robot paying more attention to one of three participants. Expectations were that the 'favored' person would pay more attention to the object and the robot, would remember more about the story the robot told, and would have a more positive attitude toward the robot. Also, favored persons were expected to be prone to engage in shared attention in the object-oriented condition.

Results indeed showed that favored participants perceived more attention received from the robot and felt they gave more attention to the robot ($F[1,53] = 91.740$, $p = 0.000$) than non-favored participants. Also, favored participants felt the robot being more present and the robot being more aware of their presence ($F[1,53] = 37.786$, $p = 0.000$) than their non-favored colleagues. Furthermore, we found that favored participants tended to like the robot more ($F[1,53] = 3.737$, $p = 0.059$) compared to non-favored participants.

A marginally significant main effect was found for being favored at implicit compliance moments ($F[1,35] = 3.390$, $p = 0.074$). Favored participants tended to look less at the robot and more at the artwork than non-favored participants in both gaze conditions. Results also showed a surprising interaction effect between gaze condition and being favored at explicit compliance moments. In the person-oriented mode, the participants looked more at the artwork when the robot told them explicitly to do so than participants in the object-oriented mode ($F[1,35] = 5.218$, $p =$

0.029). This effect influenced participants that were favored by the robot more strongly (object-oriented mode M = 0.83, sd = 0.21; person-oriented mode M = 1.00, sd = 0.00) than the non-favored participants (object-oriented mode M = 0.95, sd = 0.07; person-oriented mode M = 0.97, sd = 0.06). The values indicate the probability that a participant is looking at the artwork. This shows that contrary to our expectation, especially favored participants had more attention for the artworks in the person-oriented mode than in the object-oriented mode. At moments of explicit compliance another interaction effect showed that participants looked more at the robot and/or artwork in the person-oriented mode (F[1,35] = 4.476, p = 0.042) than in the object-oriented mode. Favored participants in the person-oriented mode looked significantly more at the artwork or the robot than favored participants in object-oriented mode. For non-favored participants this trend seemed to be the other way around, but was not significant.

GUIDELINES:

People like the human-like gaze behavior of the robot, however, the full body movement distracted them. Therefore, we propose to use a more static robot, so as not to distract people. However, people liked the expressiveness of the active robot more; therefore, another way of getting attention should be found for the robot. The robot in the experiment was very basic, so we still need to test the options to get attention. Some of the options are: a pointer that turns instead of the whole body movement and attention attracters on the screen.

5. ROBOT APPROACH BEHAVIOR

Research has been carried out on robots approaching one person (Dautenhahn et al. 2006; Satake et al. 2010; Walters et al. 2007), however, more research is needed on robots approaching groups of people. In the study reported here, we studied participants who were paired up for a task and assessed their perception and behaviors as they were approached by a robot from various angles. On an individual level participants liked approaches from the front, and they disliked being approached from the back. However, we found that the presence of a task-partner influenced participants' comfort with an approach (i.e. when the robot approaches and one is standing behind the task-partner). Apart from the positioning of the individuals, the layout of the room, position of furniture and doors, also seemed to influence their experience. This pilot study was performed with a limited number of participants (N=30). However, the study offers preliminary insights into the factors that influence the choice for a robot approach direction when approaching a pair of people that are focused on a task.

The experiment described here has been published as Late Breaking Result for HRI 2014 (Karreman et al. 2014), and the paper was nominated for best Late Breaking Result. Most parts in this paper are directly copied from the paper or slightly adjusted for this deliverable.

EFFECTS OF ROBOT APPROACH DIRECTIONS ON A PAIR OF PEOPLE

THIS SECTION IS COPIED FROM: (Karreman et al. 2014)

METHODOLOGY

We carried out a quasi-experiment with a limited number of participants for the number of variables. However, our results are in line with previous research and we offer some preliminary suggestions on how to approach pairs of people with a robot. Based on the work of Walters et al. (Walters et al. 2007) and Dautenhahn et al. (Dautenhahn et al. 2006), the following hypothesis was formulated: “When people are doing something together in pairs, in various formations, they prefer to be approached by a robot from a frontal position. This is the position where the robot is in the field of view for both persons."

The study was carried out in a controlled environment. Participants in the study were 30 students and staff from the University of Twente in the Netherlands, who participated in 15 randomly combined pairs. Average age of the participants was 21.4 (*SD*=1.92). Of the participants 27 were male and 3 were female, leading to 12 male-male pairs and 3 female-male pairs. The robot used for the study was a Giraff (http://www.giraff.org). For this study, the screen of the Giraff was equipped with two digital robot eyes. The robot was controlled remotely.

To test the hypothesis an experiment was designed in which participants rated their experience of different approach directions of the robot. Participants entered the experiment room in pairs, and were asked to stand in a predefined formation (defined with markers on the floor). The three different formations, taken from Kendon's F-formations (Kendon 1990), were standing next to each other, standing in V-formation and standing opposite to each other (see Figure 2, respectively white pair, gray pair and black pair). Formation was manipulated between-subjects. The participants stood near a table and played a game of Mikado together. While the participants played the game, the robot drove in circles around them and drove towards them from eight different directions (the order of the approach directions were randomized for each session). After each trial, the participants were asked to fill in one question of the questionnaire. The questionnaire used for each of the approaches consisted of eight 5-point Likert-scale questions (one for each trial), on a scale from 1 (uncomfortable) to 5 (comfortable). After the robot had approached the participants eight times, the participants were asked to fill out a general questionnaire. From the general questionnaire we used for this analysis only two questions were for most and least preferred approach directions (for both questions participants could choose from: front, left front, left, left back, back, right back, right, right front). The participants filled out the questionnaire based on their own orientation and how the robot approached them, however, for the analysis, their answers were transcribed to absolute approach directions (as numbered in Figure 2).

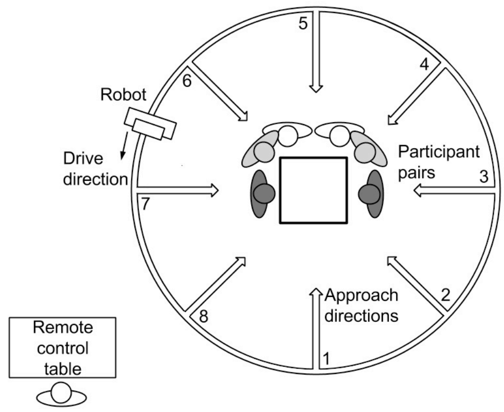


FIGURE 2: EXPERIMENT SETUP: THE ROBOT WOULD APPROACH EACH PAIR FROM EIGHT DIRECTIONS. THE DIRECTIONS ARE NUMBERED FROM 1 TO 8, HOWEVER THE PARTICIPANTS WERE NOT AWARE OF THESE DIRECTION NUMBERS. THEY FILLED OUT THE QUESTIONS BASED ON THEIR OWN ORIENTATION TO THE ROBOT.

RESULTS

In general, our findings for the participants on an individual level were in line with the findings of Dautenhahn et al. (Dautenhahn et al. 2006) and Walters et al. (Walters et al. 2007). We found that individuals preferred to be approached from the right front, left front and direct front, and that they did not like to be approached from the back. However, here we focus on the implications of being there as a pair and standing in various formations.

For participants standing next to each other (Figure 2: white pair), a significant difference in preference for approach direction was found ($F(7,71)=4.73$, $p=0.00$): participants rated approach direction 8 as most comfortable ($M=4.4$, $SD=0.52$) and approach direction 4 as least comfortable ($M=2.6$, $SD=1.17$). For the participants standing opposite to each other (Figure 2: black pair), no significant difference was found in preferences for approach: approach direction 5 scored highest on comfort ($M=3.9$, $SD=0.6$). For the participants standing in a V-formation (Figure 2: gray pair), we did not find a significant difference either: approach direction 8 scored highest on comfort ($M=4.3$, $SD=0.82$).

It is most likely that, when participants stand next to each other, the frontal approach is a frontal approach for both participants and both have a more positive experience of the approach. As the spreading of individual preferences in the other two formations was larger, no significant result for combined best preferred approach direction was found, which stresses the importance of finding a suitable way for a robot to approach a group of people.

As the participants were in pairs during the study, the position of the other person influenced the experience. When the other person was between the participant and the robot, the participant rated the approaches as slightly more comfortable than when the other person was not in between. A non-significant trend showed that participants gave the highest score for comfort when the robot approached from the individual left or right front and when the task-partner was closest to the robot ($M=3.9$, $SD=0.88$). The average lowest scores were given for the robot approaching from the individual left or right back when they were closest to the robot ($M=2.6$, $SD=1.22$).

The layout of the room might have influenced the results. Participants preferred the robot to approach from the window-side of the room. The entrance/exit was on the opposite side of the room, so probably people liked to keep the route to the door free. These are interesting observations, as in public spaces not only the formation of the group of visitors will influence the preferred approach direction, but also the layout of the environment.

GUIDELINES:

The robot should always approach visitors that are closest to the robot from within their field of view. When visitors are oriented in a semi-circle, the robot can approach from within the field of view, however, when visitors are oriented in a circle, the robot cannot approach any of the closest visitors from within their field of view. Then the robot should wait until one or more of the visitors start to look in other directions, to be able to determine a field of view and approach the group.

Also the robot should be aware of the layout of the room. The robot should never lock visitors in a corner or block the only door or a hall. Visitors should be able to easily avoid the robot, if they do not want to interact with the robot.

6. A ROBOT TOUR GUIDE IN THE WILD

Controlled experiments are very important in HRI research, and also very valuable. However, we wanted to test the robot with naïve visitors in the setting the robot would perform the task in future. Therefore, we used a basic robot, which was remote controlled, to give short tours in one of the halls of the Royal Alcázar. From this research we learned that visitors in the real-life setting show different responses to the robot than our participants in the lab. This has several reasons, but we think that the most important reason is that the visitors are not focused on the robot or the experiment in the real-life setting. This observation from our experiment was very valuable and informative. In future work, studies in the real-life setting will be performed with the FROG robot as well to define effective and efficient tour guide robot behavior.

The text for this part of the deliverable is taken from two short papers that were accepted to workshops at the ICSR 2013 and IROS 2013 conferences, as well as a paper that is submitted to RO-MAN 2014. However, to make it readable as one document, the parts were slightly adjusted.

VISITOR RESPONSES TO TOUR GUIDE ROBOT

THIS SECTION IS COPIED FROM: (KARREMAN, VAN DIJK, AND EVERS 2013, 2013)

STUDY DESIGN

An exploratory study with a basic robotic tour guide was done in one of the halls of Charles the Fifth in the Royal Alcázar in Seville (Spain). The robot gave prerecorded, short, remote controlled, English spoken, guided tours to visitors that were interested in the robot and the story.

In this study, performed in a real-life environment, we evaluated the effect of the orientation/pose of the robot and the effect of visible camera lenses at the top of the robot on human-robot interaction. From the observation of human tour guides we found that pointing or gazing into the exhibit are effective ways to steer visitor attention. However, from our the study on robot gaze we found that too much movement of the robot distracted the visitors from looking at the exhibits. Therefore, in this study, we tested two poses of the robot. In one case the robot had its front oriented towards the exhibit it was talking about. In the second condition, the robot was oriented with its front towards the visitors (the robot had its back towards the exhibit). We know the lenses of the camera will be visible, however, the question is whether we need to use them as the eyes of the robot, or to design non-functional eyes to support the interaction. Therefore, we evaluated the effect of visible camera lenses at the top of the robot on the human-robot interaction, because

The study took place on two days in May 2013. All people that entered the Royal Alcázar during those days were potential participants in the study. During an average day in May approximately 5500 visitors visit the Royal Alcázar. Tuesday, Saturday and Sunday are the days with the highest number of visitors. The busiest time of the day is usually from 9.30 am to 13.30 pm. The study was performed on a Thursday and a Friday, with on both days a session during a busy time of the day and a session during a more quite time. Visitors of the Royal Alcázar are of various ages but mainly above the age of 10 and they are of various nationalities/cultures. They come in couples, small groups of families/friends and school classes (Karreman, van Dijk, and Evers 2012). On average, visitors stay in the Royal Alcázar for 90 minutes. The Hall of Festivities, where the study was performed, is just a very small part of the Royal Alcázar, and during their visit, visitors did not have to walk through the research area. During a day, approximately 1000 visitors crossed the area, of which 500 interacted for a shorter or longer period with the robot. Most of these participants of the robot tour spoke English quite well, or at least understood what the robot was saying.

Signs with information about the study were placed at both entrances of the Hall of Festivities. The information on the signs was written in English as well as in Spanish. The signs notified the visitors that by entering the room they gave consent to participate in the research and to be recorded. The cameras were clearly visible and the visitors who entered the room did this voluntarily. Recordings were made in continuous time spans of only one and a half hours, after which the signs and cameras were removed. Then there were approximately two hours without recordings, giving visitors that did not want to participate in the study a chance to visit the room as well.

The robot used for the experiments was a data collection robot that was covered with black fabric, so the visitors of the site were not distracted by the technical insides of the robot. The robot was 1.2 meters high and had a "bumblebee stereo camera" and a Kinect at the top that were not covered. Although the camera was not running, several of the visitors reacted to the robot as if the robot was looking at them, apparently because the camera had two lenses that could be interpreted as the robot's 'eyes'. The maximum speed of the robot driving was 1.4 meters per second and the robot was remotely operated. The interaction modalities of the robot were limited; the robot was able to drive through the hall, change its orientation and play prerecorded utterances. See figure 3 for an impression of the robot.

PROCEDURE

The tour given by the robot took about 3 minutes. When visitors entered the Hall of Festivities, the robot was standing in the starting place (1) (see Figure 4) and started the tour by welcoming the visitors and telling something about the room. When the robot finished this story, it drove to the next stop, asking the visitors to follow. At the next stop (2) the robot told the visitors about the design of the figures on the wall, made with tiles, after which it drove to the next exhibit. At the third stop (3) the robot told the visitors about the banner that was hanging above an opened door. At the end of this story the robot asked the visitors to follow and it drove to the last stop (4) where it gave information about the faces visible on the wall. Before ending the tour the robot drove back to the starting point, 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.

FIGURE 3: THE TOUR GUIDE ROBOT

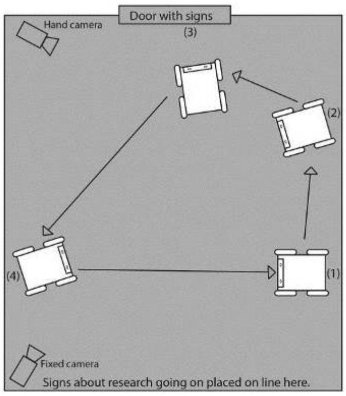


FIGURE 4: SET UP OF THE ROOM

During the study the robot sometimes tried to persuade visitors to follow with the sentences "Please follow me" and "Don't be afraid." In all cases it was up to the visitors to decide whether they followed the robot or not.

A total of approximately 4.5 hours of recordings were made with a fixed camera and approximately 4.5 hours of recordings were made with a handheld camera. The fixed camera recordings give an overview of all events that happened in the research area. The whole tour of the robot is visible in these recordings. Only, in some of the later sessions did the robot sometimes approached people outside the angle of view of the camera. The recordings of the fixed camera have been used for the analyses reported here. The handheld camera was used to zoom in on faces and to observe the behavior more closely. Also, of the visitors that followed (parts of) the tour 26 were asked to answer a few questions about their experience of being guided by the robot. The questions were asked in English and all participants were able to answer in English.

As the study was performed in a real-life setting, with uninformed naïve visitors, we sometimes had to deviate from the procedure a bit. The robot had defined places for stops, however, sometimes the robot had to stop close to the defined place, because people were walking or standing in front of the robot. Another reason to deviate was when the robot lost the interest of all the people following the tour. Then it drove back to the starting place and started over again. If some visitors lost interest and left the tour but other visitors remained interested, the robot continued the tour.

Rapid iterative research approach

During the study we used an iterative design approach (Gould, Watson, and Lewis n.d.). When the robot was recharging in between recording sessions, the person controlling the robot and the observers discussed about robot behaviors that had the intended effect and behaviors that did not work well. Where necessary some design changes were made and tested in the next session. This way we tested for instance two different conditions in the orientation of the robot. In the first condition the camera of the robot was orientated towards the point of interest. In the second condition the robot stood in front of the point of interest with its camera oriented towards the visitors. During the study both conditions were tested but we did not systematically control the order and number of trials of each condition. For instance, in one of the first trials we found that in the condition with the robot oriented towards the visitors, people did not know where to look. Hence, in the next iteration we incorporated extra text to make clear to the visitors where they could find the point of interest.

A field study was preferred over a lab experiment, because in the wild, when people have come to visit a public space and are not prepared to find a robot there, they will react differently to the robot than when they are brought into a lab and asked to pay attention to the robot. Robot behavior and proxemics have repeatedly been studied in the lab (e.g. (Joosse, Sardar, and Evers 2011), (Mumm and Mutlu 2011), (Walters et al. 2007)). However, less is known about how robots should approach people in a public space and what the effects are in terms of the distances between people and robots. Especially for the situation of guiding, guidelines need to be developed.

Results

Distance visitors kept from the robot

Most visitors stood between 30 cm and 3 meters from the robot. We found that in 11 sequences visitors stood less than 30 cm away from the robot. In 48 sequences people stood more than 3 meters away from the robot. When there were visitors standing very close or far away from the robot, there also could be visitors that stood at average distance (between 30 cm and 3 m) from the robot.

Only at exhibits one and two, visitors stood 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 exhibits. From looking back to the video, we observed that when people stood very close to the robot and the robot was oriented towards them, visitors only seemed to have 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). Hence, when visitors stood close and the robot was oriented towards the exhibit, 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 exhibit the robot presented about. Also, from related work, we know that people preferred to come closer to a robot when the robot was not looking at them (Mumm and Mutlu 2011).

Visitor attention

We found that in position two, three and four more single persons or pairs had attention for the story of the robot when the robot was oriented towards the exhibit (39 times) than when it was oriented towards the visitors (26 times) (position 1 was excluded, because in that position, the robot was always oriented towards the visitors). When the robot was oriented towards the exhibit, single persons or pairs seemed to keep their attention easier to the story of the robot, this might be because the visitors knew better what the robot was talking about as it seemed to look at the exhibit. This is strengthened by the observation that in early sessions visitors often had difficulties identifying where to look, while in later sessions this effect was less obvious because the utterances of the robot were changed iteratively between the sessions to make clear where to look.

Visitors that were interacting with the robot in a pose oriented towards them, sometimes appeared to have no clue where to look. This clearly indicates that visitors were sensitive for the "gaze-direction" of the robot. When the robot was in a pose oriented towards the visitors, the visitors needed several verbal cues to understand that the robot talked about the point of interest behind it. When the robot was oriented in a pose towards the point of interest it was clear from the beginning that the robot talked about the point of interest. To our surprise this effect still occurred in the later sessions, when the explanation of the robot was changed to make more clear where to look. During the later sessions of the field study, we observed that visitors when the robot was oriented towards them got the clue where to look later than they expected, therefore they were first looking around, and when they got the information they started to look at the right point (this is missed in the analysis of sequences, but found in notes made during the observations). We also observed that at position three when the robot was oriented towards the point of interest, visitors had difficulties to understand where the robot seemed to be looking at. The robot talked about a banner that hung above an open door, and the robot was oriented as if it looked through the door into the other room because it was not able to tilt its orientation upwards. This often confused the visitors, even when the robot was clear in its text about where to look.

Visitors walking towards the robot

We found that visitors tended to walk towards the robot (during the explanation) more often when the robot was oriented towards the exhibit than when the robot was oriented towards the visitors. It might be that the visitors felt different attitudes showed by the robot, so distance was created by a specific pose of the robot, for example, people might have felt safer to approach the robot when it was oriented towards the exhibit. Probably because the robot was keeping distance with its "eyes" when oriented towards the visitors. This finding is in line with the fact that people walked closer to a robot that was not following them with gaze then when the robot was following them with gaze, as found by Mumm and Mutlu (Mumm and Mutlu 2011).

The fewest visitors walked towards the robot at point three, most did at point four. Visitors probably did not have to walk to the robot in point three, as it was really close to point two. From point three to point four was the longest walk, and 16 times visitors walked towards the robot, probably these were the people that follow the whole tour, but were a bit reserved following the robot. In position one and two, several people were walking to the robot, because the robot had their attention and they wanted to see what it was for. However, in all cases there were a lot of people just walking past, showing no attention for the robot at all.

When visitors lost interest

From the annotations we found that if people lost interest in the story and the robot, this most often happened in point three and least often in point four. This can be explained; in point three the explanation was difficult to understand because the story was about a banner above an open door. Visitors often had difficulties to identify where to look. Next to that, point three was close to a door, the entrance to the next room, therefore people that lost interest easily walked away from the robot, into the next room. However, when visitors followed to point four, the last point of the tour, they were likely to follow the robot the whole tour. These visitors liked to hear the explanations of the robot and stayed with the robot until the final explanation/exhibit, therefore fewer visitors left the robot in point four.

Sequences that were coded as “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. Advantage was that for most people it was clear that the robot just gave a short tour, so the people that 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. However, important for the robot is that when one visitor loses interest, the robot most of the time had other visitors (either close or far) who were still interested in the robot and the story, so it went on with the story.

Visitor reactions to the “eyes”

Observations show 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 and expressed the intentions of the robot. This is seen in the fact that some visitors waved to the camera when they arrived or left the robot, and stood in front of the camera when they wanted to make contact with the robot. In addition, the pose of the robot, and thus orientation of the camera, also influenced the interaction. When the robot was oriented in a pose with the camera toward the point of interest, visitors knew intuitively where to look. However, during the study, the robot was not always oriented toward the point of interest. Sometimes it was oriented toward the visitors. When the robot did not orient to the point of interest, people tried to search where the camera was focused. We found out that in that case the robot had to tell the participants explicitly where to look. From the interviews, we learnt from a visitor that she had left the robot now the robot turned the camera away from her, because she thought the robot had no interest in her anymore. The change of pose and the shown attitude of the robot, made her to leave the robot.

All these examples make clear that visitors see the lenses of the camera as the eyes of the robot and they respond as if the robot uses the eyes in the same way as humans do. To make contact they make sure the robot can see them, they follow the gaze of the robot to understand what it is talking about, and when the robot breaks eye contact and turns away, and visitors think the robot is not interested in them anymore.

GUIDELINES:

The robot does not only catch the attention of people that are standing close, but also from visitors who choose to stay at a distance. Although these visitors are interested in the story and the robot, they do not want to be close. The tour guide robot should therefore not only focus on visitors close by, but scan the surrounding once in a while and go on with the story or tour if it detects visitors that are not standing close, but show an orientation towards the robot and stay there during the story it is telling. When a close visitor loses interest, the robot should not stop the story or interrupt the story and keep focused to that visitor, because other visitors might still be interested and can lose interest when the robot loses interest in them. Depending on the gaze direction of the robot, the robot should give the visitors sufficient information about where to look. Also, the robot should not rely solely on its detection of visitors by gaze (cameras directed to the front-side of the robot) for going on or stopping the explanations, because in some situations the visitors tend to stand next to or behind the robot, while they are still interested in the story.

The robot should make a distinction between people standing close that are following the story and people standing close that only show interest in the robot. 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. Probably the robot can catch their attention for the story and bend the playful or disturbing interaction to a guided-visitors interaction.

From our point of view there are three ways to deal with the camera that has to be placed at the top of a robot structure. First, the lenses can be hidden, so visitors will not recognize the camera. Second, the camera can be visible and in the behavior some gaze-cues will be given with the camera. Third, the camera will be visible and extra human-like features will be added to fully exploit the gaze behavior. There are arguments for and against all three options. The first option is often used (for example in the NAO), however, it is not always possible to hide the camera that well: in particular when a camera has to be placed at the top of the structure and for when aesthetic reasons the camera cannot be covered by the shell. For the second and the third option, when the camera lenses are visible, but have a function that requires them to keep being focused on the user (for instance because they are used for face recognition), the robot cannot give gaze cues such as shifting its gaze to an object. This may confuse the user, because the eyes are not functioning in the way they would expect.

From our observation, we learned that visitors saw the stereo camera at the top of the robot as the eyes of the robot. Therefore, we argue that either cameras should be fully hidden in the body design of the robot, or (when cameras cannot be hidden) the cameras should be designed as eyes, including the design of gaze cues and gaze direction. Using these cues, when people especially expect them already, will probably smoothen the HRI. Apart from this, we found in previous research on robot gaze behavior that people like the robot better when it shows human-like gaze patterns (the robot gaze behavior was based on gaze behavior human tour guides show) (Karreman, G. U. Sepúlveda Bradford, et al. 2013b). This gives a second reason to use the cameras as the eyes of the robot.

Therefore our design guideline states: even if the intention is not to design a human-like robot, human-like features might improve the HRI. In this case, the FROG robot will not be a humanoid robot, but the cameras will be designed as eyes, as this will support the mental model users will create of the robot.

7. Overview of Guidelines

In the previous reported studies we focused mainly on gaze behavior of a robot and on which visitors a robot should focus when telling a story, using full body movement to change the focus. Next to this, we focused on how a robot should approach groups of people and what effects the pose of a robot, and thus the orientation/focus of the camera lenses, had on the reactions of the visitors. In future experiments we will focus on more detailed behavior for specific modalities of a robot.

The previous sections closed with guidelines for robot appearance and behavior. In this section the guidelines are collected and divided into six categories so that the guidelines can be read in the order they will occur during interaction between the guide robot and people. These guidelines will be used in the FROG project to define the behavior of the robot, however, these guideline are also valuable for the HRI community, as they can help others designing robot (guide) behavior.

Appearance

- A robot should use a pointing device (spotlight, laser pointer, pointer, arrow on screen, picture of subject on screen) to direct the visitors' attention to the right spot in the exhibit; using this device means that the robot can be static during the explanations.
- A robot should use a screen and a projector to depict concepts by showing pictures, movies, augmented reality, projections or single words.
- If camera lenses at the top of a robot are visible, these lenses should be used as the eyes of the robot, and specific gaze cues should be developed to communicate intentions.
- If camera lenses are covered by a shell, a robot should use fake eyes to communicate its intentions.

Initiate a guided tour

- A robot should approach the closest visitors from within their field of view.
- If visitors are standing in a closed formation (e.g. a circle) the robot should wait with approaching the visitors until the formation changes.
- If visitors are not interested in the story, but try to play with the robot, the robot should react to the visitors and change the playful interaction into a guide-visitor interaction.
- Interaction between visitors and robot should be created by the robot by showing movies on the screen, projections on the floor or wall and by reactions from visitors in the form of pressing a button, making gestures and movements or showing facial expressions.

Arriving at the exhibit

- A robot should give feedback about it state (ready to start) when it arrives in the right place to explain about an exhibit.

- Before the robot starts at an exhibit, it will orientate itself between visitors and the exhibit, with the screen towards the visitors, so visitors can easily look at the screen and the exhibit.
- If the robot blocks the view by standing in front of the exhibit, the robot can stand next to it, so visitors only have to change their view over a small angle.
- The robot should stop in such a place that the visitors will make a formation around the robot that everyone can see the robot screen and exhibit well.
- When the robot wants to start at an exhibit, it should move a bit and use light and sound feedback to catch people's attention.

Explanation at the exhibit

- A robot should not make extra movements during the explanation (such as turning or driving forward/backwards), to not to distort the projection, laser pointer or visibility of the screen.
- When the robot starts at an exhibit, the first sentence should contain trivial information.
- The robot should look into the exhibit to point, or use a device to be able to point into the exhibit.
- The robot should tell curiosities to catch and keep the attention of the visitors.
- The robot should use visuals (pictures, movie, augmented reality and projections) to clarify the story.
- The robot should be explicit to the visitors about where to look (e.g. by pointing or by telling).
- The robot should be able to give certain levels of information. If the robot wants to prolong the story, the robot should be able to give information about several topics at an exhibit (broad) or the robot should be able to go in-depth on one topic.
- The robot should use games and analogies to keep children interested in the explanation.
- The robot should track the facial expressions and gestures of visitors as input for interaction, e.g. to personify the explanations by elongate or shorten the story.
- The robot should track the facial expressions to decide if people are still interested. If people show interest, the robot can elongate the story. However, if people are bored, the robot should shorten the story or finish the tour.
- The robot should make eye-contact with the closest visitor to show awareness of him/her.

Finish at an exhibit

- At the end of an exhibit, the robot should indicate the story is finished by turning left and right a bit.
- At the end of an exhibit, the robot should indicate in which direction it wants to go next.

Going to the next exhibit

- When transferring from one exhibit to the next, a robot should move in front of the group and display feedback about its task and that it is still aware of the visitors.
- A robot should never lock visitors in a corner or small space.
- A robot should not focus on close visitors only, as visitors far away also could show interest in the story.
- If visitors leave, the robot should first check whether any other visitors show interest (close, far, behind) before stopping the story.

- When the robot has oriented the screen away from the visitors, the robot should give feedback about the task it is performing and to show it is still aware of the visitors.

Apart from these guidelines a decision was made to work with a split personality for the robot. The robot guides the visitors through the site, but another personality gives the explanations at the exhibits. This means that the robot can use mainly non-verbal behavior. The other personality/voice-over that explains about the exhibits appears when the robot is ready to start at the exhibit and disappears when the robot finishes at an exhibit. During the explanation at the exhibit the robot is "sleeping," and the "narrator mode" is on.

8. How these guidelines affect work of other partners in the project

The guidelines described in the above sections will be used to inform the project partners about desirable robot behavior. The behaviors that will be implemented in the robot still need to be validated in an evaluation study. The described behaviors will influence the work of other partners in several ways. As is described in D4.1b we observed three main aspects in a guided tour: Guidance, Content and Engagement. Below we described how these aspects influence the development of behaviors for the FROG robot.

Main aspect of a guided tour

Guidance

Guidance consists of safe navigation and localization in the environment, making sure that there is space to go to the next place and that the robot will not collide with people. In the project, members from Universidad Pablo de Olavide are working on safe navigation, localization and collision avoidance for the robot. However, guidance also means to have people standing in suitable formations to look at an exhibit and to listen to the robot, and have them walking in the right direction without always explicitly telling them which way to go. To develop this kind of the guidance we analyzed the behavior of human tour guides, and then we transformed, reduced or abstracted this behavior to behavior guidelines that will serve as input for the navigation task of Universidad Pablo de Olavide.

The robot will choose a route through the site. A human tour guide adapts the pace, route and content based on the interests of the visitors. The robot can also adjust the tour based on the visitors' interests. If the robot detects the visitors are no longer interested at one exhibit, the robot can go on to the next. However, if people like the information, the robot can enhance the tour. The human tour guide also has to stick to a time schedule. For a robot that will be different. From previous research, we know that people only have attention for the robot for 10 to 20 minutes (Karreman et al. 2012). Therefore, the tour of the robot will contain 2 to 4 exhibits, based on the interest of visitors and with a maximum time of 20 minutes.

We propose that the robot will turn during the last sentence at an exhibit into the direction of the next exhibit. However, we intend that the robot can show the direction to follow next; the robot will not have arms to point with. An option will be that the robot projects an arrow of the direction to follow on the ground, so visitors know which way to go. Another advantage of projecting while driving is that the visitors receive a cue that the robot is still guiding them.

Content

In the FROG project the content will be developed by YDreams. However, content and behavior influence each other. Behaviors for giving content and meaning to the tour will be analyzed by us and we will discuss the results of effective behaviors with YDreams as input for their content.

So, similar to a human tour guide, the robot should have content. However the content of the robot will not be as extended as of human tour guides. The story, visuals, and curiosities a human tour guide provides during the tour should be assessed as inspiration for the robot. The tour of the robot will be shorter and in limited areas, so the content will be differently ordered and less extensive. Important content for the robot will be presenting curiosities, because visitors do like that a lot, and with the curiosities, the robot will get the attention of the visitors.

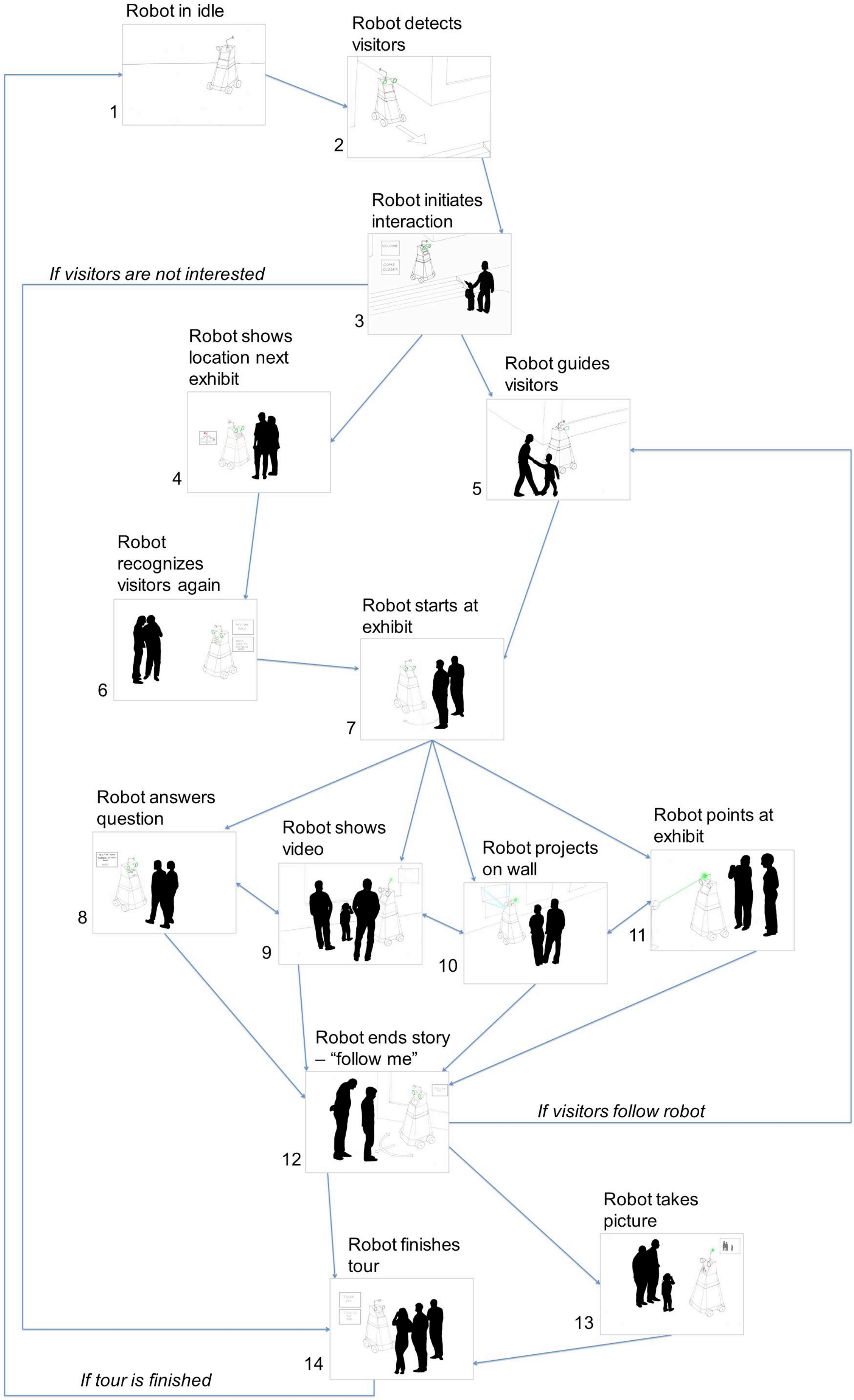
Also, similar to human tour guides the FROG robot will choose one of the visitors to get the main feedback from. Probably this will be the closest visitor (biggest head in data collection), because the face would be easiest to track for the members of Imperial College London. The closest visitor will provide information on the level of interest, by the robot examining the gaze direction, nodding and laughing. This information will help the FROG robot to adapt the content to that visitor's interest and change the story accordingly, assuming that the interest of the tracked visitor is sample for the group. If the visitor seems to be bored, the robot will go on to the next subject, but if the visitor indicates that he/she are interested (nodding, gazing at the guide or gazing at the object of the talk) the robot will extend the story a bit more.

The robot will not be able to point, depict or show visuals in the same way as a human tour guide does. However, the robot can show pictures and movies on a screen to support the story it is presenting. Also other output modalities, such as pointing using a laser pointer or a spotlight, projecting images, movies and directions on the wall or the floor, or presentations of a voice-over, and gaze, can be used in the robot. This implicates that the meaning to the content will be given in a different way, but this also lends opportunities to present extensive visual material to support the story.

Behavior scenario

The guidelines given for the behavior of the FROG robot are combined in a behavior scenario flow chart that also shows the follow-up possibilities for a specific behavior. All specific behaviors are numbered and the explanation of the robot actions during that behavior are listed later in the paragraph.

In the explanations of the actions of the robot, also some modalities that probably will not be implemented in the FROG-robot are described. The actions of the behaviors are described as complete as possible, but will still be understandable if one or two of the modalities fall out. However, these modalities are described in this deliverable, to give a full overview of the opportunities for robot behavior.


Robot in idle
1
Robot detects visitors
2
Robot initiates interaction
3
If visitors are not interested
Robot shows location next exhibit
4
Robot guides visitors
5
Robot recognizes visitors again
6
Robot starts at exhibit
7
Robot answers question
8
Robot shows video
9
Robot projects on wall
10
Robot points at exhibit
11
Robot ends story – "follow me"
12
If visitors follow robot
Robot takes picture
13
Robot finishes tour
14
If tour is finished

1: Robot is in idle:

Envisioned robot actions	Remarks
Robot is in "idle mode" (eyes and body lights are off)	
Robot is slowly driving forward (sometimes making turns to not to collide)	
Pointer on top is in rest, laser is off	
Screen is turned off	
Sound is functional motor sound	Based on sound research

2: Robot detects visitors

Envisioned robot actions	Remarks
Robot is in "robot mode" (eyes and body lights are on)	
Robot is slowly driving forward (sometimes making turns to not to collide). The robot always tries to approach the closest visitor from within his/her point of view	
Robot body light displays weak light (for example rainbow colors) to show it is on and searching for contact	Not intended for the FROG-robot
The eyes are slowly pulsing from bright to weak light	
Pointer on top is turning around as if it is scanning for visitors, light is on, laser is off	
Screen is turned off	
Sound is functional motor sound	Based on sound research

3: Robot initiates interaction

Envisioned robot actions	Remarks
Robot is in "robot mode" (eyes and body lights are on)	
Robot drives towards visitors, stops 1.5 meters from them and starts turning 45 degrees to both sides of the static position until one of the visitors looks at the robot	Based on analysis of human tour guides. To detect if visitors are looking at the robot, the robot can move for a few seconds, and then stop for a while to detect. If visitors are not looking, the robot starts moving again and repeats the sequence.
Robot body light displays excitement (for example, exited rainbow colors flashing light) for making contact with the visitor	Not intended for the FROG-robot
Eyes are playing a sequence that attracts attention	
Pointer on top is pointing at visitors, light is on, laser is off	
Screen displays the text "welcome" and "come closer"	
Robot plays happy sound for "found visitors"	

4: Robot shows location next exhibit

Envisioned robot actions	Remarks
Robot is in "robot mode" (eyes and body light are on)	

Robot is oriented towards the visitors	
Robot light indicates that the robot is explaining route (for example: intense green light)	Not intended for the FROG-robot
Eyes are playing animation as if looking at the screen	
Pointer on top is pointing towards the direction the visitors need to follow, laser is off, light turns on when voice-over finished the explanation	
Screen displays a map of where to go, arrow is drawn on the screen while voice-over explains	
Voice over tells how to walk to next exhibit	

5: Robot Guides visitors

Envisioned robot actions	**Remarks**
Robot is in "robot mode" (eyes and body lights are on)	
Robot turns and drives in front of the visitors towards the exhibit	Based on exploratory study Seville 2013
Robot body light displays guiding light (for example: calm orange pulsing light) to show visitors the robot is still aware of them	Not intended for the FROG-robot
Eyes are slowly pulsing from bright to weak light	
Pointer on top is pointing at the exhibit the robot is going to, however, once in a while the pointer makes a round as if it the robot is checking whether the visitors are still following, light is on, laser is off	Based on analysis of human tour guides
Screen displays the text "follow me" (start showing text before the robot has turned)	Based on exploratory study Seville 2013
Robot plays sound for "guiding visitors"	
Just before turning the mechanic voice of the robot says "follow me"	

6: Robot recognizes visitors again

Envisioned robot actions	**Remarks**
Robot is in "robot mode" (eyes and body light are on)	
Robot drives towards visitors and stops 1.5 meters from them	Based on analysis of human tour guides
Robot body light displays attention searching (for example: orange flashing light) for getting the attention of the visitors	Not intended for the FROG-robot
Eyes are playing a sequence that attracts attention	
Pointer on top is pointing at the returned visitors, laser is off	
Screen displays the text "welcome back" and "press here to continue"	
Robot plays happy sound for "found visitors"	

7: Robot starts at exhibit

Envisioned robot actions	**Remarks**
Robot is in "robot mode" (eyes and body light are on)	
Robot moves a bit to attract the attention of the visitors and then orient itself with the screen towards the visitors	
Robot light indicates that the robot has stopped driving and has attention for the visitors (for example: calm	Not intended for the FROG-robot

fading green light)	
Eyes play sequence showing excitement and "close" as the robot changes to "narrator mode"	
Pointer on top is pointing towards all visitors first before it starts pointing at the exhibit, laser is off	
Screen is showing "Do you have a question?"	
Robot is playing fading sound and the voice over starts with some trivial information about the exhibit	

8: Robot answers question

Envisioned robot actions	Remarks
Robot is in "robotr mode" (eyes and body light are on)	
Robot is oriented with the screen towards the visitors	
Robot light indicates that the robot has attention for the visitors (for example: calm orange pulsing)	Not intended for the FROG-robot
Eyes slowly pulse from weak to normal and look down at the screen	
Pointer on top is pointing towards the visitors, light is weakly on, laser is off	
Screen displays "Do you have a question?" and "Press here to continue"	
Robot is playing waiting/repeating sound	

9: Robot shows video

Envisioned robot actions	Remarks
Robot is in "narrator mode" (body light is off, screen is on)	
Robot stands so that the visitors can easily see the screen of the robot and look into the exhibit (only small angle between both).	Based on analysis of human tour guides
Pointer on top is pointing at the exhibit the robot is presenting about and once in a while checking if the visitors are still there, light is on, laser is off	
Eyes are "closed"	
Screen displays virtual reality, movies or pictures or words that support the story	
Voice-over presents story	
If visitors seem to be interested in the story, the story will be elongated with broad topics or in-depth. If visitors seem to be bored, the robot will shorten the story	

10: Robot projects on wall

Envisioned robot actions	Remarks
Robot is in "narrator mode" (body light and eyes are turned off, pointer is on)	
Robot oriented screen towards the visitors	Based on exploratory study Seville 2013
Eyes are "closed"	
Pointer on top is pointing at the exhibit the robot is presenting about, every once in a while it scans if the visitors are still there. As soon as the story is finished, the pointer turns to the visitors, as if it is scanning if the	Based on study on gaze behavior

visitors are still there. Laser is on as long it is pointing on the exhibit, when it turns to the visitor, the laser is off. The light is on all the time	
The robot projects information/highlights information on the board. The screen is turned off	
Screen is turned off, as visitors cannot see the screen	Based on exploratory study Seville 2013
Voice-over tells story	
If visitors seem to be interested in the story, the story will be elongated with broad topics or in-depth. If visitors seem to be bored, the robot will shorten the story	

11: Robot points at exhibit

Envisioned robot actions	Remarks
Robot is in "narrator mode" (body light and eyes are turned off, pointer is on)	
Robot is oriented with the screen towards the visitors	Based on exploratory study Seville 2013
Eyes are "closed"	
Pointer on top is pointing at the exhibit the robot is presenting about, every once in a while it scans if the visitors are still there. As soon as the story is finished, the pointer turns to the visitors, as if it is scanning if the visitors are still there. Laser is on as long it is pointing on the exhibit, when it turns to the visitor, the laser is off. The light is on all the time	Based on study on gaze behavior
Screen is turned off/showing stand by screen	Based on exploratory study Seville 2013
Voice-over tells story	
If visitors seem to be interested in the story, the story will be elongated with broad topics or in-depth. If visitors seem to be bored, the robot will shorten the story	

12: Robot ends story

Envisioned robot actions	Remarks
Robot changes from "narrator mode" (eyes and body light are off) to "robot mode" (eyes and body light are on)	
Robot is slightly turning round static position right after the last sentence of the voice-over. After the robot is awake again, the robot starts to drive forward very slowly to a small gap between the visitors	Based on analysis of human tour guides
Robot light indicates that it needs space to go through the group (for example: intense purple light)	Not intended for the FROG-robot
Eyes turn on again, playing an sequence, first weak and becoming brighter	
Pointer on top is pointing at the exhibit the robot is going to, light is on, laser is off	Based on analysis of human tour guides
Screen displays the text "follow me"	Based on exploratory study Seville 2013
Robot plays sound for "guiding visitors"	
Robot mechanic voice says "follow me" and "excuse me" if visitors are blocking the path when it wants to guide visitors for a short way. Robot mechanic voice says "pleas, look at map" when it want to show visitors the route to	

the next exhibit.	

13: Robot takes picture

Envisioned robot actions	Remarks
Robot is in "robot mode" (eyes and body light are on)	
Robot is oriented towards the visitors, as it will make a picture of them	
Body light is pulses exited but weak	Not intended for the FROG-robot
Eyes are on and static, turning around when the robot says "say cheese"	
Pointer on top is pointing at visitors, being the eye catcher, laser is off	
Screen displays the picture the robot will make, eventually including a augmented reality overlay	
Robot plays funny sound	
Robot mechanic voice says "say cheese"	

14: Robot finishes tour

Envisioned robot actions	Remarks
Robot switches off "robot mode" (eyes and body light turn off)	
Robot is slightly turning round static position, as if it looks a last time to all visitors before it turns 180 degrees and drives away	Based on analysis of human tour guides
Eyes slowly fade out	
Pointer on top is pointing at visitors, and lowers when the robot drives away, laser is off	
Screen displays the text "thank you" and "this is the end of the tour"	
Robot plays sound for "leaving visitors"	
Robot mechanic voice says "good bye"	

9. Conclusions and Future work:

The guidelines found in the several studies we have performed will inform the partners of the project to design socially accepted approach and navigation behavior and to develop a behavior tree, but also will inform the HRI community on guide robot behavior. To develop the behaviors for the FROG robot, the observation of human tour guides inspired the development of the guidelines. The behaviors and strategies of the human tour guides were transformed, reduced and abstracted to come to specific robot behavior. Several robot behaviors were tested with robots in controlled settings and in the real world with recruited participants and naïve visitors of the Royal Alcazar.

From controlled experiments we found that the movement of the robot distracts people, therefore, a pointing device and attention grabbers are needed. When the robot approached a pair of people, people felt most comfortable when the robot approached from within their field of view and when the other participant was between them and the robot. For groups this means that the robot needs to be aware of the field of view of people and only approach when in the field of view and when there is no other visitor in between of which the robot is not in his/her field of view.

"In the wild" we found some surprising visitor reactions. In the wild the visitors reacted differently to the robot from participants in the controlled settings. People react strongly to the visible camera lenses of the robot, therefore the lenses should be designed as the eyes, including gaze cues. Also, we found that some people tend to stand far from the robot, but follow the whole tour. The robot should be aware of these visitors, and not stop the story when all close visitors leave.

Future work on analysis of robot behavior will include analysis of data obtained at upcoming meetings and research weeks in the Royal Alcázar. The FROG robot itself will show guide behavior and it will interact with naïve visitors. The visitor reactions as well as the robot behaviors and personality will be evaluated to iteratively revise (if necessary) and perfect the behaviors and personality of the robot. As not all proposed behaviors (based on the human tour guide behavior) have been evaluated yet, more experiments in the real world with naïve visitors will be done. This will include an experiment to social navigation behaviors together with members of the Pablo the Olavide University.

Future work will include the analysis of convincing and fun guide robot personality, of which the results will be reported in Deliverable 4.1d.

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