EXPLORING THE UNCANNY VALLEY WITH GEMINOID HI-1 IN A REAL-WORLD APPLICATION

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ABSTRACT

This paper presents a qualitative analysis of 24 interviews with visitors of the ARS Electronica festival in September 2009 in Linz, Austria, who interacted with the android robot Geminoid HI-1, while it was tele-operated by the first author. Only 37.5% of the interviewed visitors reported an uncanny feeling with 29% even enjoying the conversation. In five cases the interviewees' feelings even changed during the interaction with Geminoid HI-1. A number of possible improvements regarding Geminoid's bodily movements, facial expressivity, and ability to direct its gaze became apparent, which inform our future research with and development of android robots.

KEYWORDS

Android Science, Human Robot Interaction, Real-world Application, Tele-operation, Uncanny Valley.

1. INTRODUCTION

Within the last decade the development of very human-like anthropomorphic robots, which are at first glance indistinguishable from real humans and often referred to as "androids", has become feasible. The combined outcome of several laboratory studies allows the conclusion that the sheer outer appearance of an android heavily influences an interlocutor's expectations and attitudes, especially so when the android is eye-blinking and slightly swaying with its body. The first impression changes, however, when people start realizing the android's artificiality. In that moment, they often report a strange feeling of uncanniness and Mori (1970) predicted this effect and summarized it as the "uncanny valley" hypothesis, which we set out to investigate further.

In the exploratory study presented here we address the question, if the android Geminoid HI-1 enacts similar uncanny feelings in humans when it is embedded in a completely different situational context outside of a laboratory. This "real-world application" was realized during 2009's "ARS Electronica" festival, which takes place every year in Linz, Austria. The android Geminoid HI-1 together with its creator was announced as a special attraction in the overall context of the arts festival. It was installed in the basement of the ARS Electronica building and for the research question at hand it was tele-operated from a distant location by the first author. In effect, visitors interacting with Geminoid HI-1 were prone to believing that Geminoid HI-1 was either (1) a real human interlocutor, or (2) an autonomous, artificially intelligent, android robot, or (3) a tele-operated "puppet" robot, as it was indeed the case.

In order to assess the impressions, feelings, and opinions after having conversed with Geminoid HI-1, we conducted post-hoc one-on-one interviews with 24 randomly selected visitors of a total of approximately 100 visitors, who took the chance to interact with the tele-operated android. This article presents the results of a qualitative interview analysis and our preliminary finding is that the uncanniness of a tele-operated android like Geminoid HI-1 can be diminished, if an operator is good at entertaining an audience and the android is embedded in a situational context that is suitable for such an entertainment.

The remainder of this paper is structured as follows: In the following section related work will be introduced. In Section 3 we will first give a general outline of the setup, before we describe the acquisition of 24 personal impressions. The results of a qualitative analysis of these interviews will be presented in Section 4 and the final Section5 will conclude the paper with a discussion.

2. RELATED WORK

Geminoid HI-1 was developed as to closely resemble the outer appearance of its creator Prof. Hiroshi Ishiguro. In fact, the term "Geminoid" (Nishio, Ishiguro, & Hagita, 2007) is derived from the latin word "geminus" meaning twin and "~oides" meaning similarity. In contrast to humanoid robots (Kanda, Hirano, Eaton, & Ishiguro, 2004), which are similarly designed to let people associate them with humans, the outer appearances of android robots such as Repliee R1 (Minato, Shimada, Ishiguro, & Itakura, 2004), Repliee Q2 (Shimada, Minato, Itakura, & Ishiguro, 2006), or Geminoid HI-1 (Nishio, Ishiguro, & Hagita, 2007) even feature artificial skin and hair, and they are modeled to the finest detail in the aim to make them indistinguishable from real humans at first sight. With these androids it is possible to pursue research in the field of "Android Science"(Ishiguro, 2005), in which these special robots are seen as "a key testing ground for social, cognitive, and neuroscientific theories." (MacDorman & Ishiguro, 2006)

The effects of an android's anthropomorphic appearance and its body movements have so far mainly been investigated in a number of empirical studies within laboratory environments. The high level of control that can be achieved in such a setting is certainly helpful to collect fine-grained data on specific aspects of human-android interaction. Minato, Shimada, Ishiguro, & Itakura (2004) used the android Repliee R1, for example, to investigate the hypothesis that the uncanny feeling diminishes together with increased complexity of the android's behavior. This hypothesis was supported by a number of subsequent laboratory studies, e.g. (Shimada, Minato, Itakura, & Ishiguro, 2006), but it is still a prime motivation underlying android science research.

Laboratory interactions are rather artificial in nature, because the situational context influences the participants' expectations and attitudes. Bartneck, Kanda, Ishiguro, and Hagita (2007) point to these framing effects, which should be taken into account when investigating the "uncanny valley". Such processes of framing are hypothesized to help cognitive systems (such as humans) to deal with the complexity of decision making by providing explicit situational contexts. Thereby, certain considerations about possible causes and consequences are automatically excluded such that expectations can be generated efficiently. Although Bartneck et al. (2007) did not find evidence for this framing effect in their survey, our data suggests that in case of tele-operated human-android interaction in a public space people seemed to feel less uncanny than in case of similar interactions in laboratory environments.

Accordingly, the research presented here aims to explore, how ordinary people feel during face-to-face interaction with an android robot presented in the context of an arts exhibition. Two important aspects have to be pointed out: First, Geminoid HI-1 could be approached for the first time in a public space instead of a laboratory environment and, second, the android was tele-operated during its interaction with the visitors. Similar real-world setups have been realized and evaluated with less anthropomorphic, humanoid robots, such as "Robovie II" in a science museum (Shiomi, Kanda, Ishiguro, & Hagita, 2007) or in an elementary school (Kanda, Hirano, Eaton, & Ishiguro, 2004) as well as "QRIO" in a classroom of toddlers (Tanaka, Cicourel, & Movellan, 2007). To the best of our knowledge, however, it was the first time ever that multimodal human-android interaction took place in a public space. Accordingly, we hope to provide additional insights that help answering the question of whether or not tele-operated androids might be employed for mediated social interaction in the future.

3. GEMINOID HI-1 AT ARS ELECTRONICA

First, the general tele-operation setup of Geminoid HI-1 (see Figure 1) in the ARS Electronica building in Linz, Austria, is introduced. Then we describe how a selection of visitors has been asked about their impressions and feelings after they interacted with Geminoid HI-1.

Figure 1. Geminoid HI-1 with its creator Hiroshi Ishiguro (left) and in a conversation with two visitors (right)

3.1 General Setup

Figure 2. The tele-operation console (left) and the android Geminoid HI-1 (right) as it was installed during the ARS Electronica festival in Linz, Austria

Figure 2 presents the general tele-operation setup that allowed a human operator (left) to control Geminoid HI-1's head and lip movements in synchrony with the transmission of his voice. Under both arm rests of Geminoid HI-1's chair microphones had been installed (cp. Figure 1) such that the operator could listen to the remote conversation in stereo.

Two video monitors provided the operator with an overview of Geminoid HI-1's surrounding; see Figure 2, left. Between these two screens two webcams were installed both recording the operators upper body. The video stream of the operator acquired by one of them was continuously analyzed for the operator's head orientation and mouth movements using the "faceAPI" software (Seeing Machines). The smaller screen in the bottom center showed the output of this analysis for control purposes.

The acquired head motion data was used to drive Geminoid HI-1's head orientation (up-down and left-right) and mouth movements (opening and closing the lower jaw). The operator's voice was synchronized with the lip movements by delaying it for approx. 0.5 seconds such that Geminoid HI-1 appeared to speak by itself. Furthermore, a trained operator could manage to turn Geminoid HI-1's head as if it were looking at a specific conversation partner. In parallel to these tele-operated movements a separate software module continuously triggered small movements in Geminoid HI-1's face opening and closing its eye lids and moving its cheeks slightly up and down from time to time. [1]

3.2 Structure of the Interviews and Data Acquisition

In order to assess the subjective impressions of randomly selected visitors, we instructed ARS Electronica personnel to conduct structured interviews in German, which were digitally recorded. The two female (75% of the interviews) and two male interviewers (25%) were provided with a two-page instruction sheet to ensure that the same open-response questions were always being asked in the same order.

In the beginning of each interview, we collected each visitor's gender, age, and nationality. Then they were asked whether they worked in the ARS Electronica building, how often they had seen Geminoid HI-1 at ARS Electronica in total, and if they knew Geminoid HI-1 already from either the print media, the television, or from the time of its installation in the Cafe CUBUS of ARS Electronica. The latter was possible because Geminoid HI-1 had been installed secretly in the cafe one month prior to the official ARS Electronica festival for other research projects. The visitors were then asked, if they were school or university students (in the latter case also whether their research area was social science, computer science/robotics, or another one), or currently employed in either the service sector, private sector, or another sector, or if they had retired.

The subsequent open-response part of the interview consisted of the following four parts:

1. Please describe the robot "Geminoid HI-1".
2. Did you get closer to Geminoid? Please justify.
3. How did you feel, when you conversed with Geminoid?
4. Do you believe that android robots like Geminoid could be used to attend meetings or conferences in other countries in the future? Which other application could you possibly imagine for this technology?

The resulting audio files (all but one in German language) were transcribed and a qualitative analysis of these interviews is presented next.

4. RESULTS OF A QUALITATIVE ANALYSIS

4.1 Subjects

Seventeen interviewees are Austrians, three Germans, three Swiss, and one British. Of these 24 interviewed visitors 11 are male and 13 are female and their average age is 38 years (standard deviation 13.9 years). Only one of them worked at ARS Electronica and all except for one had not seen Geminoid HI-1 at ARS Electronica before. Nine reported to having seen Geminoid HI-1 in the print media before (37.5%), six had seen it on TV (25%, three of these also had seen it in the print media), and none of them had seen it at cafe CUBUS. Thirteen (54%) did not know Geminoid HI-1 at all before they interacted with it at the festival.

Two high school students and a total of five university students took part in the interviews. One university student's major was social sciences and none of them studied computer science or robotics. Seven interviewees worked in the service sector, seven in the private sector, and three in another sector. Three retired persons took part in the interviews.

[1] Videos of this scenario are available at http://www.becker-asano.de

4.2 Results

4.2.1 Descriptions of Geminoid HI-1

At first the visitors were asked to describe Geminoid HI-1 in their own words (cp. Section 3.2). To qualitatively analyze their descriptions we extracted all statements that featured either positive (cp. Table 1) or negative (cp. Table 2) connotations.

Table 1. All positive descriptions of Geminoid HI-1 that the visitors came up with grouped by general type of description. The numbers in parentheses represent how often the corresponding description was given

Positive descriptions of Geminoid HI-1 (44 in total)

Human / human-like (13)		
"very human-like" (4)	"looks like a human from a distance" (2)	"eye movement and mouth remind one of human"
"confusingly similar to human original"	"strikingly looking like human"	"outer appearance very similar to human"
"very close to human"	"constructed very human-like"	"reacts very human"
Natural / real (10)		
"very natural" (3)	"very real" (3)	"very realistic from a distance"
"touching hand feels real"	"looks real at first sight"	"realistic head movements"
"feels very good in physical contact"		
Communication skills (5)		
"fun to talk with" (2)	"striking verbal skills"	"verbal skills quite convincing"
"unbelievable verbal skills"		
Interesting (4)		
"interesting to talk to" (2)	"(very) interesting" (2)	
Others (12)		
"(a bit) impressive" (2)	"terrific"	"very likeable"
"very friendly"	"very enjoyable"	"fascinating"
"very convincing behavior"	"nearly lifelike"	"amazingly true-to-detail"
"good facial expressions"	"smartly dressed"	

As summarized in Table 1 in case of positive descriptions the visitors most often either referred to Geminoid HI-1's human-likeness (30%) or to its degree of naturalness / realism (23%). The operator's ability to make people feel positive about Geminoid HI-1 is directly reflected in the visitors' positive impressions of its communication skills (11%) and might also have influenced their interest in Geminoid HI-1 (9%). The remaining 12 descriptions (27%) of Geminoid HI-1 (see "Others" in Table 1) are difficult to categorize, but interestingly with three of them the visitors' directly addressed their positive impressions of Geminoid HI-1's outer appearance and facial movements as well as overall behavior.

In contrast to these 45 positive descriptions of Geminoid HI-1, a total of 30 descriptions appeared to have a rather negative undertone, see Table 2. Only eight (27%) of the negative descriptions were related to the fact that Geminoid HI-1 is a robot and not a real human. Notably, in two of these cases the visitors noticed only from a close distance that Geminoid HI-1 is artificial. In the opposite case, when Geminoid HI-1 was mistaken for a human (see "Human / human-like" in Table 1), two visitors explicitly mentioned that they

only had been fooled as long as they were far away from the android. Ten times (33%) the visitors used emotional expressions to describe negative aspects of Geminoid HI-1.

Table 2. All negative descriptions of Geminoid HI-1 that the visitors gave grouped by type of description. The numbers in parentheses give the number of times the corresponding description appeared

Negative descriptions of Geminoid HI-1 (30 in total)

Robot / not real (8)		
"from close distance artificial figure"	"from close distance not real person"	"one notices that it is a robot"
"because of delayed motor functions not real"	"movements and language reveal that it is not human"	"facial expressions reveal that it is a robot"
"surreal"		
Emotional reactions (10)		
"(a bit) scary" (2)	"a nerving look on his face"	"frightening because so real"
"dreadful real"	"fear is a factor"	"threatening on first sight"
"Face expressionless and frightening"	"scary that one got so far with robots"	"irritating, cannot not smile or laugh"
Outer appearance / movements (12)		
"looks concerned or confused" (2)	"looks a little upset or disturbed"	"seems bored or nervous sometimes"
"feels leathery"	"facial expressions not yet perfect"	"facial expressions are mechanical"
"facial expressions always similar"	"stiff face does not match voice"	"like a Japanese with plastic skin"
"quite thick fingers"	"non-scientist's haircut"	

4.2.2 Approaching Geminoid HI-1 or not

Next, the visitors were asked, whether and why they got closer to Geminoid HI-1 or not. The reasons for approaching Geminoid HI-1 are summarized in Table 3 ordered by descending frequency.

Table 3. Reasons for approaching Geminoid HI-1 given by those 22 visitors, who did get closer to the android

Reason for approaching Geminoid HI-1	**# visitors**	**Reason for approaching Geminoid HI-1**	**# visitors**
To touch it (hand, face, or shoulder)	11	Out of curiosity / novelty effect	4
To check its mechanical design or movements	8	Because of Geminoid HI-1's invitation	3
To start a conversation with it	4	To take a picture	2

Only two of the 24 interviewees did not get closer to the android one of them arguing that she was "not motivated to touch it." The other one preferred to observe her children touching it. Of the remaining 11 visitors who touch the android, three explicitly mentioned that they had followed Geminoid HI-1's invitation. In fact, the operator always tried to persuade visitors not to shy away from touching or even kissing the android Geminoid HI-1. The second most prominent reason for getting closer to Geminoid HI-1 was the visitors' intention to check its mechanical design and movements (cp. Table 3) with some of them intending to make sure that it is indeed a robot.

4.2.3 The Visitors' Feelings

As we set out to explore the "uncanny valley" hypothesis, the interview consisted of one question, in which we directly addressed the visitors' feelings during interaction with it. The visitors' answers are summarized in Table 4.

A total of 14 reported feelings were quite clearly positively valenced, whereas 18 reported feelings had a rather negative connotation (see Table 4, first row). The most frequently reported positive feeling was "amusement", which together with the similar feeling "entertainment" gained a frequency count of seven.

Notably, the one visitor's feeling of entertainment did not result from his interaction with Geminoid HI-1, but from the presence of the other visitors.

These seven positive comments are contrasted by a frequency count of nine for the most frequent negative feeling of "strangeness/uncanniness/weirdness". In only two of these nine cases the visitor's "strange feeling" resulted from him or her touching Geminoid HI-1. Otherwise, this feeling was experienced during conversation alone. It is noteworthy, however, that five responses contained descriptions of both negative as well as positive feelings. For example, for one visitor the conversation with Geminoid HI-1 was "amusing" at first, but after having realized that he only talked "to a computer", he reported having experienced a "weird" feeling. Thus, at least in some cases the visitors either experienced mixed feelings or changed their feelings depending on how the situation evolved over time.

Table 4. Summary of the positive and negative feelings reported by 21 visitors in response to the third question

positive feelings	**# of occurrences (14)**	**negative feelings**	**# of occurrences (18)**
amusing/entertaining	6/1	strange/uncanny/weird	6/2/1
impressive/amazing/respect/cool	1/1/1/1	frightening	3
pleasant	2	unpleasant	2
nothing repellent	1	disgusting/antipathetic	1/1
		confusing /unusual	1/1

Although our question directly addressed the visitors' feelings, three of the 24 responses did not contain any emotion-related information.

4.2.4 Using Geminoid HI-1 for tele-conferencing

Finally, we asked each interviewee, if he or she believed that android robots such as Geminoid HI-1 could be used to remotely attend a meeting or a conference in a foreign country. The majority (42%) of the interviewed visitors did not believe in this possible future application saying "no." The second most frequent reply was a clear "yes" (33%), followed by a "Yes, but..." response (17%), in which cases the visitors believed in the technical possibility but did not find it necessary or in one case even dangerous to use androids for such purposes. Only two visitors (8%) were too uncertain to give a definite answer.

With respect to the question of further future applications of such a technology, the responses suggest that those visitors, who stated example applications, had been influenced by reports on robot technology in the media. Thus, we consider this part of the interview as too biased for taking it into further consideration.

5. CONCLUSIONS

The results can hardly be generalized, because the visitors could only interact with one special type of tele-operated android. Nevertheless, the following preliminary conclusions inform our future research.

When asked to describe Geminoid HI-1, the visitors gave more positive than negative descriptions; cp. Table 1 with Table 2. Especially the operator's entertainment skills seemed to improve the visitors' impressions of the android and one visitor even reported that Geminoid HI-1's eye and mouth movements reminded her of a real human. Most of the negative descriptions, however, were related to the android's outer appearance—especially its face—and imperfections of its movements.

Concerning the visitors' feelings, fear was the predominant emotion—an emotional reaction which is clearly related to the uncanny valley hypothesis, because in contrast to, e.g., anger, fear indicates a person's submissive behavioral tendency to withdraw from a threatening or unfamiliar situation (Ortony, Norman, & Revelle, 2005). In order for someone to feel dominant (i.e., not submissive) and in control, one needs to be able to predict the reactions of an interaction partner from his or her verbal as well as non-verbal feedback (Becker-Asano & Wachsmuth, 2010). Geminoid HI-1's inadequate facial expressivity as well as its insufficient means of producing situation-appropriate social signals (such as a smile or laughter, see Table 2) seems to impede a human's ability to predict the conversation flow.

Accordingly, the results inform our improvements on a Geminoid's ability to transport an operator's social signals. For example, we recently tested the appropriateness of Geminoid HI-1 laughing (Becker-Asano & Ishiguro, 2009) during playful interaction and a new Geminoid android with improved mechanical design has recently been developed.

Concerning the envisaged practical application the majority of the visitors were very skeptical about the future use of Geminoids as the new tele-conferencing medium. Perhaps, however, this skepticism is comparable to the situation just before the widespread success of mobile telephony (McGuigan, 2005) and further research needs to clarify the advantages and drawbacks of this novel interaction technology.

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