FROG - Fun Robotic Outdoor Guide

Deliverable: **D4.1 part a**

Identification, evaluation and design of guide robot personality and behaviours: Engaging Personalities and Behaviours

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ENGAGING PERSONALITIES AND BEHAVIORS

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1. Summary

To date several tour guide robots have been developed and evaluated with the public in museums. These robots were all capable of showing awareness of the visitors and could establish some kind of interaction with the visitors. The behaviors and personalities these robots showed ranged from somehow effective to very effective in interaction. In this deliverable the behaviors and personalities and factors that influence these are described using examples from the reported studies of previously developed tour guide robots.

From previous research it is known that a museum-like setting is a good place to have robots trying to interact with visitors, as visitors have time to interact with the robot and might choose to follow the guided tour. A guided tour can be distinguished in four phases. In this deliverable, the four phases of a guided tour are used to provide the structure. These four phases are: approach visitors, guide visitors, engage visitors with information about exhibits and leave visitors. Outcomes of previously performed research on effective behaviors and personalities for robots that were performing a (part of a) guiding task will be discussed.

The effectiveness of the robot in engaging visitors influences how visitors experience the tour given by the robot. The robot behavior, personality and appearance will influence the visitor experience. Also, modalities and moods of the robot will influence the appearance, behavior and personality of the robot. A model on how these factors influence each other will be presented in this deliverable.

A basic scenario, as presented in D1.1, will be visually presented in the deliverable and will be used to discuss, extend and specify the final behavior and personality of the FROG robot.

2. Introduction

This literature review is deliverable D4.1 part a for the EU FP7 project FROG (Fun Robotic Outdoor Guide). In this document we will discuss the relevant literature concerning guide robots and those aspects of Human Robot Interaction that are relevant when designing and developing robots for guiding small groups of people.

In the FROG project an outdoor guide robot is being developed to autonomously approach small groups of visitors and offer them an interactive experience in outdoor cultural heritage sites or other sites of specific interest. A valid question may be what the arguments for developing a robotic tour guide are, as information in tourist sites is usually offered through text signs, audio tours or human guides. Why should a robotic tour guide for indoor and outdoor touristic sites, such as the Lisbon City Zoo and the Royal Alcázar, be developed, as there are already human tour guides? There are three arguments in answer to this question. First, there are visitors at tourist sites who may not be inclined to join a tour because it involves joining a group of strangers, the tours may be given at inconvenient time intervals or the cost might be high. These visitors may have a disappointing visit as they cannot obtain the information they would like to about the tourist site [1]. Second, visitors in small groups such as friends, colleagues or small families often wish to visit a site at their own pace and leisure. However, at times there is little information given on information signs and the audio guide is for individuals, cutting them off from a shared experience. For small groups of visitors that go around on their own, a robot could offer an informative, engaging experience of a site, guiding them for a short time. Third, the development of a robot that functions in outdoor environments will allow innovations in terms of robot navigation and localization in changing environments, and in computer vision in full sunlight and changing light conditions as well as insights into people's everyday responses to robots in real-world environments.

Interaction between robots and people is inevitable when robots leave factory environments and start operating in semi-public spaces such as museums or outdoor settings. However, most robots are currently not yet sufficiently sophisticated to have natural conversations with people. Robots do not use the same mechanisms (such as natural language, facial expressions and body language) as extensively as people do to engage in an ongoing dialogue.

From robots that are designed to look like humans - with the same facial expressions, having ears, mouth and eyes - people will expect the robot to be able to see them and to recognize them, to listen to what they are saying and even to understand what they are saying. Also, the appearance of a robot influences the way people think about the robot's capabilities [2]. For instance, Lohse et al. found that the appearance of a robot strongly influenced the user's perception of the robot, when asked for possible functions of and preference to own the iCat, Aibo, BIRON and BARTHOC robots [3]. Hinds et al. found that people felt more personal responsibility for a task when co-working with a more machine-like robot [4], which indicated that people expect more abilities from a more human-like robot than from a machine-like robot.

Autonomous robots have to perceive and interpret the world around them to be able to make decisions, and perform coordinated actions to carry out their tasks [5]. Most robots do not *have* to interact with people. However, when a robot has a social task or function such as a police officer, a receptionist or a tour guide, this interaction with people is key. Robots that carry out social tasks can be described as social robots. To define social robots we use the definition as proposed by Bartneck and Forlizzi [6].

“*A social robot is an autonomous or semi-autonomous robot that interacts and communicates with humans by following the behavioral norms expected by the people with whom the robot is intended to interact.*”

Breazeal classified social robots in four categories [5] as described below:

> **Socially evocative**: encouraging people to anthropomorphize technology in order to interact with it.
>
> **Social interface**: using human-like social cues and communication modalities in order to facilitate both natural and familiar interactions with people.
>
> **Socially receptive**: this subclass contains robots that learn from interacting with humans, for example motor-skills or language.
>
> **Sociable**: socially participative creatures with their own internal goals and motivations.

Fong et al. added three categories to this classification [7].

> **Socially situated**: surrounded by a social environment that they perceive and react to.
>
> **Socially embedded**: interactive with a social environment and other agents and humans, structurally coupled with their social environment and (partially) aware of human interactional structures (e.g., turn-taking).

Socially intelligent: showing aspects of human style social intelligence, based on deep models of human cognition and social competence.

Fong et al. state, “it (*the robot*) must establish appropriate social expectations, it must regulate social interaction (using dialogue and action), and it must follow social convention and norms.” [8]. Most forms and behaviors for robots are copied from people (anthropomorphism), or animals (zoomorphic), because people tend to understand human-like or animal-like cues best. However, even though copying behavior from humans may be the standard to solve the interaction barrier between robot technology and its users, it may not be the ultimate solution. The first computers - a robot is essentially an advanced and dynamic computer - were not designed to resemble humans. Nevertheless, many people tended to treat the computer as a social actor; they applied human social behavior norms to a computer. For example, when a computer needs time to solve a task, people perceive that as thinking, like we do ourselves when trying to solve a difficult task [9]. That is also the case with robots, and since they enter our environments more explicitly, perform tasks originally intended for people, collaborate with people in tasks, and at times look very anthropomorphic this effect may be stronger [10].

Currently, Breazeal’s classification places the robotic tour guides in the subclass “social interface” [5]. However, for the purpose of FROG, we intend to develop a tour guide robot that is socially evocative, offers social interaction to explore a site, is socially receptive as it adapts to people’s emotional states and is sociable as the robot’s goal is to engage small groups. To be able to design a more enhanced robot, we propose to use a product design inspired approach for designing robots and their behaviors where the form, function and transparency of design are key in communicating the products usefulness and state. To do so an iterative design strategy [11] will be used. The results of our research will be evaluated with end users continually using a user centered design approach to understand, influence and improve the reactions and experiences of the end user.

This literature review focuses on the latest developments in robotic tour guides in museums, exhibitions, fairs, conferences or cultural heritage sites. To achieve better insight into the abilities of the current tour guide robots, we will focus on previously developed tour guide robots – those that guide visitors through museums or other kind of exhibition settings and convey information about the exhibits – and the way they interacted with the visitors. Also, robot technology with other relevant functions and roles that may be helpful for the development of a tour guide robot will be investigated.

Much of the previous work on guide robots focuses predominantly on the technical challenges of navigation, localization and collision avoidance, vision, manipulation or robustness. These are essential preconditions for the guide robots, but in this review, we will aim to describe those studies that offer insights into the way people experience and respond to robot behaviors and designs.

The paper is organized as follows; in section 3, several tour guide robots will be described and then the functional behaviors for robots in each phase of guiding visitors will be discussed. In section 4, a theoretical overview of effective robot personalities and behaviors will be described. In section 5 a usage scenario and low fidelity prototype as used in the FROG project to inform the robot's behaviors will be given and in section 6 we will finish with the discussion and conclusions.

3. Robots as tour guides

This section will report on tour guide robots and their behaviors. In "The first robot tour guides" some of the robot tour guides to date will be introduced, to give an overview of the various opportunities in appearance and behavior for robots to guide people around and engage and entertain them.

The following sections will address relevant literature on how people respond to robot behaviors. This will be discussed along the four main phases in guided tours. Namely, 1) approaching and first meeting the group, then 2) leading the group to exhibits, 3) presenting something about the exhibits and 4) finishing the tour. Phase 2 and 3 are likely to be repeated several times during a tour.

The first robot tour guides

Some of the first guide robots were Rhino [12] developed by Burgard et al. and its successor Minerva [13] developed by Thrun et al. and the robots used in the Mobot Museum experiment by Graf et al. [14]. For these robots, many technical specifications are available and much effort was put into the development of robot autonomous navigation and collision avoidance [12]–[14]. The robots were equipped with guiding behaviors such as guiding visitors to several exhibits and presenting information at an exhibit. However, there are no studies available that focus on the visitor experience of these first museum robots.

The first robot created was Rhino by Burgard et al. [12] that was employed in the Deutsches Museum Bonn (see figure 1). This faceless robot offered tours to visitors, and led them through an exhibition using a mixed-media interface that integrated graphics, sound, and motion. At several exhibits, visitors could request further information on the exhibit by pressing a button linked to some optional information presented on the screen. If the visitors did not respond to this opportunity, the robot would proceed with the short program. If visitors were standing in the way of Rhino, it first slowed down and waited for people to step aside, then it made a detour around the people standing in the way, and if the visitors continued to block the path of the robot, it blew a horn to make clear that it wanted to pass. Visitors to the museum were mostly surprised by the fact that the robot was aware of their presence. The robot also had a web-interface and could be controlled by visitors to the web page. So, even though the capabilities of the robot were limited and the appearance was machine-like, people showed interest in the robot and its autonomous reactions.

Figure 1: RHINO GUIDING VISITORS
(obtained from: http://www.cs.cmu.edu/~dfox/museum-projects.html)

Minerva was the successor of Rhino, introduced in the Smithsonian's National Museum of American History for a period two weeks by Thrun et al. [15] (see figure 2). Minerva had an expressive face that was able to convey four different emotions. Unlike Rhino, Minerva asked visitors to move out of her way when they were blocking the path. In "happy" mode, this was a friendly request, but in "angry" mode, her voice became more angry. Minerva updated its internal map of the environment with the data it acquired during guiding. A tour given by Minerva took about 6 minutes, and the next exhibits to be presented were chosen based on the remaining tour time.

FIGURE 2: MINERVA GUIDING VISITORS
(obtained from: http://www.cs.cmu.edu/~dfox/museum-projects.html)

The 5-Year Mobot museum experiment consisted of four robots, all based on the same physical platform, operating system and programming environment. The first to be developed, Chips, was an autonomous robot intended to be a permanent member of the museum staff at the Carnegie Museum of Natural History in Pittsburgh, Pennsylvania. Chips provided audio and visual material to the visitors in the Dinosaur-Hall. The second robot, Sweetlips (visible in figure 3), had the goal of bringing more visitors to the quiet area of the North American Wildlife hall and bringing the stories to life by using high-quality video. The third robot was Joe Historybot, who welcomed visitors, provided tours and tutorials to visitors [14]. These robots needed markers in the environment to know where they were. For Chips and Sweetlips, a complex long-term mood-system was used for creating emotional expression, but because it confused the visitors, it was not implemented in Joe Historybot. Sage was the fourth robot; however, this one did not operate in the same museum (see figure 4).

FIGURE 3: SWEETLIPS
(HTTP://WWW.CS.CMU.EDU/~ILLAH/SAGE/)

FIGURE 4: SAGE
HTTP://WWW.CS.CMU.EDU/~ILLAH/SAGE/)

Other examples of tour guide robots are Rackham, a tour guide robot in “Cité de l’Espace” which is shown in figure 5 [16]. The autonomous tour guide Jinny was developed by Kim et al. [17] to guide visitors around the National Science Museum of Korea (see figure 6). The Robox’ robots performed at Expo.02 (see figure 7) [18]. Tour guide robots have also been developed that were more anthropomorphic such as Robotinho (visible in figure 8), a full-body walking humanoid robot that used speech, emotional expression and several gestures to interact with the visitors around it [19]. Fritz, was a tour guide robot that used a pointing mechanism where the finger and the eye gaze were in-line (see figure 9) [20]. Kuno et al. developed robot guides with effective head motions [21] and [22], for an example see figure 10. Kobayashi et al. worked on a robot that chooses a visitor to answer a question, just as human tour guides do (see figure 11) [23], [24]. From the studies above we can infer that to date at least 10 robots have been specifically developed for museum tour guide application. These robots vary in shape, functionality, interaction capability and research papers mostly report technical specifications rather than early user experiences. We are interested to learn about the effects of tour guide behaviors on visitor experiences.

Figure 5: Rackham (http://www.laas.fr/robots/rackham/data/en/robot.php)

Figure 6: Jinny (http://isrlab.tistory.com/34)

Figure 7: Robox at Expo.02 http://www.bluebotics.com/mobile-robotics/expo02-robox/

Figure 8: Robotinho guiding visitors (taken from[19])

Figure 9: Fritz (taken from [20])

FIGURE 10: ROBOVIE WITH TIMED HEAD MOTION (TAKEN FROM [21])

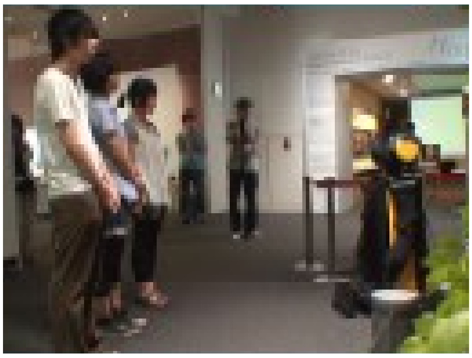

FIGURE 11: ROBOVIE CHOSING A VISITOR THAT IS LIKELY TO PROVIDE AN ANSWER (TAKEN FROM [24])

Since the early robot studies that were mostly technical in nature, several interaction studies have been performed where robotic guides have been tested in museums and at exhibitions to assess their abilities to attract people [25] and their specific (non-verbal) abilities to convey information [22]. Even though we could not find dedicated user studies for all guide robots, the more technical research papers at times discuss observations the research teams had of visitor responses. For example, Burgard et al. states in [12] that the user interfaces of the robot must be robust and intuitive, which is even more important because visitors usually spend less than 15 minutes with the robot. In [14] Nourbakhsh et al. mentioned that the appearance of the robot, the motion – driving around as well as little motion during presentations at an exhibit - and the awareness of the people closeby are of main importance to attract the attention of people. Schulte et al. reported in [26] that they found from observation that people understood the mood changes of the robot when the path of the robot was blocked. These findings even though they are not extended user experience reports, are very helpful when developing new robots for museums and tourist sites.

In the following sections, effective and ineffective behavior of (tour guide) robots will be described divided over four sections that correspond to the four phases of a guided tour.

TOUR GUIDE ROBOTS THAT APPROACH VISITORS

The first thing a robot tour guide should do to establish interaction with people is to recognize and approach them. The context in which people are approached is important. A museum, zoo or cultural heritage site is probably a good place to approach people, as they have time to spend with the robot. Research showed that when people are busy and travelling to or from work or school, they are not interested in a robot that is placed in the environment and that they can look at [27]. Only the people that are not busy look at the robot or even stop and watch the robot's actions. This also happens when a robot actively interacts with people in the street. For instance this happened for ACE, that asked passersby for the right direction [23,] or GRACE, that asked participants of a conference where the lady with the pink hat went [29]. After being asked, people can choose whether or not they want to interact. It seems that in their idle time, people give much more attention to robots than when they are in a rush. When robots are guides in museums, the interest of people is therefore expected to be quite high, because people have time to spend to see the museum and its exhibits, of which the robot is part.

There are different ways of initiating the interaction between a robot and visitors. For example waiting until visitors come to the robot (passive) or searching for visitors and approaching them (proactive). One of the robots in the Osaka-science museum passively waited for visitors to come closer [25]. When visitors were close enough, the robot could read the RFID-tag on the visitor's bracelet and would call the name of the visitors. This invited visitors to come closer and interact with the robot. Several robots have been developed that actively search for visitors (for example [18], [30], [31]). Studies have been performed that focused on understanding the effect of robot approaches on people's experience. For example, Satake et al. developed a model of the way a robot could approach visitors of a shopping mall from observations [32]. They found that the robot had to carefully pick out who it would approach, because people who were idling were found to show interest. The route and speed of the robot's approach was highly important in this interaction too, because if the robot arrived too late at a position, people did not notice the robot.

As Walters et al. showed, when a robot is actively approaching, people prefer the robot to approach from a left or the right frontal position [33]. A robot approaching directly from in front might be experienced as threatening, especially when people are standing with a wall behind them. Not only the direction from which a robot approaches a person influences the user experience, also the path it takes and the gestures it makes. Shi et al. copied the behaviors of people that successfully handed out flyers to a robot. Their eventual algorithm mainly focused on the path the robot would take toward the person (a swoop in from the side) and the handover gesture the robot would make [31]. Another aspect that was found to influence the way a robot's approach was experienced was sound. Lohse et al. [34] found that when a simple wheeled robot would accelerate and decelerate, people were most comfortable when the sounds of accelerating matched the speeding up and slowing down [34].

Satake et al. described four main mechanisms of failing to start an interaction between robot and people; people were unapproachable (because the robot was slower than the target person or the person was leaving), people were unaware of the robot, people were unsure if the robot was talking to them or people rejected the interaction with the robot [32]. Successfully approaching a returning visitor requires recognition abilities and diversity in behaviors. The Inciting, one of the three robots in the Museum für Kommunikation in Berlin actively approached and welcomed groups of visitors to an exhibit. It remembered where each visitor was standing as it welcomed them and therefore did not welcome visitors more than once [30].

Sometimes, visitors need to select interaction modes or languages to interact with guide robots. If the need for user choices are not obvious from the start, this can impede the interaction. A long-term experiment with 11 guide robots at the Expo.02, the Swiss National Exposition in 2002 offered visitors tours guided by a robot. Robox at the Expo.02 was able to use several languages and visitors had to choose one before the robot would start interacting [35]. However, people started interacting with the robot before choosing a language. This lead to confusing situations; the robot was not able to make clear from the beginning what it had to offer to the visitors [18]. However, even after such a difficult start, the interaction between robot and visitors was found to improve the satisfaction.

The studies above show that robot approach behaviors in motion, sound direction and pro-activeness can all influence the human robot interaction. Not only its approach behaviors, also the appearance of a robot can influence people's perception of and experience with the robot. The next section will focus on related literature.

The influence of a robot's appearance on user experience of approaching robots

Robot's will have different interaction modalities which will also influence the appearance of the robot. Having a screen or not makes a big difference, even if a robot has an expressive face. To obtain an interesting and promising interaction between robots and people, the behavior of the robot is important, yet the appearance of the robot must not be neglected. From television and science fiction movies, people have many preconceptions about robots. However, contemporary robots in real life are not as sophisticated as the robots in the movies. When people see a robot their expectations are influenced by popular culture, but robots often cannot fulfill these expectations. The appearance of the robot can help to create a realistic expectation about the abilities of the robot. This makes the physical design of the robot very important. From the presented appearance, people must not overestimate the capabilities of the robot [2]. Not only is anthropomorphism used in the design of robots, it is also used in the design of everyday products. In such products the use of anthropomorphism can have four different functions: (1) Keep things the same; (2) Explain the unknown; (3) Reflect product attributes; and (4) Reflect human values [36]. Anthropomorphism is also used to personalize the product by suggesting, for example a "happy" car or a "sturdy" car.

If robots resemble humans very closely, the *uncanny valley* effect may occur. This theory states that when a robot looks more human-like than machine-like, people tend to associate themselves more with the human-like robot. However, there is a valley where people feel eeriness at the moment the robot becomes more human-like, but does not match the expectations. This effect is even more pronounced when the robots are moving [37]. The more human-like the robots look, the more people are inclined to follow familiar human social rules in the interaction with the robot, as happened with Chips, Sweetlips and Joe Historybot [14]. This application of social rules to the robot can be leveraged by designers of robots, because it predicts people's behaviors. It seems that people anthropomorphize robot features to understand what the robot is doing, and therefore the appearance needs to match the abilities of the robot [2]. Designers use this tendency people have to anthropomorphize to communicate the functions and abilities of the robot. This implies that designers should carefully design the appearance and the functionality of the robot, so these communicate the same abilities of the robot. For designers of robots it is important to understand user expectations. To collect user input on the design of the robot behaviors, personality and appearance early on in the development of the guide robot, the behavior and personality should be evaluated using a user-centered [38] and iterative design approach [11].

Conclusions for Tour Guide Robots that approach visitors

Museums and tourist sites are good places to introduce robots to the public. In these places people have time to explore the entity and have interaction with the robot. A (guide) robot can attract the attention of visitors in an active or in a passive way. However, sometimes the attraction of attention fails as described by Satake et al. in [32]. A passive way to attract the attention of visitors is to stay in one place, call the visitors' names and wait until they approach [25]. An active way of approaching people, is to check whether the people are not busy and then drive to a point while the path taken by the people is calculated and the point to approach is recalculated all the time [39]. When being approached, people like best to be approached from left or right side, so the robot is always in the field of view [33]. Also the appearance of the robot plays a large role during the approach on the understandability and experience of people, as people create an expectation of the robot when it is approaching them. Therefore, the abilities and functionality of the robot should become clear to people already during the approach.

Tour guide robots that Guide visitors from A to B

A guide robot will need to effectively take small groups of people to a next location of interest. Taking a group to a next location is a natural and an easy thing for people, especially for experienced guides, but for robots it is a challenging social task to navigate along or in front of a group in motion. Research on museum robots so far has shown that most people are not experienced with robots. Therefore, they were found to be very curious about the abilities of the robot. In the case of the museum-robot Rhino, people started blocking the path of the robot, to see the reaction of the robot [12]. Rhino would search for a short detour to get past the people and, when the visitors kept standing in the way, Rhino blew a horn. It is interesting that the authors found that people seemed to like to make the robot blow the horn and repeatedly stepped in front of the robot. It seems that people like to test or tease robots, perhaps to have fun with each other. For the successor of Rhino, Minerva, researchers tried another way to get people to step aside. The robot first asked people in a friendly way to move aside. However, when they did not step aside, eventually, the robot would display annoyance by getting a bit more angry every time the robot had to ask people to step aside [13]. This strategy made the robot better capable of clearing a path and guiding visitors around.

It is vital that robots communicate their internal state. Just as for other products, if robots do not give any clue about their status during an action, people will think they are turned off or broken and will lose interest in the product [8]. Keeping people informed about the actions of the robot as they move from exhibit to exhibit is important so as not to lose the visitors. Rackham, for example, showed the visitors on a screen where they were in the tour, and gave information about why they stopped. The robot gave the visitors the feeling that it knew their presence and location all the time [16]. Another good reason to give redundant feedback was found in the five-year Mobot project. The researchers found that redundant responses from the robot were necessary, because people were often part of a group. In that case, some visitors could not hear the robot, or see the screen, because of the crowded area and noisy environment.

Giving feedback on the screen as the robot Rackham did is a useful option. However, people also can read subtly designed cues. There are snail-like guide robots in the Santander bank that use no screen or verbal expressions. Just a line of LED's oriented upwards when requesting which direction the people wish to go and a line of LED's oriented to the floor when guiding, makes the intention of the robot "please follow me, I will bring you to the requested point" clear to the users.

Conclusions on Tour guide robots that Guide visitors from A to B

When robots start moving, people get curious about the abilities and the boundaries of the system of the robot and try to find the limitations, for example by blocking its path. Several robots had different strategies to deal with this visitor behavior, the robot Rhino blew a horn, while the robot Minerva showed moods from happy to angry when requesting visitors to clear the path.

While guiding people to a next point, communicating the intentions of the robot and giving feedback about the actions of the robot is important, otherwise visitors will feel unsure about what is happening or lose interest in the robot. This can be done by giving extensive feedback as the robot Rackham does, however, the guide robots in the Santander bank showed carefully designed subtle cues that were also understood by visitors.

Tour guide robots that engage visitors

A guide robot, unlike a service robot that delivers or retrieves items, needs to engage people in interaction. In this interaction, the robot wants to present the exhibits shown in a museum or tourist site. From the literature on several projects was found that visitors show interest in the tour guides, as they follow them for at least some time. The interactivity of these robots to interact with the visitors was of several levels. Some robots interacted with each other and engaged the visitors with their presence, while other robots had successful guide-visitors interactions with the visitors.

Some of these different levels of interactivity were present with the three robots in the Museum für Kommunikation in Berlin [30]. The three robots had different functions and therefore different behaviors. The robot Twiddling played with a ball, would let it roll away and then searched for it. Visitors could help in searching and bringing the ball back. When Twiddling lost its ball, all the robots started searching together and eventually asked visitors for the ball [30]. This action would entertain visitors without explicit input by the visitors. However, visitors could make a game out of hiding the ball, and this lead to some interaction between the robot and visitors. To be able to establish interaction between robots and visitors, robots need to have an awareness of where the visitors are. This information could be used when welcoming visitors [30]. The Berlin robots remembered the locations where visitors stood, so they would not address the same visitor twice. This location information was also used when guiding visitors and giving information about exhibits. The interaction possibilities were still limited, because visitors could not really communicate with the robot. The robot reacted to the visitors based on limited awareness. This was different for the robot Rackham that was introduced by Clodic et al. [16]. This reacted to people's requests for further information and where they wanted to go. Also, Rackham gave feedback about its understanding of the visitor feedback and its own intentions.

In several projects with robots in museums people were found to be curious about the robots, but they were also destructive, either purposely or accidentally [14], [30]. When robots showed awareness of bystanders most of these were willing to interact with it. The way in which such interactions happened depended highly on the robot's capabilities. We can distinguish between positive and negative interaction. If the robot only has limited capabilities and after a while can no longer entertaining people with its appearance, people typically start to confuse the robot by searching for the system boundaries. In previous research people blocked the robot's path when the robot tried to move from a to b (so as to hear the horn blowing) [12]. This can be seen as a kind of interaction, because a person and a robot react to each other, but we term this negative interaction, as the interaction does not make full use of the robot's capabilities and opportunities of guiding. This kind of interaction can be explained by the fact that the presence of a robot is new for most people, and they want to know more about the abilities and functions [12].

Positive interaction is when the robot can attract people and when people and a robot have a cooperative interaction. In order to achieve this, the robot needs to be really clear of its expectations of the bystanders. ACE, for example, asked passers-by to point to the direction of its desired destination. While ACE talked to people, they could only answer by making gestures and pushing buttons. As ACE was explicit about this, users were found to have no problems in interacting with the robot [28]. From this experiment, Weiss et al. learned that people recognized the object as a robot and were curious about what it was doing. People are willing to interact with the robot, as long as the first interaction is positive. Furthermore, people who had been interacting with the robot were more positive about it than people who just watched the same interaction.

Even when a robot has a quite positive interaction with some people, other people can disturb the interaction. In the Osaka Science Museum in Japan, some robots were deployed. One of these robots read the RFID-tags people were wearing and called their name if they were close, to start an interaction. Even while this worked well sometimes. At other times when the robot called someone’s name to get attention, other people gathered around the robot, too, and wanted to have their name called as well [25], so they disturbed the interaction.

Another problem may be that visitors might interact with the robot and are having fun, but may not pay attention to the information given by the robot. This was found for the interactive robot Robovie at a train station (Gakken Nara-Tomigaoka Station) close to Osaka in Japan [27]. People were asking the robot for directions, even if the destinations were in sight, just because they wanted to interact with the robot. However, the other way around is also possible. Shiomi et al. found with their project in the Osaka Science Museum that when a robot attracted children’s attention, and presented information about the exhibit, the children also became interested in the exhibit, because the robot was guiding them there [25]. This shows that perhaps especially for children, a robot tour guide could attract attention effectively, and focus their attention towards objects of interest but the right balance between attracting attention and directing attention to the objects of interest is needed.

A tour guide robot can use different modalities to interact with users, depending on its functionality and morphology. By communicating through gestures, sound, GUI, head movement and such, a robot can gain and guide the users’ engagement.

Robot Guide Behaviors are defined by appearance

The ongoing interaction between a guide robot and visitors is comparable to a dialogue, even if the interaction is non-verbal. However, the way the robots are able to communicate with visitors is not always human-like as the robots do not have the modalities to perform exact human-like behavior. So, the appearance of the robot, which is partly defined by the modalities to interact with the robot and partly by the creativity of the designer, influences the dialog.

Some of the robots described have emergency buttons. These are to give people interacting with the robots a greater feeling of safety, as they can have some power over the robot. However, in some cases people pushed the emergency buttons just for fun, just to find out what would happen [14], [30]. Although the buttons are not intended for interaction, people tried to interact with the system by pushing the button. Therefore, the design of the robot should make clear that the robot can be stopped in case of emergency, but that it is not an actual way of interaction, as people are also discouraged from pushing fire alarm buttons in buildings.

Multiple methods of interaction, such as speech, touchscreen or gestures are possible for the robot. It is important to provide redundant ways of interacting with the robot, as people also use redundancy to interact with other people [16]. Museum guide robots to date can roughly be distinguished into two types: the ones with screens and ones that are more anthropomorphic. The robots with screens are more like mobile kiosks; the screen is the premier mode of communicating information and interaction, such as for the robots Rhino, and Rackham. More anthropomorphic or humanoid robots display more human-like mannerisms in interaction with the visitors, such as the robots Fritz and Robotinho. However, combinations of both ways are also used, such as is the case for Robox, Minerva and Jinny.

Some of the robots described use a touchscreen or buttons that allow visitors to react to the robot. This is a useful way to interact, because then speech recognition is not necessary – as this can yield problems in noisy environments in public spaces - and the screen can present how to interact with the robot. However, the disadvantage of using only a screen for interaction is that when the robot is using natural language (either prerecorded or synthesized) to the visitors, visitors need to figure out how to react to the robot in the beginning, since reacting using a screen is not straightforward while also interacting with a talking entity [18]. The robot ACE suffered from this problem, too, but the robot was very good at explaining to visitors how to answer questions through gestures, so that the way to interact with the robot became clear to the visitors [28].

Robots may use emotional cues such as happiness or sadness to interact with people. However, not all emotional cues can be applied to all kinds of robot faces. For example, problems can occur when using more machine-like faces or faces with fewer degrees of freedom. Of the features in the face, people's eyes give most information. So, when cameras are used in the robot, they are often visible - the lenses cannot be covered if they are to record the presence and location of the visitors - and people tend to see them as the "eyes" of the robot. Although the robot is not always able to recognize visitors through the camera, the camera can be very useful for indicating the direction in which the robot wants to go. The "gaze" of the robot is directed toward the object it wants to go to, so visitors do understand such a cue from human-to-human interaction [13].

There is a difference between robots that use prerecorded speech and synthesized speech and those that do not. Using prerecorded speech the robot will always say the same, or make the same remarks. If there is enough variation, this does not have to be a problem, because museum visitors tend to interact with the robot for a short time and many are not frequent visitors. For synthesized speech, the robot creates sentences with the words it knows and can react more adaptively to the visitors. However, a truly reactive dialogue through speech generation is difficult to achieve and requires a very context- specific setting and extensive modeling of possible dialogues, hence the resulting synthesized speech is often unrelated to the user's question or of poor quality [8].

People use gestures in communication; this includes pointing, depicting with their hands, or just supporting gestures while telling the story. These gestures, especially pointing, will also be of importance for the guide robots. The robots Robotinho by Faber et al. [19] and Fritz by Bennewitz et al. [20] were able to point and turn their head to the point of interest, as if they were focusing on the object of interest. This was found to be a very effective way of directing the attention of the user. However, not all robots will have the modalities available to display human-like behaviors such as a turning head. Gaze only is already a very effective way that people use to communicate intentions to each other and to show their focus of attention [21]. Mutlu et al. showed in a study where they exposed participants to a robot that only gazed at an object that participants had to pick, that gaze alone can direct the users' attention. People leak information to each other through gaze cues (for instance glancing at an object they want to grab), and according to Mutlu et al. people are also able to read such leakage from robots [40].

All robots make sound, because they have motors that make their joint-movements function. These motors make sound that should not be neglected when considering interaction design [41]. This sound can be functional, for example for people to hear that the robot is about to stop (like a car decelerating). On the other hand, communicational sound can be added. This can be in the form of beeps or horns, but also in the form of speech. This choice will influence the other factors of the design of the robot.

Robots can use light to express moods when they do not have an expressive face (fewer degrees of freedom or static face). For example, the robot Daryl uses a combination of light and body language that is especially designed for that robot. The designers have abstracted the human expressions and translated them into robot- specific cues. People were found to be very good at understanding the resulting robot-specific cues [42]. More information about expressive behavior, such as showing moods and emotions, will be described in the section "expression of the internal state/moods."

How Robot personality influences engagement

Personality is, as we use the definition of Tapus et al., "*the pattern of collective character, behavioral, temperamental, emotional and mental traits of an individual that have consistency over time and situations*" [43]. To measure personality traits in people, several scales have been developed in the field of Human Psychology. These scales are also used to measure the perceived personality of robots. One of the most frequently applied personality scales in human robot interaction is the "Big Five Inventory" [44]. This model consists of five traits, being Emotional Stability, Extraversion, Agreeableness, Conscientiousness and Intellect.

Not many cases of applied robot personality in guiding robots have been described. In other areas of robot development, personality is used more often. For robots, mainly the dimension extrovert-introvert is used, because people can distinguish this personality trait in robots very well. The other traits are more difficult to show in robots, however, they are being used more and more [45]–[47].

The question is, why to apply personality to a robot? Designing a personality for a robot makes sense because a personality makes the robot consistent in its behavior and in the interaction, so people can predict what the robot will do next [7]. Research in the field of Human-Computer Interaction (HCI) shows that people are attracted by agents with a complementary personality. Isbister reports in [48] that participants in a study with virtual agents showing several personalities can accurately identify the character's personality type, prefer consistent characters, tend to prefer a character whose personality was complementary with their own. Researchers expect this theory to be true for Human-Robot Interaction as well.

Robots are physically embodied agents. Several studies have been performed to investigate people's preferences for robot's synthetic personalities. People were found to recognize the personality traits of the robot [49]. However, different studies led to various and contradictory results, as will be described in this section, referring to [43] and [49]. For research on robot personality and people's attraction to these robots, mostly only the personality trait extroversion is used. The researchers used different robots with very different appearances; from machine-like, to animal-like, to human-like. Also, the kind of participants participating in the experiments differed as well; from students only, to healthy persons of all ages, to persons in a rehabilitation program. This broad spread of participants make that the conclusion of user's preference for specific robot personality will not become general, however some authors draw these conclusions after the research [43], [49]). The result is that there are multiple best options for robot synthetic personalities possible for different user groups.

In interaction with robots, people tend to apply social rules to the robot, depending on its personality. Below, two main theories for applying social rules to robots are described. First, similarity attraction, which means that participants like robots with the same personality traits they themselves have better than a robot with different personality traits, for example, both are extrovert. Second is complementary attraction, this means that participants like the robot with a different personality trait better than the one with the same personality, for example the person is introvert and the robot is extrovert. Lee et al. found evidence for the theory "complementary attraction" in human robot interaction [49], while Tapus found that "similarity attraction" holds for human robot interaction [43]. The research of Lee et al. was done with a AIBO a dog-like robot (highly zoomorphic), while the research of Tapus et al. was done with a small machine-like robot (less anthropomorphic features). Both are true in their own sub-field of human-robot interaction. Choosing a personality trait based on the theory of "similarity attraction" or "complementary attraction" therefore depends on the kind of robot used, the people the robot will interact with and the sub-field of Human-Robot Interaction.

In other research Woods et al. did not find any projection of own personality to a robot, regardless of whether the robot was in a socially ignorant state or in socially interactive state. However, they found that older persons (above 35, little experience with technology) did not project their own personality to the robot (indicating complementary attraction), but that younger persons (under 35, much experience with technology) did project their own personality to the robot, which suggested similarity attraction [47].

In order to convey and communicate a consistent personality of a robot, a consistent set of behaviors needs to be designed so that there is no incongruity. Even if people interact only for a short time with the robot (as is often the case in museum or exhibit areas), the behavior needs to be consistent (and therefore a specific personality that is consistently represented in the robots' multimodal behaviors is needed).

The perceived personality for a robot depends on the task the robot is performing. Although people like a fun robot, they perform serious tasks better and for a longer timespan with a serious robot. Vice versa, a fun task is better performed with a fun robot personality [50], [51]. In guiding, robot personality has not yet been used extensively. However some of the guide robots show moods to communicate their internal states. Moods are used for guiding robots. And moods are an expression of personality.

Expression of the internal state, robot affect and mood

People are very good at reading facial expressions of other people, even if they are very subtle. Also, these cues when imitated in robots' faces, lead to a better understanding of the robot than when the robot is not showing these cues through facial expressions [40]. Much research has already been done into the communication abilities of robots and the perception of people talking to these robots. For example, the Kismet robot head is able to use human emotional interaction cues and facial expressions in conversation [52]. The ability to express moods gives the robot the opportunity to make clear to people what state the robot is in. Moods are anthropomorphized states of the robot, so people will understand the changing behavior of the robot. Even if moods are robot specific, people can understand such mood cues very well. This was proved with the robot named Daryl, which shows moods by lights and body language [42].

MINERVA [13] and RoboX [35] also did not find major problems in interacting, because they were able to express themselves. These robots had different moods and used these in their reaction to people. Also when people tried to find their boundaries (e.g. blocking its path or playing with the buttons) they told the users to stop, in an angry mood if necessary. The robot felt more like a peer to the visitors, because the robot showed this emotion. Also the robot reacted to people's positive and negative interaction purposes, and therefore people treated it more as a peer. These robots do not display a personality but communicate their internal state through behaviors that suggest emotions such as disappointment, anger, and happiness.

How robots should interact with groups of people

In a museum or a tourist site, visitors are seldom alone. More often people visit as part of a small group of friends or families. For robots, it can be very difficult to interact intuitively with *groups* of people. People have dedicated strategies for group situations, while robots still encounter problems while interacting with many people at the same time. Hence visitors need to take turns [29], or the robot must be equipped with a method to interact with a group - a special group attention control [53] -, or visitors can observe the interaction between another visitor and the robot. People easily understand that a robot is not able to interact with more than one person at once. Therefore, people started to take turns in their interaction with GRACE [29]. This made that all bystanders had an opportunity to interact with the robot, without overloading the robot. However, the robot was not prepared for the turn-taking behavior of the visitors, and therefore had some problems with understanding the interaction.

Conclusions for robots engaging visitors

The previously deployed (guide) robots that had to engage visitors had different levels of interactivity. Either the robots entertained visitors with their presence and interaction with each other (e.g. [30]), or they reacted to the visitors' presence (e.g. [30]), or they established a guide-visitor interaction and effectively guided visitors past exhibits (e.g. [16], [18]).

The studies above show those aspects that need addressing when engaging visitors in a guide-setting. These include providing ways for robots to get out of situations where they are 'tested' by visitors, guiding the interaction by getting explicit feedback from users, directing the visitors attention, using emotional cues to convey internal states and intentions, having consistent personalities and dealing with small groups of people. For the purpose of the FROG project these are all very relevant focus areas. However, more insight is especially needed in guiding the visitors attention and guiding small groups from one location to the next.

Disengaging and ending the interaction

The FROG robot is intended to accompany small groups of visitors for a short while as they explore the environment. Therefore, the robot is envisioned to just give short tours (or parts of tours) and then search for new visitors [1]. A successful tour includes an effective closing. The tour guide robot needs to end the tour appropriately, disengage from the group of visitors and search for the next group.

From the research papers about tour guide robots no information about the robot leaving the visitors could be found. This is probably caused by the fact that people tend to follow the guide robots from a few minutes [16], an average of less than 15 minutes [12], [14], [15], to a maximum of 30 minutes [35] and then just leave the robot even if the tour is not finished. To our knowledge, nothing is reported about either proper reactions of the robot when visitors are leaving or about effective and friendly behavior for the robot when the robot is leaving the visitors. However, also if the aim is to guide visitors just for a short time, the robot should give proper feedback about the end of the tour and say goodbye to the visitors.

Conclusions for leaving visitors

From the research papers no information about leaving the visitors at the end of the tour has been found, as the visitors mostly left the robot before the tour was finished. For the FROG project this means that there should be some research done on the behavior of the robot when visitors are leaving and how the robot can leave the visitors, while the visitors will maintain a positive experience of the tour.

4. Overview of effective robot personalities and behaviors based on relevant literature

As has become clear from the previous chapters, in the design of social robots, several factors play a role - especially if the user experience is taken as the starting point for the design of the robot. First, the robot needs to have an appropriate appearance. The robot also needs to display consistent and congruent behaviours. When it has multiple modalities for interaction (speech, gestures, facial expressions, movement) these need to be aligned to convey a consistent personality. Finally, this personality can make the behavior of the robot understandable and predictable for people. All these factors influence each other, as is made visible in figure 12. To give an example, when the morphology and therefore the interaction modalities of the robot changes – for example arms or not - the behavior of the robot will also change – a robot with arms can point, a robot with eyes can direct attention with its gaze, a robot with a laser pointer will direct attention by pointing the laser.

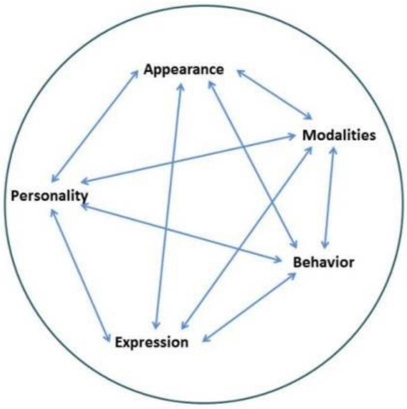

Figure 12: influencing factors of the design of a robot

To classify the previously developed robots, a classification method is used. This method is partly based on the Breazeal's categorization described in the Introduction. These categories are adapted to categorize the robotic tour guides developed to date. *Socially evocative* for a tour guide robot means that people recognize the robot as an anthropomorphic creature and attribute human-like communication features to it although the robot does not really have such features. Also people recognize the communication features of the robot. *Social interface* is the robot giving the people the opportunity to interact and communicate with the robot; however, at this level there is no deep understanding about the human-like social cues and the social communication cues of the robot. *Socially receptive* is for the class of tour guide robots that learn from interacting with visitors, and become better communication partners over time. Finally, a *sociable tour guide robot* is an autonomous entity that decides itself where to go and what to say to visitors, as is classified in chapter 1.

In table 1, the horizontal axis shows robot features found in the literature that support the interaction between robot and people. First, the appearance is given and next the modalities the robot can use to communicate are given, then the actual communication is given, the expression of some emotions to empower the message given by the robot is given and finally, the personality to make the interaction predictable and consistent is given. The goal while developing a robot tour guide is to reach the "the robot as tour guide – personality" level, since at this level the robot acts as an autonomous and social entity.

This table will be used to classify all previously developed museum and tour guide robots. Before that, the robots that will be placed in the diagram will be shortly described.

TABLE 1: DESCRIPTION OF TOUR GUIDE ROBOT ABILITIES IN SOCIAL CLASSIFICATION.

	Appearance	**Modalities**	**Behavior**	**Expression**	**Personality**
Recognize the robot (socially evocative)	Recognize the robot	Recognize the communication features	Understand the robot (imitated) communication features in action	Understand the robots specific expression	Understand the robots predictable and consistent behavior
Interacting with the robot (Social Interface)			Interact with the robot communication features	Interact with the robot as communication partner	Interact with the guide robot
The robot as source of information (Socially receptive)				Communicate meaningfully with the robot	Communicate with the personal tour guide
The robot as tour guide (Sociable)					Learn from and enjoy the autonomous social entity

TABLE 2: CLASSIFICATION OF PREVIOUSLY DEVELOPED TOUR GUIDE ROBOTS.

	Appearance Showing presence	**Modalities** Showing liveliness	**Behavior** Initiate interaction	**Expression** Showing moods	**Personality** Showing personality
Recognize the robot (socially evocative)		Rhino [12]		Chips [14] Sweetlips [14]	
Interacting with the robot (Social Interface)		Inciting [30] Educator [30] Twiddling [30]	Science museum [25]	Minerva [13] Joe Historybot [14] Robox (Expo.02) robots [18] Fritz [20]	
The robot as source of information (Socially receptive)		Head motion robots [21], [22]	Jinny [17] Rackham [16]	Robotinho [19]	
The robot as tour guide (Sociable)					

From table 1 we learn which modalities/behavior/personality a guide robot needs to have to belong to one of the classes of the classification of Breazeal. In table 2 the guide robots to date have been classified in the definitions of table 1. From this table it becomes clear that guide robots are not that sophisticated yet, and that there are still some steps to take to improve the (experienced) social level of the guide robots.

5. BASIC BEHAVIOR SCENARIO FOR THE FROG ROBOT

In the FROG project we aim to develop an indoor/outdoor tour guide robot that is autonomous, shows socially accepted behavior, and that reacts to the actions of the visitors. Also the robot should show a convincing, fun and clear personality. In this deliverable we have focused on the behavior and personality of previously developed tour guide robots to come to effective behaviors and a convincing personality for the FROG robot.

The knowledge obtained by studying previously developed robot behavior and personality, combined with the technical abilities that will be implemented in the FROG robot, lead to a basic scenario for the behavior of the FROG robot. In D1.1 basic behaviors for interaction with visitors are described. A visual representation of these behaviors can be found in figure 13.

This scenario is based on some phases that are part of the robot guiding task (approach visitors, guide visitors, engage visitors with presenting information about an exhibit and leaving visitors) and one phase that is required to be able to start a guided tour (riding in idle; searching for visitors) and will be used to discuss the robot behavior and personality. This scenario shows the basic phases of a guided tour given by the FROG robot, which can be extended by phases, such as added functionality (e.g. indicate exhibits by showing a map to people) or specification of existing phases (e.g. showing a movie or point at exhibit when presenting at an exhibit).

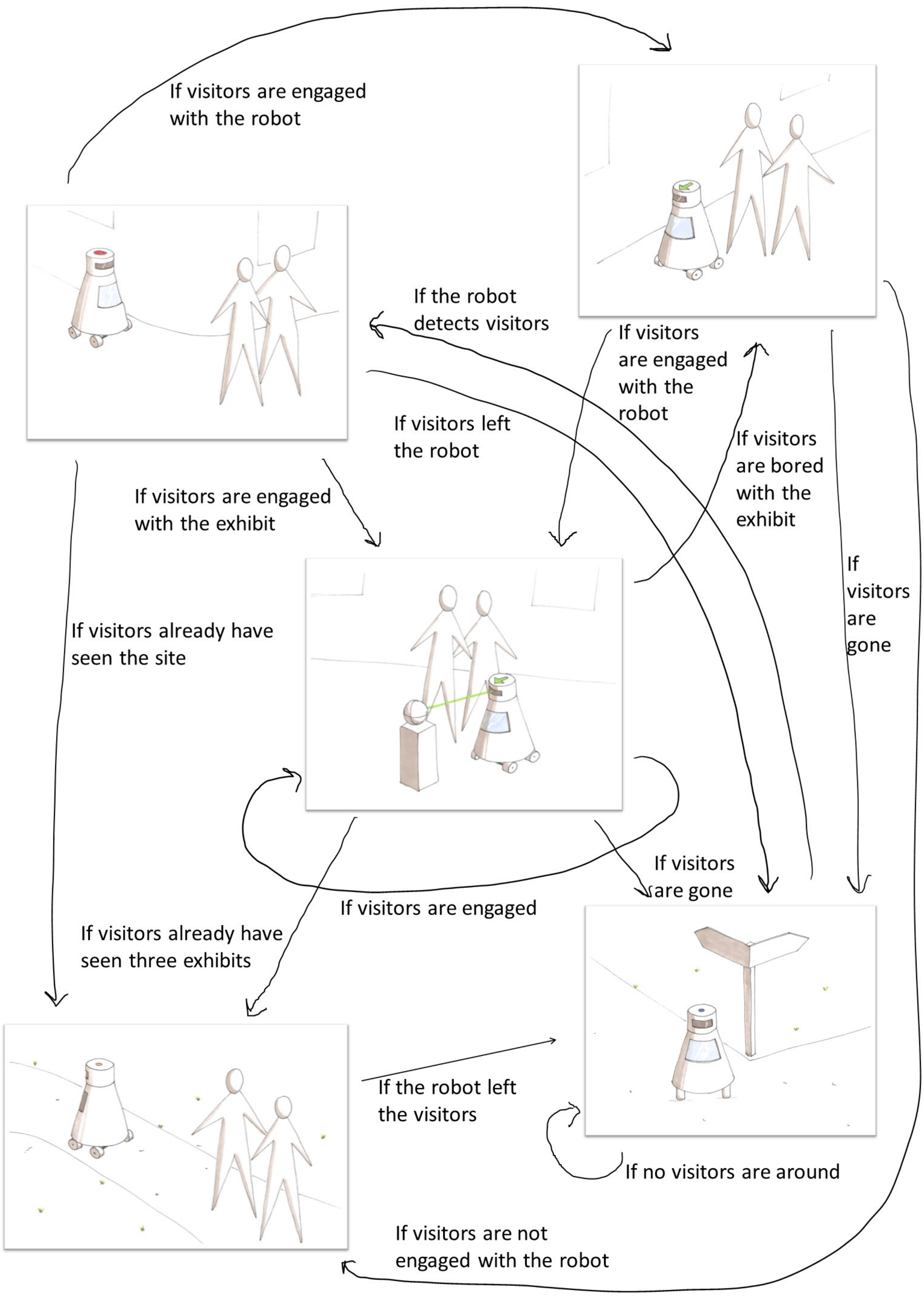

Figure 13: Basic scenario for the FROG robot

6. DISCUSSION

To date several museum and guide robots have been developed. In papers about this previous research a lot of information is given about the technical specifications of the robots; less information about visitors experiences of interacting with these robots and visitor's preferences for robot behavior and personality is given. Still some lessons can be learned from the earlier deployed (guide) robots, which will influence decisions made for the FROG project. The lessons learned that might influence the FROG project are briefly discussed in this section.

From research done with tour guide robots that were developed for museums and tourist sites was found that these leisure sites are good places to introduce robots to the public. In these places people take time to explore the entity and are positive about having interactions with a robot. This is positive for the development of the FROG robot, as the main opportunity for the FROG robot is to give short tours to small groups of people in a part of an indoor/outdoor site, because often less information is given in specific parts of a site and not all people like to join an extended guided tour.

Already a lot is known about robots approaching people and the experience of people of being approached, namely people prefer to be approached from the right or left fontal approach, and when approaching people, the robot should take the path of the users into account to meet them in the right place. This path planning is necessary, because if the robot arrives too soon or too late at the place to meet, people are likely to ignore the robot. However, some issues are still unaddressed in approaching behavior for robots. For example, there should be more research on approaching a group of people that has the focus on something other than the robot, which will be the case for the FROG robot. Also, more research should be done on how to design a robot appearance that communicates the functionality and the capabilities of the robot in a clear manner already when the robot approaches visitors, so that naïve visitors can have short and fun interactions with the robot without dealing with a long learning curve to understand the behavior and personality of the robot.

During a guided tour the FROG robot will lead visitors from one exhibit to another. From previous research was found that it is important for the robot to communicate its intentions during the walk and to give feedback about its actions to the visitors, otherwise visitors are likely to lose interest in the robot and the tour. To make the guided tours of the FROG robot successful, more research should be done on how the robot can communicate its intentions. Our aim is to use limited verbal cues, so the robot needs to use movement, eye animations, information on the screen and/or sound cues. The cues that can be given by the FROG robot depend on the modalities the robot will have, therefore, the effectiveness of the given cues and learnability of the specific cues to understand the intentions of the robot should be researched.

For the previously deployed (guide) robots different levels of interactivity can be observed, for example the robot shows awareness for the presence of people or the robot and the visitors communicate about the topics that the robot will present. During the interactions a distinction can be made between positive and negative interactions. Negative interaction occurs when the robot cannot make full use of its abilities. Positive interaction occurs when the robot can fulfill its task, which is only possible when the robot can communicate its intentions and expectations to the users. In the FROG project the robot should steer the interactions to positive interactions, for example by giving redundant and repetitive cues.

The method of interaction between people and a robot depends on the modalities of the robot. It can be more human-like, which is easy to understand for visitors, or if the robot does not have a human-like face, the robot can use other modalities during the interaction. Several robots used buttons, a (touch) screen, (prerecorded or synthesized) speech and sound and gesture recognition to interact with the visitors. Often the robot was talking to the visitors, but it was not able to recognize the speech of visitors. In these cases the robot had to make clear at the start of the interaction how visitors could react to the robot, as the means for communication are not equal. The FROG robot will not be able to understand visitor's speech, however, to keep the interaction equal, the robot will not talk either. Instead, sound cues to communicate intentions and a voice-over to present content at exhibits will be used.

A personality can be applied to a guide robot to make the behavior and the expressions of the robot consistent. Important in this is that the robot personality must fit the robot function and task it has to perform [50]. For the FROG project more research is needed on robot personality for robots that will interact with multiple people that probably have different personalities.

Until now robots have difficulties in interacting with more than one person (i.e. groups), as most previous research is done on interactions between a robot and a single user. However, in museums and tourist sites, people usually visit in small groups. Therefore, more research on robots approaching groups and interacting with groups is needed for the FROG project.

At the end of a guided tour visitors will leave the robot or the robot has to leave the visitors. The FROG robot should perform this action in a way that is consistent with the rest of its behavior, so some research about how to say goodbye to visitors will be done. However, from previous research we have learned that visitors often leave the robot before the tour is finished. In that case the FROG robot can best ignore the leaving visitors and continue the tour for the remaining visitors.

To come to effective robot behavior and a convincing and consistent robot personality a method for defining behavior that fits the personality, appearance, modalities and expressions should be developed and used. Using this method a guide robot can be created that will educate people while they enjoy following the tour conducted by the autonomous social robot.

7. Conclusions and Future work

To date several guide robots have been developed and all had designed behaviors and personalities to support the interactions with people that were more or less effective. Some behavior, such as blowing a horn to ask people to clear the way, was not effective, because people blocked the robot on purpose to hear the horn as a reward [12]. Minerva used moods, it first asked in a happy way to clear the path, but if people did not react the robot became angry, which was an effective way of communicating the intentions of the robot [13]. All the effective and less effective behaviors of the previously designed robots inspired the behavior for the FROG robot.

How visitors experience their interaction with a robot, depends on several factors; being: behavior, personality and appearance. These three factors also influence each other, as, for example, a fun and toy-like robot with a serious personality will probably not attract people.

The behavior of the robot and the reactivity to the visitors influences the visitors' experiences in such a way that the interactivity becomes natural or requires a long learning curve. Human-like behavior for robots can make the behavior intuitively understandable. However, when not applied well, it can make the interaction awkward. Therefore, the behavior for robots that only have short term interactions with people should be designed to be understandable and clear to people at first interaction.

The appearance of the robot is of importance to the interaction between robot and people. The appearance of the robot is influenced by and the presence of modalities (e.g. a human-like face, arms, a screen), which has an effect on the opportunities for behavior and interaction.

Personality can be applied to robots, and it will help to make the behavior of a robot more consistent. To date much research has been done on which robot personality will attract which human personality (similarity or complementary attraction). The FROG robot will interact with all kinds of human personalities, sometimes even different personalities in one group, which makes it impossible to fit the robot personality to the personalities of all visitors. Most important for the FROG robot is that the personality will fit the task the robot performs. For example, the tours given by the FROG robot should be fun to follow, therefore the robot should have a fun personality rather than a very serious personality.

In guiding visitors though museums, zoos or cultural heritage sites, four phases in guiding visitors can be distinguished. All phases ask for specific behaviors of the robot. First the robot should approach the visitors without scaring them; a good way to approach them is from within their field of view. Then the robot should guide them to an exhibit; in this phase it is very important to keep giving feedback about the actions and intentions of the robot, otherwise it will lose visitors. At exhibits the guide robot should engage the visitors and present information; the behaviors found for the different robots varied a lot based on their modalities, however, reaction to visitor actions was important for all robots to be able to engage visitors. At the end of a tour the robot should leave the visitors, or visitors will leave the robot; this should also influence the visitors experience in a positive manner.

In future work, first human tour guides will be observed to get inspiration for the behavior and personality for the FROG robot. After that the behavior for the robot will be iteratively tested and evaluated in controlled lab experiments as well as in field studies. The full deliverable D4.1 will report on effective guide behavior, present a list of design guidelines for robot specific behavior and a list of guidelines for designing a convincing robot tour guide personality.

Also in future work the guide scenario for the FROG robot will be extended and specified as more becomes known about effective behavior and personality and expected functionality.

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