Int J Soc Robot
DOI 10.1007/s12369-013-0198-7

The Uncanny in the Wild. Analysis of Unscripted Human–Android Interaction in the Field

Astrid M. Rosenthal-von der Pütten · Nicole C. Krämer · Christian Becker-Asano · Kohei Ogawa · Shuichi Nishio · Hiroshi Ishiguro

Accepted: 30 May 2013

Abstract Against the background of the uncanny valley hypothesis we investigated how people react towards an android robot in a natural environment dependent on the behavior displayed by the robot (still vs. moving) in a quasi-experimental observational field study. We present data on unscripted interactions between humans and the android robot "Geminoid HI-1" in an Austrian public café and subsequent interviews. Data were analyzed with regard to the participants' nonverbal behavior (e.g. attention paid to the robot, proximity). We found that participants' behavior towards the android robot as well as their interview answers were influenced by the behavior the robot displayed. In addition, we found huge inter-individual differences in the participants' behavior. Implications for the uncanny valley and research on social human–robot interactions are discussed.

Keywords Human–robot interaction · Field study · Observation · Multimodal evaluation of human interaction with robots · Uncanny valley

A.M. Rosenthal-von der Pütten (✉) · N.C. Krämer
University of Duisburg Essen, Forsthausweg 2, 47048 Duisburg, Germany
e-mail: a.rosenthalvdpuetten@uni-due.de

C. Becker-Asano
Albert-Ludwigs-Universität Freiburg, Georges-Köhler-Allee 52, 79110 Freiburg, Germany

K. Ogawa · H. Ishiguro
Osaka University, 1-3 Machikaneyama Toyonaka, Osaka 560-8531, Japan

K. Ogawa · S. Nishio · H. Ishiguro
Advanced Telecommunications Research Institute International, 2-2 Hikaridai, Keihanna Science City, Kyoto 619-0288, Japan

1 Introduction

Since Karel Capek's science fiction play *R.U.R.—Rossum's Universal Robots* in 1920 and Isaac Asimov's books like "I, robot", robots—especially humanoid and android robots—are part of our popular culture. The advantages and risks they bring, as well as moral and ethical questions concerning artificial life of very humanlike or android robots are core themes in numerous books and movies. But it is only with the recent advancements in robotics that robots are also becoming more salient in public discourse with regard to the actual applicability of robots to support or accompany us in our daily lives.

Nowadays, the development of robots is considered to have the potential to solve major societal problems (e.g. compensate for decreasing numbers of healthcare employees by providing support in low-priority tasks [1]; rehabilitation of e.g. post-stroke participants [2, 3]) which has been widely discussed [4–6] and indicated by the increasing number of funded research projects. A controversial topic has been and still is how robots should be designed. While some scholars follow a minimal design approach when designing robots (e.g. [7, 8]) others favor robots resembling humans in detail [9]. Ishiguro [9] stated that "humanoids and androids have a possibility to become ideal human interfaces accepted by all generations" (p. 2), because they provide all communicative channels already known to humans. This assumption stands at least partly in contrast to the uncanny valley hypothesis [10] which states that people will react increasingly positively towards increasingly humanlike robots until a certain peak is reached, after which the effect reverses, resulting in negative reactions. Early work on the uncanny valley effect tried to prove its existence using pictures and videos of robots [11–13]. Further studies investigated the uncanny valley in laboratory settings during human–robot interaction. These studies vary greatly in

Published online: 09 July 2013

their addressed research questions, because the uncanny valley is tangent to diverse concepts like anthropomorphism and robot appearance or the perception of agency. The uncanny valley theory has been put into question or critically discussed by several researchers (e.g. [14–16]) who pointed out its conceptual shortcomings and the lack of empirical evidence on the topic. Moreover, there have been attempts to revise or refine Mori's thought experiment in order to transform it into a more fine grained theory [9, 17, 18]. Still a lot of questions remain unanswered, for instance what exactly are the negative or even repulsive reactions and when do they occur? Do they stem from emotional or cognitive processes and how may these reactions be explained? Moreover, it is unclear whether the effect is just a spontaneous short-term reaction which can be overcome by habituation.

With the development of android robots, research on Mori's hypothesis becomes even more important, because androids may be considered to fall into the uncanny valley. A number of studies have been conducted with android robots in laboratory settings (e.g. examining the uncanny valley effect with gaze behavior during human–robot interaction [19–21]). But only little work has been done on androids in field trials. Therefore, we do not know how humans would react to or interact with an android robot in natural unscripted situations. Studies utilizing easily displayable commercial robots (e.g. [22–24]), mobile robots (e.g. [25]) or humanoid robots (e.g. [26–28]) in field studies already revealed that participants show huge inter-individual differences in their behavior towards these robots. We expect that these inter-individual differences in participants' behavior will also be found in interactions with android robots. Moreover, against the background of the uncanny valley hypothesis, we are interested in the impact of the android robot's animation (still vs. moving) on participants' behavior and impressions of the robot. We therefore conducted a quasi-experimental observational field study to investigate how people react towards an android robot in a natural environment dependent on the behavior displayed by the robot. We present data on unscripted interactions between humans and the android robot "Geminoid HI-1" (cf. Fig. 1), which we analyzed with regard to the participants' nonverbal behavior (e.g. attention paid to the robot and proximity).

Fig. 1 Geminoid HI-1 with its human counterpart and originator Prof. Hiroshi Ishiguro

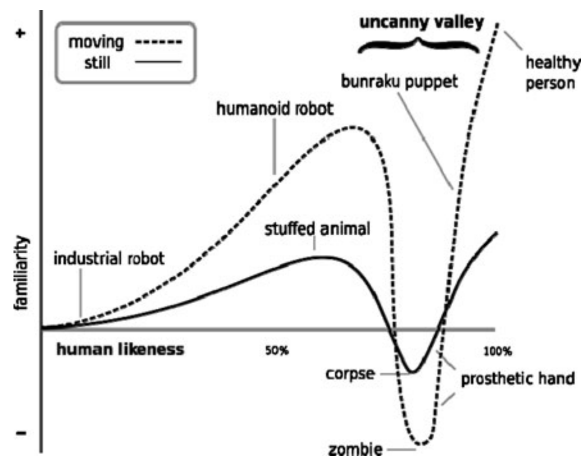

Fig. 2 The Uncanny valley (Ishiguro & MacDorman, 2006)

2 Related Work

2.1 The Uncanny Valley

Recent advancements in robotics, in the field of humanoid and android robots, render the investigation of the uncanny valley increasingly relevant and possible. Ishiguro [9] regards humanoids and androids as ideal human interfaces, because with their humanlike appearance, they offer the human interaction partner all interactive possibilities to which he or she is accustomed in human–human interaction. The uncanny valley theory, however, restricts these possibilities, as will be described in the following. In particular, in the present study, Mori's uncanny valley theory [10] becomes relevant, because according to this theory, people feel more familiar with robots and are more willing to accept them the more humanlike these robots become. However, shortly before the ideal of perfect humanness, the curve breaks inwards; familiarity reverses into uncanniness (cf. Fig. 2) and people react negatively towards the robot (e.g. disgusted, distressed).

Mori describes this effect for *still* as well as for *moving* objects, although the latter are considered as eliciting stronger effects. Although—or because—Mori's theory lacks precise definitions for *realism* or *human-likeness* and *familiarity*, it is suitable for various applications. Also the translation of Mori's dimensions is controversial. The x-axis is represented as the dimension of human-likeness or as the dimension of anthropomorphism. For a long time, the y-axis has been translated as *familiarity*. Bartneck and colleagues [18, 29] discussed that Mori's term *shinwa-kan* might be better translated as *affinity* or *likability* than familiarity. Indeed, a new translation of the original article also poses *affinity* as the most appropriate translation for *shinwa-kan* [30]. With regard to the uncanny valley theory the term *affinity* indeed makes more sense, since it includes a state of acceptance or rejection which is not generally included in the term *familiarity*. Despite the early introduction of the uncanny valley theory to scientific discourse, researchers mostly refer to it anecdotally as an explanation for their unexpected results (e.g. [31, 32]). Thus, since the 1970s, the uncanny valley has been an often-cited explanation in science as well as in the public sphere, which has barely been tested empirically. However, starting in the year 2005 robot scientists have set about the task of investigating the uncanny valley more systematically. First attempts aimed to provide the empirical evidence for its existence [11–13] or to explain the uncanny valley effect using classical work from communication theories [11]. Further studies vary greatly in their addressed research questions, because the uncanny valley is tangent to diverse concepts like anthropomorphism and robot appearance or the perception of agency. For instance Kanda et al. [33] examined the effect of appearance (human vs. bipedal robot vs. wheeled robot) on participants' nonverbal behavior; and Tondu and Bardou [34] discuss implications of anthropomorphism for the uncanny valley; while Gray and Wegner [35] concentrate on mind perception and the uncanny valley.

The following section reports on previous work on the uncanny valley phenomenon as well as previous studies using the same android in similar real world settings and gives a short review on proposed explanations for the occurrence of the uncanny valley effect.

2.2 Laboratory Studies Investigating the Uncanny Valley

Several studies experimentally analyzed the uncanny valley. The approaches of these studies vary a lot and range from employing a single or a set of pictures to videos and interactions with real android robots. A first study by MacDorman ([36], also reported in [11]) addressed possible explanations for the uncanny valley. MacDorman presented participants a picture of a young woman or a picture of a turned-off female android (alongside with other stimuli) and attempted to show that the android reminded the subjects of their own mortality indicated by the emergence of distal defense reactions according to the terror management theory [37]. Participants in the android group showed more distal defense reactions relative to the control group. However, the author discussed that these reactions apply to one particular stimulus, making it necessary to further investigate different stimuli.

Also on the basis of unanimated pictures MacDorman and Ishiguro [11] investigated peoples' reactions towards morphed pictures on a continuum from *mechanical robot* to *humanoid robot* to *human*. Indeed, results showed that at the threshold between mechanical and humanoid robot the perception/experience of *uncanniness* was increasing and the picture was also rated as less *human*. Admittedly, these results were relativized by Hanson [15] who repeated the study based on the same stimulus material (the same mechanical robot, the same human person) but created two different sets of morphs: the first set was identical to MacDorman and Ishiguro's study, the second set comprised morphs which were more attractive. While for the first set the previous results of MacDorman and Ishiguro could be replicated, there was no uncanny valley effect for the more attractive morphs. Hanson concluded that the uncanny valley and the connected negative reactions can be avoided by clever manipulation at least on the level of appearance.

However, the results of these experiments reflect only one side of the uncanny valley, those of the not animated subjects and should be extended also addressing uncanny robotic movement. Consecutively, it has been investigated whether this effect also occurs (and maybe even stronger) while presenting animated stimuli. MacDorman [12] conducted a study in which participants rated 14 videos of various robots with regard to their human-likeness, their familiarity and their eeriness. The set of videos contained two control videos (a human and an industrial robot arm) and 12 videos of predominantly humanoid and android robots which were filmed in different settings fulfilling different tasks. Results did not show a clear uncanny valley effect on the continuum human-likeness. The author concluded that the alikeness with a human is just one of many factors determining the perception of a robot as humanlike, familiar or even uncanny. MacDorman saw this result as indicator that the uncanny valley can be overcome by the manipulation of these other factors (e.g. movement). In contrast to the morphed pictures in previous studies which presented themselves in a consistently gradient change the videos differed extremely with regard to setting, tasks the robots fulfilled, accompanying sound and speech output respectively. The variation of these additional factors movement, tasks, setting, speech output could thus overcome the uncanny valley, which was reported as in line with the results of Hanson's study [15] in which the uncanny valley effect was extinguished by the manipulation of attractiveness.

Ho, MacDorman and Pramono [38] replicated the study based on the evaluation of videos, but concentrated on the assessment of the participants' emotions. In contrast to the previous study, the authors used more comparable videos which did not include sound and showed predominantly the head of the robots. In addition to the typical uncanny valley related items (e.g. "The figure looks strange/eerie/creepy/humanlike.") participants should report their emotional state (e.g. "The figure makes me feel ___."; blanks were filled with emotional term: e.g. disgusted, happy, fear). As a result the authors conclude that eerie and creepy are more appropriate than strange to describe the uncanny valley phenomenon. Moreover, they state that fear is highly predictive for eerie and creepy. The authors conclude that their results cannot rule out one of the two focused explanations (fear of own mortality, mechanism for pathogen avoidance) and frame the uncanny valley as "nexus of phenomena with disparate causes" (p. 175).

Besides the use of pictures and videos also android robots were used in laboratory experiments. In a study by Noma and colleagues [39] participants were confronted in what the authors call a Total Turing Test [40, 41]. Participants saw a human woman or the female android ReplieeQ2 showing either no movement (static condition) or natural movements. Participants were exposed to one of these conditions for either one or two seconds and were asked whether they saw a human or a robot. Not surprisingly the human woman was identified as human most often, followed by the moving android and the static android. Moreover, the fellow human was rated as significantly more humanlike than the static android, while there was no significant difference between human and moving android. The authors see this as an indicator that movement contributes to the human-likeness of the android. The displayed behaviors were, however, still very limited, because they imitated a human sitting naturally. In addition, the authors discuss that the idea of a Total Turing Test is that people are not able to distinguish human and machine on the basis of a longer interaction. In this study, the exposure time was very short, thus, longer exposure could elicit different effects. In a study by Bartneck, Kanda, Ishiguro and Hagita [29] participants engaged in short interactions with an android robot. The study addressed two dimensions of the uncanny valley in a laboratory study using the android robot Geminoid HI-1. First, they compared an actual human with his android counterpart (Geminoid HI-1 and its originator Prof. Ishiguro) and varied the factor *anthropomorphism* for the android (masked android with a visor, android wearing glasses). Second, the movement of the android (or person respectively) was varied. The android or person either showed full movement (head movement, gaze, and randomized subtle movements) or limited movement (look straight ahead at the participant). For the android conditions prerecorded sentences of Prof. Ishiguro were used as well as his nonverbal behavior which was recorded using motion-capturing. For the android in the limited movement condition all movements except lip-synchronization and eye-blinking were deactivated. Participants engaged in a short interaction with the person or android in which they were asked for their age, university affiliation and name. Results showed that the human was rated as more humanlike. However, the human was not rated as more likable, nor were differences found between the android conditions with regard to human-likeness and likability. Movement in the android conditions did not result in any significant effect. However, Prof. Ishiguro was rated as less humanlike in the limited movement condition compared to the full movement condition. The authors discuss the possibility that participants punished the human, because his behavior did not comply with social standards. The android robots, however, may not be subject to these social standards and might therefore be unaffected in their ratings. The authors conclude (a) that movement should be considered as multi-dimensional factor, because it carries social meaning which might also vary between humans and robots, and (b) that also anthropomorphism is a multi-dimensional concept that includes not only appearance, but also behavior. Again, the exposure time was quite short and the interactions were very restricted, thus, we expect that results might be different when participants encounter an android robot for a longer period of time with more freedom regarding the content of the interaction.

2.3 Geminoid HI-1 in the Uncanny Valley? Previous Observations on Geminoid HI-1 in the Field

In fall 2009, the annual "ARS Electronica" festival in Linz, Austria, featured the android Geminoid HI-1 and its creator, Hiroshi Ishiguro, as a special attraction in the overall context of the arts festival. Before the official beginning of the festival, Geminoid HI-1 was placed in the Café CUBUS in the ARS Electronica building. The android robot sat behind a table, with a laptop in front of it and an information desk about Kyoto and its attractions beside it (see Sect. 3 for a more detailed description of the setting). During the festival itself, it was installed as an exhibit in the basement of the ARS Electronica building. Within both settings, different studies (including the study reported in the current paper) took place investigating diverse research questions. Two of these studies will be presented in the following.

Within the Café CUBUS setting, 30 visitor dialogues with Geminoid HI-1 (teleoperated by a fellow participant) were analyzed with regard to the identity perception of the interlocutor facing Geminoid HI-1 and identity creation of participants teleoperating the robot (see [42]). The results show the tendency of both—the teleoperator and the interlocutor—to ascribe an identity to the android robot

Geminoid HI-1, which is independent of the identity of the person controlling the robot. The authors conclude that the humanoid features of Geminoid HI-1 elicit assumptions on the part of the user about the robot's (humanlike) character, expected reactions and conversational skills, which is therefore treated as a social actor (cf. [43, 44]). However, the analysis of the speech sequences also revealed that Geminoid is placed as an "entity 'in-between' " [42], referred to with anthropomorphizing words and human characteristics as well as robotic characteristics. This finding seems to be connected to the argument of Ramey [45], who states that the categorization of objects and experiences is imperative for humans. Robots, however, cannot be categorized easily and reliably into either "human" or "machine" or "alive" and "not alive", because they are at the boundary between these categories.

Becker-Asano et al. [46] report on interviews conducted with 24 visitors to the festival who previously interacted with Geminoid HI-1 within the exhibition. When asked to describe the android robot, the visitors gave more positive descriptions of Geminoid HI-1 (e.g. very humanlike, striking verbal skills, terrific, very likable) than negative descriptions (e.g. surreal, quite thick fingers, too obviously robotlike, a bit scary). When asked directly about their emotional reactions towards the robot, 37.5 % (9 participants) of the interviewed visitors reported an uncanny (or strange or weird) feeling, and 29 % (7 participants) stated that they enjoyed the conversation. Interestingly, for five of these cases, the interviewees' feelings even changed during the interaction. For example, one reported that the interaction was "amusing" at first, but that he experienced a "weird" feeling when he discovered that his interaction partner was actually a robot. Most descriptions of Geminoid HI-1 were related to its outward appearance, with negative attributes being uttered here in particular. Negative descriptions also referred to imperfections of its movements. With respect to emotional reactions, fear was found to be the predominant emotion which relates to the uncanny valley hypothesis, because in theories on emotion fear is regarded as indicating a person's submissive behavioral tendency to withdraw from a threatening or unfamiliar situation (cf. [47]), an assumption which is in line with the work of MacDorman and colleagues [11, 38]. The authors conclude that "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, [...]) seems to impede a human's ability to predict the conversation flow" [46], thus causing feelings of not being in control of the situation.

2.4 Proposed Explanations for the Uncanny Valley Effect and Revised Models

The present study will not directly address possible explanations for the uncanny valley effect, but will examine whether uncanny valley related reactions are also observable in a real world scenario. However, we regard it as important to review the explanations which have been proposed so far in order to discuss our results also with regard to these possible explanations.

Proposed explanations for the uncanny valley effect can be roughly classified as cognitive-oriented approaches and evolutionary-biological approaches. With regard to the cognitive-oriented approaches, MacDorman and Ishiguro [11] identified different explanations for the uncanny valley, for instance the violation of previously triggered expectations. In this context, Cowley and MacDorman [48] emphasize the importance of nature norms (e.g. average body temperature of 36 °C) and interactional social norms. However, androids often violate the expectations of their human interaction partner. This triggering and violating of norms can occur across different modalities and include various perceptual and sensorimotor processes. A very similar explanation has been proposed by Bartneck and colleagues [18] who refer to Minsky's framing theory [49] which explains that we organize knowledge on previous experiences with stereotyped situations in so called frames. Bartneck et al. state that when people encounter a machine-like robot they would select a "machine frame". They propose that the human-like features this robot has would deviate from the expectations, but would attract attention, because humans tend to like other humans. However, when people would meet an android robot, they would select a "human frame". Again the deviations from the expectations—in this case machine like features—will attract attention. Only in this case, these deviations would be disturbing.

An analogical explanation mentioned by MacDorman and Ishiguro [11] is the violation of category boundaries from Ramey [45, 50] who stated that for humans a categorization of all objects and events is obligatory. However, the categorization of humanoid robots or even androids into one of the categories "animate" or "inanimate" cannot be done easily and reliably, because they are at the boundaries between these categories. Since category boundaries are not static, there is the possibility that humans form a third category about humanoid robots through repeated contact which would solve the dilemma. This approach does not see the uncanny valley as a unique phenomenon only involving humanoid robots, but rather regards the uncanny valley as part of a class of cognitive and perceptive states of uncertainty at category boundaries.

MacDorman and Ishiguro [11] also present approaches with origins in evolutionary biology. First, they state that androids are uncanny to the extent to which they differ from the nature norm of physical attractiveness. And second, the authors refer to Rozin's theory of disgust [51, 52]. Disgust is described as an evolutionary developed cognitive mechanism to avoid the risk of infection and the risk of genetically inadequate mating partners. Genetically similar organisms comprise the risk of transferring diseases. Therefore, organisms with completely different genes are not disgusting and neither are healthy exemplars of the own species. Diseased or potential partners with bad genes, however, elicit disgust. MacDorman and Ishiguro [11] summarized that the uncanny valley is a mixture of different phenomena and thus may or must have different causes.

2.5 Research Questions

In conclusion, the uncanny valley is a highly debated theory. As summarized by Bartneck et al. [18] and Blow et al. [53] the proof for Mori's hypothesis has been rather scarce. Studies on the phenomenon show very mixed results. The hypothesis alludes to different concepts which are in itself multi-dimensional (e.g. familiarity, likability and anthropomorphism) and thus cannot be projected into the two-dimensional space of the original uncanny valley graph. Previous experiences with robots will influence our familiarity with them and thus familiarity will change over time. Likability is also a multi-dimensional construct. Whether we like someone (or something) is influenced by manifold factors. We tend to like members of our in-group which has been shown to be true also for fictional groups consisting of humans and computers [54]. Von der Pütten and Krämer [55] identified different characteristics of robot appearances (e.g. mechanical/humanoid/android, but also toy-like and colours) which resulted in different ratings of the robots with regard to their likability. The android robots received different ratings on likability. The mostly Caucasian participants rated the Caucasian looking android as more likable than the Asian or Arabic looking androids. While there is little known about what exactly is perceived as likable when it comes to robots which are not android, it can be assumed that the perception of androids follows the same complex social psychological principles of e.g. group conformity and physical attractiveness which are usually applied in human–human interactions.

With regard to previous work on the uncanny valley hypothesis most studies are limited in their explanatory power, because they use pictures and videos instead of real robots or utilize only one single robot. However, given the limited number of existing android robots, their availability and the immense time and cost effort to conduct a comparative study involving several of these robots, research in the near future will still be limited and only be able to examine specific aspects of the uncanny valley phenomenon.

Also in the present study we will focus on two specific aspects of the uncanny valley phenomenon. First, we want to explore whether uncanny related responses are also observable in human–android interactions in the field where participants are not prompted about the robotic nature of the android and where the situation does not follow predefined scripts. And second, we examine the influence of android movement on uncanny valley related responses in this real world scenario.

According to the uncanny valley hypothesis, the android robot used in this observational field study might fall into the uncanny valley, since the android looks strikingly humanlike. The displayed behavior, however, is very limited and does not reach the quality of the android's outer appearance. It is therefore worthwhile to analyze the gathered data in light of the uncanny valley effect. The presented research provides interesting insights into how people interact with robots in natural environments, although all these studies have certain limitations. In the previously presented Geminoid HI-1 studies, the visitors were prompted to talk about the robotic nature of Geminoid HI-1 or about the experimental situation, because it was explicitly placed at the festival as an exhibit or subjects were invited to take part in a conversation with a tele-presence robot, respectively. The present study also took place within the described setting of the ARS Electronica Festival. In contrast to the studies of Straub et al. [42] and Becker-Asano et al. [46], however, participants were not informed about the robot. Thus, an analysis of these unprompted, unscripted interactions might reveal different reactions towards the robot. Furthermore, interviews only allow for the assessment of reactions that are under conscious control or upon which the participants are able to reflect. What has not yet been analyzed in depth is the human interlocutors' nonverbal behavior, which is more direct and spontaneous. An analysis of participants' nonverbal behavior might thus offer valuable clues as to the nature of human–robot interaction. Finally, addressing an important aspect of the uncanny valley hypothesis, we varied the behavior displayed by the android robot in a quasi-experimental setting in order to investigate whether and how the robot's behavior (still vs. moving) influences the participants' nonverbal behavior (e.g. attention paid to the robot, proximity).

Since the displayed behavior of the robot is not as perfect as its outer appearance suggests, we assume that people encountering the moving android will more easily recognize that they face a robot. According to the uncanny valley hypothesis moving objects will elicit stronger uncanny valley responses than still objects. We thus pose the following hypotheses:

H1: People encountering the moving android will more easily recognize Geminoid HI-1 as a robot than people encountering a still android.

H2: People encountering the moving android will more often report on feelings related to the uncanny valley effect than people encountering a still android.

Moreover, we are interested how people react towards an android in unprompted and unscripted interactions and whether the robot's behavior (still vs. moving) influences participants' nonverbal behavior, leading to the following research question:

RQ1: How do people behave towards robots in a natural environment in unscripted and unprompted situations?
RQ2: Is the participants' nonverbal behavior influenced by the robot's behavior?

3 Method

3.1 General Setup

Prior and during the Ars Electronica Festival 2009 Geminoid HI-1 was placed in two locations at the ARS Electronica Center (AEC) in Linz. The android robot was on display as an exhibit during the festival in the basement of the AEC and prior to the festival it was placed in the Café CUBUS which is also part of the AEC and a well-known tourist café. During the whole time period data were collected for different purposes using different set-ups.

The analyzed data we present here was collected during Geminoid HI-1's time in the Café CUBUS from the 10th to the 30th of August. From this time period we chose those eleven days where Geminoid HI-1 was displayed in the same setting: the android sat on a chair behind a small table with a laptop in front of it in order to give the impression of a working visitor; cf. Fig. 3. Next to the robot, people could find information material about traveling to Japan. The scene was video-recorded from five camera perspectives: one behind the android to record participants just in front of it (cf. Fig. 4), one facing and recording the android (cf. Fig. 5) and three cameras covering the rest of the room.

People were not given any hints that they might encounter a robot within the café. Most of the guests entered the café using the elevator. They then passed the robot on their way to the bar, where the interviewer asked them to participate in a short interview (see Fig. 3). Some guests came from the stairway ("behind" the yellow wall in the direction of the bar) or from the outside patio.

3.2 The Android Geminoid HI-1 in Different Conditions

Geminoid HI-1 is an android robot and a duplicate of its scientific originator Hiroshi Ishiguro (HI). Geminoid HI-1 was designed to function as an embodied interaction tool in a human shape, which can be controlled from a distant location by teleoperation. The robot is covered by silicone skin with natural skin tone, wrinkles etc. Geminoid HI-1 is able to show facial expressions and move its head, torso, arms and legs driven by 50 pneumatic actuators [56]. The robot features idle behavior, which includes breathing, eye blinking and in some cases posture shifts and was designed

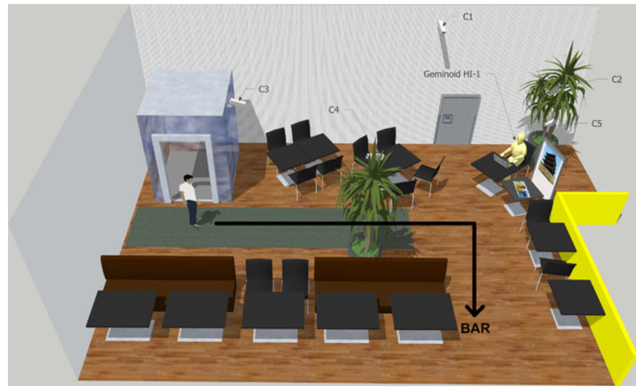

Fig. 3 Setup with Geminoid HI-1 in the Café CUBUS

Fig. 4 View from camera behind Geminoid HI-1

Fig. 5 Camera view recording Geminoid HI-1

to express animation. Further expressive movements can either be separately programmed or executed in real time via teleoperation. During the eleven days of data collection for this analysis, Geminoid HI-1 was presented in two different conditions, which are listed in the following.

Still Condition Geminoid HI-1 was presented in the *still mode*, in which the robot was merely looking down at the

Table 1 Distribution of subjects across conditions

Geminoid HI-1	Hiroshi Ishiguro
Still: $n = 30$	
Moving: $n = 45$	$n = 7$
Total $N = 82$	

laptop in front of it, ignoring passersby. It showed the above-mentioned idle behavior.

Moving Condition In the *moving mode*, Geminoid HI-1 looked up when the participant looked straight in its direction or more precisely in the direction of the camera behind Geminoid HI-1, which used face-tracker software. The face-tracker software module was an extension of the OpenCV-based "Face Detection" source code [57]. It tracked one or more frontal faces over a sequence of images taken from a video stream, allowing Geminoid HI-1 to follow one particular visitor with its gaze, even if he or she was moving slightly. Eight to ten times per second, the algorithm checked with the previously stored information about recognized faces at the very same position. When a previously recognized face stayed in the same place and kept looking frontally into the camera, the algorithm gave this face a one-step-higher priority. If a new person joined the situation and faced the camera frontally, the algorithm started the same procedure of counting up (beginning with priority zero) for the new face. A priority shift took place when the "old" face broke eye contact with Geminoid HI-1, because, for instance, the subject turned to face the newcomer. In this case, the "old" face was no longer observed. The new face then had a higher priority and Geminoid HI-1 faced the newcomer. When nobody interacted with Geminoid HI-1 and the algorithm did not recognize any faces, Geminoid HI-1 returned to look down at the laptop.

Furthermore, seven participants interacted with the human counterpart of Geminoid HI-1, *Prof. Hiroshi Ishiguro*, who sat at the very same table as Geminoid HI-1 working quietly until he was addressed by the subjects.

Table 1 shows the distribution of subjects across conditions. As people went to the café to enjoy their free time and not with the intention to take part in an experiment, we were dependent on their willingness to participate in the interviews. Thus, it was not possible to ensure to have an equal distribution. The experimental design, however, was not the most important aspect of this study, because the investigation of the general reactions towards Geminoid HI-1 was also important. Since the group of participants interacting with Prof. Hiroshi Ishiguro is too small to compute comparisons with the other experimental groups, results will be reported anecdotally in a separate section.

3.3 Interviews

On 11 of the 20 days, passersby were asked to participate in an interview. The interviewer addressed the participants with the following standardized sentences: "Hello. We would like to conduct a brief interview with you if you have a moment. It does not take longer than ten minutes and you would be volunteering to contribute to scientific research." If participants asked what the interview was about, the interviewer told them the following: "The interview is about your personal experience within the last five minutes since you entered the café. We won't ask personal questions and you may withdraw from the interview at any time without giving reasons for withdrawal". The interviewer stood at the entrance to the bar of the Café CUBUS, recruited participants and guided them into a quieter corner of the bar. From the moment of recruitment, participants had no possibility to look back into the room where Geminoid HI-1 and the information desk were placed. The interview was held in German or if necessary in English. First, subjects were asked to provide some demographic information (age, gender, nationality, profession). They were also asked whether they work at the AEC or had been in the café CUBUS before. Then, the interviewer asked whether they noticed the info table next to Geminoid HI-1. If the participants gave a positive answer, they were requested to describe the table. If they had not noticed the table, they were asked whether they perceived something unusual or special when they entered the café. From these follow-up questions, we derived whether the interviewees recognized the robot or mistook it for a human being. As last question all participants were asked whether they happen to know the robot Geminoid HI-1. Participants were debriefed and thanked for their participation.

3.4 Analysis of Videos

We identified the 82 subjects who agreed to be interviewed and videotaped within the video material and extracted the interaction sequences starting from the moment of the subjects' first appearance until they were recruited and guided into the next room by the interviewer. The video material was annotated in ELAN (Max Planck Institute for Psycholinguistics, Nijmegen, The Netherlands; http://www.lat-mpi.eu/tools/elan/, [58]). We assessed different behaviors of the participants. First, we assessed the total time for which people appeared in the videotaped area (which is coded as *appearance time*) and had the possibility to notice the info table and the robot and engage in interactions. We then annotated the participants' attention directed to Geminoid HI-1. In this category, we subsumed two different behaviors: when subjects were in the direct vicinity of Geminoid HI-1, we were able to observe gaze behavior and coded the eye contact established with Geminoid HI-1; when participants were further away, we assessed the amount of time

Fig. 6 Proximity areas

for which they faced Geminoid HI-1 frontally. Both times were summed up as *attention directed towards Geminoid HI-1*. In addition, we coded the *participants' verbal behavior*. We assessed whether, and if so for how long, they talked to Geminoid HI-1, to third persons or said something unrelated to the situation. Furthermore, we looked for *behaviors which attempt to test Geminoid HI-1's capabilities and reactions*, e.g., waving in front of the robot's face, grimacing or making a funny face, raising eyebrows, taking a picture, etc. Lastly, we coded the participant's *proximity* to Geminoid HI-1. Proximity was always coded using the same camera perspective (camera 1) so as to guarantee reliable coding and was based on previously defined proximity areas, namely the "outer area", the "vicinity area", the "adjacencies or table area" and "touch", which are illustrated in Fig. 6. The proximities areas were identified using landmarks which are easily to detect in the videos and did not change during the cause of the experiment. The proximity areas are very close to Hall's proximity zones [59, 60] of the intimate space (<0.46 m = touch), personal space (<1.22 m = table area), social space (<3.66 m = vicinity area) and the public space (>3.66 m = outer area).

We assessed the amount of "eye contact" established by Geminoid HI-1 (looking up and facing a participant). On the one hand we wanted to ensure that in the *moving condition* Geminoid HI-1 was really looking up. On the other hand, the amount of eye contact established by Geminoid varied in the *moving condition*, in dependence of the number of participants surrounding Geminoid HI-1 and participants' eye contact. Furthermore, it was coded whether there was a group situation when the participants encountered the robot (Geminoid HI-1 is alone vs. Geminoid HI-1 is surrounded by visitors when subject arrives) and whether the participants were in company (subject is alone vs. in company) when they entered the café.

Ten percent of the coded video material (videos of 10 participants) was coded by a second rater. The ratings were checked for agreement between the two raters using the inbuilt function in ELAN for comparing annotators. Within this function, the begin time and end time of each annotation is given, and the amount of overlap, the total extent (time from lowest begin time until highest end time) and a value indicating the agreement is calculated (overlap/extent) for each category in each video, which were then averaged over all 10 videos used for cross-coding. The inter-rater reliability values are as follows: 96 % for the category "appearance time of participants", 86 % for the category "attention to Geminoid HI-1", 86 % for category "Geminoid HI-1's eye contact with participant", and 94 % for category proximity. Annotators agreed 100 % on the occurrences of specific behaviors (such as talking to Geminoid HI-1, waving hands in front of the robot's face, taking pictures, grimaces).

3.5 Sample

107 guests were interviewed, of whom 98 (38 male, 60 female) agreed to be audio- and videotaped. Their age ranged from 8 to 71 years ($M = 38.43$, $SD = 14.98$). The majority were Austrians (81), followed by visitors from Germany (12), Italy (2), Spain (1), Belgium (1) and the Netherlands (1). Nine participants were retired, 20 were school pupils or university students, and 61 were employees. Eight participants did not indicate their profession. From these 98 volunteers, 16 interacted with Geminoid HI-1 when it was remote-controlled by a confederate. These data sets were not included into the analysis, because there was too much variation in Geminoid HI-1's behavior. Moreover, seven participants interacted with Prof. Hiroshi Ishiguro. The sample size of this group was too small, thus, these results will be reported separately. The remaining 75 data sets were included for the analysis of interviews and behavior.

Although the Café CUBUS is part of the AEC, it does not only attract visitors to the Center. As it offers upscale cuisine, unique architecture and an outstanding view over the Danube and the local recreation area next to the river, it has many frequent guests as well as tourists coming in. Fourteen participants stated that they had visited the café before, while some stated that their travel guide recommended the café. We thus assume that our interviewees are not predominantly interested in the ACE or the festival, which began two weeks after the data collection. Indeed, only three participants stated that they visited the ACE exhibition before entering the café. We asked participants whether they heard about Geminoid before. Twelve participants indicated that they probably heard of Geminoid. But when the interviewer told them that Geminoid was the Asian man sitting in the café, they were utterly surprised and it was obvious they did not know beforehand what exactly the "Geminoid robot" is. Only two participants were in the exhibition and read about it. One participant was told beforehand by an acquaintance

Table 2 Detection of Geminoid HI-1 as a robot

Recognize Geminoid as...	Still *n*	Moving *n*	Total *n*
A human being	10 (13 %)	7 (10 %)	17 (23 %)
A robot or a puppet	10 (13 %)	30 (40 %)	40 (53 %)
From those who recognized the robot, some stated that they mistook him as a human in the first stance.	*4*	*16*	*20*
Did not recognize Geminoid HI-1 or the info table at all.	10 (13 %)	8 (11 %)	18 (24 %)
Total	*30*	*45*	*75*

All percentages of total $N = 75$

that there is a robot in the café. Thus we are sure that the majority of the participants were neither biased nor had prior experiences with Geminoid.

4 Results

4.1 Interviews

To answer H1, we derived from several open questions (see above) whether participants recognized the robot or mistook it for a human being. Of the 75 participants, 18 made no comments on this question (24 %), because they had noticed neither the table nor the robot. They interpreted the questions as addressing the architecture of the café, which indicates that Geminoid HI-1 was not recognized as uncommon and did not become sufficiently salient for the participants. From the 57 participants (76 %) who recognized the setting with Geminoid HI-1, 17 people mistook Geminoid HI-1 for a human being. Most of these participants did not believe that it was indeed a robot even after the experimenter had told them, and some announced that they would return for a second interaction. Forty participants clearly stated that they had seen a robot, although 20 of these mentioned that they initially mistook the robot for a human (cp. Table 2 for distribution of these statements across conditions).

We calculated Pearson's chi-square test and found a significant association between the manipulated condition (still, moving) and whether or not participants would recognize Geminoid HI-1 as a robot $\chi^2(2) = 8.075$, $p = 0.018$ (see Table 2). This seems to represent the fact that, based on the odds ratio, the odds of participants recognizing Geminoid HI-1 as a robot were 4.35 times higher when Geminoid Hi-1 was displayed in the moving mode.

With regard to H2, namely whether participants make uncanny valley-related statements, we analyzed which reasons people gave for why they recognized Geminoid HI-1 as a robot and whether they stated that they experienced negative emotions. In order to avoid artificially prompting or suggesting experiences of uncanniness, there were no explicit questions regarding participants' possible (negative) emotional experiences with regard to the uncanny valley. However, we found that only four participants mentioned unprompted that Geminoid HI-1 gave them an uneasy feeling ($n = 4$; "it looks so real, a little uncanny"; "I think that might be unpleasant" (to use Geminoid HI-1 for advertising)). When asked why they recognized that Geminoid HI-1 is not human, most participants referred to the stiff posture and abrupt movements ($n = 12$, e.g.: "he sits there in a weird way"; "his movements are too jerky"; "I recognized no movement, the hands..."; "his restricted motor activity") or the lack of movements ($n = 2$, e.g.: "We waved, but he didn't wave back."). Others mentioned that his face seemed like a mask ($n = 5$) and his hands looked unnatural ($n = 8$). Two mentioned that they recognized that the "man" sitting there was jacked up in some way (e.g. "he was jacked up"; "I saw cables"). One participant initially concluded that Geminoid HI-1 might be a disabled person and two thought it was a wax figure. Some participants had difficulties in formulating their first impression of Geminoid HI-1 and eventually described it as "kind of artificial being", "extraterrestrial", or just a "weird person". In sum, different aspects seemed to influence the participants' perception of Geminoid HI-1. As suggested by the uncanny valley theory, crucial factors were the movement as well as the unnatural hands and its unexpressive face.

With regard to the participants' interest in the robot, we found that among the forty participants who recognized Geminoid HI-1 as being a robot, twelve participants stated that they did not engage in longer interactions, because getting a coffee or something to eat was of higher priority than dealing with a robot. However, some suggested that they planned to go back and have a closer look later on.

4.2 Videos of Interactions

According to RQ1, we analyzed different behaviors such as the time people appeared in the café, whether they performed actions to test the robot's capabilities, whether they spoke to Geminoid HI-1, and their nonverbal behavior (proximity to the robot, attention directed towards the robot).

4.2.1 Appearance Time and Testing Actions

The amount of time for which people interacted with (or passed by) Geminoid HI-1 lay between 9.25 seconds and 277.44 seconds (M = 48.17; SD = 47.17). The high standard deviation shows how large the individual differences are in terms of the amount of time people spent in the café before they were asked to be interviewed. Some people quickly passed by the robot, whereas others spent several minutes exploring the robot's capabilities. A one-way ANOVA with the independent variable *condition* resulted in a main effect (cp. Table 3). Participants in the moving condition spent significantly more time in the part of the café where Geminoid HI-1 was placed. A one-way ANOVA with the independent variable *detection of the robot* also resulted in a main effect (cp. Table 4). Participants who recognized Geminoid HI-1 as a robot spent significantly more time in the part of the café where Geminoid HI-1 was placed.

People tried different actions to test whether Geminoid HI-1 would react to them. Only one person touched the robot, although we observed that some accompanying persons touched Geminoid HI-1 while the interviewees watched or took a picture of the interaction. Four subjects waved (partially in front of Geminoid HI-1's face), one stuck out her tongue; one grimaced and two persons raised their eyebrows in an exaggerated manner. Two subjects took a picture or videotaped the interaction and five participants talked to Geminoid HI-1 (for the distribution across conditions, cp. Table 5). Interestingly, these actions by the participants to test Geminoid HI-1 were not performed in the *still condition*, but only in the *moving condition*. Moreover, all the participants who performed these actions stated that they recognized the robot as a robot, except one participant who seemed to be confused by the indirect questions and stated that she did not recognize the info table or anything special or unusual at all, but she observed the robot and waved to the robot.

Table 3 Participants' appearance in seconds in dependence of the condition

	Still	Moving	F	p	η_p^2
	M (SD)	M (SD)			
Appearance time	32.33 (19.94)	58.73 (56.52)	6.02	0.017	0.076

4.2.2 Proximity

Regarding proximity, we wished to ascertain how close people came to Geminoid HI-1 and how long they stayed in the different proximity areas. Here, too, we found great inter-individual differences, indicated by the high standard deviations over all proximity categories. The time spent within the "outer area" varied between 7.48 s and 147.25 s (M = 27.98; SD = 20.35). Most participants at least briefly went through the "vicinity area" and only three of the visitors chose a different path to cross the dining area to reach the bar. The remaining 72 participants were in the vicinity area for between 1.36 s and 243.31 s (M = 12.25; SD = 28.97). Seventeen subjects (22.6 %) entered the "table area" and stood close to the table in front of the robot or surrounded the table to have a closer look at the robot. Subjects remained in the "table area" from 1.14 s to 214.36 s (M = 9.27; SD = 29.44). Only one person touched Geminoid HI-1.

A one-way ANOVA with condition as independent variable and the proximity categories as dependent variables revealed no significant effects (for mean values cf. Table 6). A one-way ANOVA with the independent variable "detect Geminoid HI-1 as robot" and the proximity (vicinity area) as dependent variable revealed a significant effect which shows that people who recognized Geminoid HI-1 as a robot spent more time in the vicinity area (cp. Table 7).

4.2.3 Participants' Attention Towards Geminoid HI-1

We coded the attention which participants paid to the robot as described above. By means of a one-way ANOVA, we found that participants encountering Geminoid HI-1 in the *still condition* paid significantly less attention to the android than participants in the *moving condition* (cp. Table 8). Moreover, a one-way ANOVA with the independent variable "detect Geminoid HI-1 as robot" and the attention participants paid to the robot as dependent variables revealed a significant effect which shows that people who recognized Geminoid HI-1 as a robot paid more attention to it (cp. Table 9).

Table 4 Participants' appearance in seconds in dependence of whether participants recognized the robot

	Recognized Geminoid HI-1 as...			F	p	η_p^2
	... a human	... a robot	... no statement			
	M (SD)	M (SD)	M (SD)			
Vicinity area $n = 75$	29.53 (11.25) $n = 17$	64.31 (58.83) $n = 40$	29.91 (17.71) $n = 18$	5.645	0.005	0.136

Table 5 Distribution of testing actions for the *moving condition* (no actions in *still condition*)

	Touch	Wave	Grimace	Tongue	Picture	Raise eyebrows	Talk to Geminoid
Moving	1	4	1	1	2	1	5

4.2.4 Speech

With regard to speech, we analyzed whether or not people addressed Geminoid HI-1 verbally and how this behavior was distributed across conditions. None of the people in the *still condition* and 11 % in the *moving condition* spoke to Geminoid HI-1 (cp. Table 5). Participants' utterances in the *moving condition* were quite short (three only said "hello", one said "I may take this [brochure], right?" and one said "I am going to take a picture, now. No! Please look up again").

4.2.5 Detection of the Robot

From the interviews, we already know that participants in the *moving condition* were more likely to recognize Geminoid HI-1 as a robot. Besides the actual manipulation of the experiment there might be other factors influencing peoples' ability to recognize that Geminoid HI-1 is a robot. We observed that some participants came alone to the café whereas others came in pairs or groups (participants' company). When people passed Geminoid HI-1 the robot was sometimes surrounded by other visitors and sometimes sitting there alone (group situation). Moreover, the eye contact Geminoid HI-1 established with participants and also the attention paid to Geminoid varied in length. All these factors might influence participants' ability to detect the robot as a robot. Thus, we calculated a correlation analyses between *participants' ability to detect the robot* and the *Geminoid HI-1's eye contact with the participant, group situation* (Geminoid HI-1 is alone vs. Geminoid HI-1 is surrounded by visitors when subject arrives), *company* (subject is alone vs. in company), the length of *subject's attention paid to Geminoid HI-1*. There were positive correlations for participants ability to detect the robot and *participants' attention paid to the robot* ($r = 0.388$, $p = 0.001$, $n = 75$) and *Geminoid HI-1's eye contact with the participant* ($r = 0.364$, $p = 0.001$, $n = 75$). In the following, we wanted to know whether both factors also predict participants' ability to recognize the robot and conducted binary logistic regression analyses [61].

We found that participants' attention paid to Geminoid was predictive. The more attention participants paid to the robot, the more easily people detected it as a robot (cp. Table 10). In addition, we found that Geminoid HI-1's eye contact was predictive. The more eye contact the robot showed, the more easily people detected it as a robot (cp. Table 11).

We assumed this effect to be mediated by the time people spent in the vicinity area. And indeed, the relationship between Geminoid HI-1's eye contact and the participants' ability to detect that Geminoid HI-1 is a robot was fully mediated by the time they spent in the vicinity area. As Fig. 7 illustrates, the standardized regression coefficient between Geminoid HI-1's eye contact and detection decreased sub-

Table 6 Time spent in the vicinity area in seconds in dependence of the condition

	Still	Moving
	M (SD)	M (SD)
Vicinity area	5.13 (7.61)	16.99 (36.27)

Table 7 Time spent in the vicinity area in seconds in dependence of whether participants recognized the robot

	Recognized Geminoid HI-1 as...			F	p	η_p^2
	...a human	...a robot	...no statement			
	M (SD)	M (SD)	M (SD)			
Vicinity area $n = 75$	2.92 (1.34) $n = 17$	20.10 (38.09) $n = 40$	3.58 (3.18) $n = 18$	3.359	0.040	0.085

Table 8 Participants' attention directed towards Geminoid HI-1 in seconds in dependence of the condition

	Still	Moving	F	p	η_p^2
	M (SD)	M (SD)			
Participants' attention	4.09 (7.90)	22.72 (35.65)	7.896	0.006	0.098

Table 9 Participants' attention directed towards Geminoid HI-1 in seconds in dependence of whether they recognized the robot

	Recognized Geminoid HI-1 as...			F	p	η_p^2
	...a human	...a robot	...no statement			
	M (SD)	M (SD)	M (SD)			
Participants' attention $n = 75$	2.81 (3.88) $n = 17$	25.87 (36.47) $n = 40$	3.45 (11.39) $n = 18$	6.389	0.003	0.151

Table 10 Logistic regression for *Detection of Robot* with the predictor *participants' attention paid to Geminoid HI-1*

	B (SE)	95 % CI for odds ratio		
		Lower	Odds ratio	Upper
Included				
Constant	−0.806 (0.32)			
Participants' attention	0.118* (0.03)	1.04	1.125	1.21

Note: $R^2 = 0.35$ (Hosmer & Lemeshow); 0.28 (Cox & Snell), 0.36 (Nagelkerke). Model $x^2(1) = 24.14$, $p < 0.001$. $^*p < 0.01$

Table 11 Logistic regression for *Detection of Robot* with the predictor *Geminoid HI-1's Eye Contact*

	B (SE)	95 % CI for odds ratio		
		Lower	Odds ratio	Upper
Included				
Constant	−0.494 (0.29)			
Geminoid HI-1's eye contact	0.048* (0.02)	1.01	1.049	1.08

Note: $R^2 = 0.14$ (Hosmer & Lemeshow); 0.18 (Cox & Snell), 0.24 (Nagelkerke). Model $x^2(1) = 14.86$, $p < 0.001$. $^*p < 0.01$

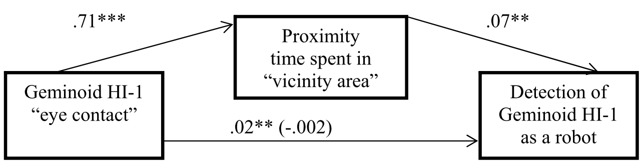

Fig. 7 Standardized regression coefficients for the relationship between Geminoid HI-1's eye contact and the participants' ability to detect that Geminoid HI-1 is a robot as mediated by the time spent in the vicinity area (proximity). The standardized regression coefficient between Geminoid HI-1's eye contact and the detection of Geminoid HI-1 as a robot controlling for time spent in vicinity area is in parentheses. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

stantially when controlling for the time spent in the vicinity area. The other conditions of mediation were also met: Geminoid HI-1's eye contact was a significant predictor of the participants' ability to detect that Geminoid HI-1 is a robot (cp. Table 11) and of the time spent in the vicinity area ($\beta = 0.71$, $t(88) = 9.53$, $p < 0.001$, and also explained a significant proportion of variance, $R^2 = 0.51$, $F(1, 90) = 90.81$, $p < 0.001$). The time spent in the vicinity area was a significant predictor of the participants' ability to detect that Geminoid HI-1 is a robot while controlling for Geminoid HI-1's eye contact (cp. Table 12).

4.3 Participants Meeting Prof. Ishiguro

Of the seven participants who met Prof. Ishiguro, five reported that they had noticed a (human) man behind the table

Table 12 Logistic regression for *Detection of Robot* with the predictor *Proximity* (*vicinity area*)

	B (SE)	95 % CI for odds ratio		
		Lower	Odds ratio	Upper
Included				
Constant	−1.086 (0.32)			
Proximity	0.07* (0.02)	1.03	1.07	1.12

Note: $R^2 = 0.21$ (Hosmer & Lemeshow); 0.21 (Cox & Snell), 0.29 (Nagelkerke). Model $x^2(1) = 21.09$, $p < 0.001$. $^*p < 0.01$

and the remaining two did not notice anything special at all. Prof. Ishiguro established eye contact with all of the participants (M = 29.96 seconds; SD = 49.43). However, participants' eye contact was rather short (M = 8.35; SD = 13.71). One older couple stood in the (or next to the) table area looking at the brochures and asking Prof. Ishiguro briefly whether they were allowed to take one. All other participants did not engage in interactions and just passed by.

5 Discussion

The study aimed to open up a new perspective on the investigation of human–robot interaction with android robots in the field. Thus, this observational field study presented data of unprompted and unscripted interactions between humans and the android robot Geminoid HI-1 in an Austrian café. Ninety-eight participants were invited to take part in an interview and their interactions with Geminoid HI-1 were analyzed with regard to the following dimensions: the appearance time, proximity to the robot, attention paid to the robot, actions to test the robot's capabilities and verbal addressing of the robot.

Unlike previous research investigating human–robot interactions with androids in laboratory settings or in field trials, in which the investigative nature of the study was obvious to the participants [42, 46], participants in this study would not expect to encounter a robot. There were no hints that they would interact with an android robot and the interactions did not follow any script. Given this very free situational context, we were interested in the question of whether people would recognize the android as a robot and whether this is mediated by different degrees of displayed behavior. We found that thirty-five participants either mistook Geminoid HI-1 for a human, or even did not notice it at all, because it did not seem to appear conspicuously non-human. This effect was mediated by the displayed behavior of the android. People in the moving condition were able to most reliably tell that Geminoid HI-1 was a robot, which might be caused by the rather jerky movements of looking up from the table to the participant or re-directing the attention to another participant. The effect was fully mediated by the time people spent in the direct area around Geminoid HI-1. This means that Geminoid HI-1's eye contact caused people to spent more time in its adjacency and thus they clearly also had more time to explore the robot's capabilities.

When subjects became aware of the robot, they took a closer look and some explored Geminoid HI-1's capabilities. Only in the moving condition, participants tested Geminoid HI-1's capabilities by waving their hands in front of its face, saying hello to it, making a grimace or sticking out their tongue in anticipation of an appropriate reaction. Interestingly, these actions were not performed in the *still condition* (also not in the condition with Prof. Ishiguro). This might be due to the fact that people also spent less time in front of Geminoid HI-1 when it did not react at all to the participants. This is in line with the answers to the question of why participants recognized that Geminoid HI-1 is not human given that most participants referred to the stiff posture and abrupt movements. Participants who encountered Geminoid HI-1 in the *still condition* were only able to see very subtle movements (blinking, breathing), if any at all and therefore did not perceive this cue. Two participants mentioned that they recognized that the "man" sitting there was jacked up in some way. Participants in both conditions also mentioned other reasons why they detected the robotic nature of the Asian "man", for instance the lack of movement, its unexpressive face, the clumsy hands or its skin.

With regard to the uncanny valley effect, we assessed whether people reported unprompted about (negative) feelings regarded as being related to the uncanny valley effect such as distress, fear or disgust. In contrast to Becker-Asano et al. [46], who showed that around 37 % of the participants mentioned emotional terms related to fear and disgust, participants in the present study did report less negative feelings in the interviews. Only three people (4 %) mentioned that Geminoid HI-1 gave them an uneasy feeling. We see two explanations for this lack of negative feelings. First, we did not explicitly ask for the participants' feelings and they might hold back with this information, because they did not regard this as important or appropriate to be mentioned during the interview. The second explanation could be that the majority of the participants either did not experience negative feelings, or these negative feelings were only short-term and were not reported during the interview, because the feeling has already vanished or has been resolved during and after the interaction with the robot.

Against the background of Ramey's [45] thoughts on the uncanny valley and his theory that it is difficult to categorize robots into either "alive" or "not alive", it is very interesting that some participants indeed did not instantly describe Geminoid HI-1 as either a human being or a robot. They rather described their first impressions with words indicating their difficulties in categorizing the robot, e.g. "kind of artificial being" or "extraterrestrial". Others described the robot with terms like "disabled person" or "weird person" indicating that they predominantly had the impression of a human being, but recognized something that did not fit into the stereotype of a healthy man. This is in line with the findings of Straub et al. [42], who found that Geminoid HI-1 was perceived as an entity "in-between". However, with regard to the participants' behavior, we found that those participants who noticed that Geminoid HI-1 was a robot showed interest rather than negative reactions. In general, the behavioral data show that although Geminoid HI-1 should fall into the uncanny valley, people were rather relaxed when meeting it in public in this unscripted situation.

Based on related work showing inter-individual differences in HRI [22–28], we assumed that people would show huge inter-individual differences in their behavior. We therefore wished to establish which different nonverbal behaviors can be observed. Indeed, we found inter-individual differences with regard to all categories, as indicated by the high standard deviations for the coded behaviors: appearance time, attention and proximity. When considering the factor whether people recognized Geminoid HI-1 as a robot, we see that for people who failed in recognizing him appearance time was shorter as well as they spent less attention to the robot and spent less time in the vicinity area. For these people the behavior was quite homogeneous as indicated by small standard deviations. For people recognizing the robot as such, appearance time, attention and the time spent in the vicinity area on average were much higher. But the standard deviations indicate that these people showed very different behavior. With regard to the occurrence of testing actions, we also saw that some people tried very different methods to test the robot's capabilities, while others merely observed the scenery.

Furthermore, an interesting finding is that there were also a lot of participants (about 15 %) who virtually ignored the robot and quickly passed by. Although stating in the interviews that they recognized it as being a robot, they decided that getting a coffee was of higher priority than exploring it. This suggests that for a certain amount of people, robots (at least of this type) did not seem to be of high interest. At least in the given situation, they seemed not to care about them being around and proceeded with their planned activities. This corresponds to the findings of Hayashi et al. [26]. In their field study with robots in a train station, people were found to differ in their amount of interest in the robots depending on the time of day and the day of the week. For example, during rush hour, people showed less interest, presumably because they wanted to get to work in time. It is noteworthy that our participants were not predominantly visitors to the Ars Electronica Center, but rather tourists and locals who visit the café frequently because of its good cuisine. Only three participants stated that they visited the AEC before they entered the café. We thus assume that the majority of our participants were not particularly interested in robots. Therefore, further studies should control for the general interest in robots by, for instance, including corresponding questions in their post-experimental questionnaires.

6 Limitations

The quasi-experimental setting of this study was accompanied by several problems. We were dependent on the visitors to the café agreeing to take part in the interviews. This caused an uneven distribution over the conditions, because, for instance, fewer people happened to agree to participate on the days when we installed the *still* set-up. Only those participants that agreed to engage in interviews were included in the video evaluation and this might have skewed the results. When regarding for instance the touching of the robot, we saw that in some cases the participant who agreed to be interviewed did not touch the robot, while the person accompanying the participants touched it. However, the participants' companions were not included unless they agreed in the interviews and video analysis, because we wanted to combine both measures. For future analyses it would be very interesting to analyze the interactions of all persons interacting with Geminoid HI-1. Moreover, the data could be qualitatively analyzed using interaction analysis and conversation analysis techniques.

With regard to the data analysis of the participants' nonverbal behavior, we had to rely on those behaviors that were easily observable in the videos. Although other studies showed that smiling is also an important nonverbal behavior to investigate [22], the quality of the video material did not allow us to code smiling behavior.

Furthermore, we were only able to draw implicit conclusions with regard to the uncanny valley, because the questionnaire did not comprise specific questions asking, for example, participants about their feelings while encountering the robot. For the present study, we did not want to prompt people on the possible uncanniness of the robot to avoid that participants respond socially desirable. However, future studies examining the uncanny valley effect in a similar setting could include interview questions asking for the participants' feelings and their general attitudes towards the robot.

Like the results of other field and laboratory studies, our results apply for the robot used in this study, the android robot Geminoid HI-1, and might not be generalizable to other android robots.

Acknowledgements This work was partially supported by a doctoral fellowship of the Studienstiftung des deutschen Volkes (German National Academic Foundation), by Grant-in-Aid for Scientific Research (S), KAKENHI (20220002) and a post-doctoral fellowship of the Japan Society for the Promotion of Science (JSPS).

References

1. Onishi M, Luo Z, Odashima T et al (2007) Generation of human care behaviors by human–interactive robot RI-MAN. In: Proceedings of the IEEE international conference on robotics and automation, ICRA'07. IEEE Press, New York, pp 3128–3129
2. Matarić MJ, Eriksson J, Feil-Seifer DJ et al (2007) Socially assistive robotics for post-stroke rehabilitation. J NeuroEng Rehabil 4(1):5. doi:10.1186/1743-0003-4-5
3. Matarić MJ (2006) Socially assistive robotics. IEEE Intell Syst 21(4):81–83
4. Broadbent E, Stafford R, MacDonald B (2009) Acceptance of healthcare robots for the older population: review and future directions. Int J Soc Robot 1(4):319–330. doi:10.1007/s12369-009-0030-6
5. Ceccarelli M (2011) Problems and issues for service robots in new applications. Int J Soc Robot 3(3):299–312. doi:10.1007/s12369-011-0097-8
6. Stafford RQ, MacDonald BA, Jayawardena C et al (2013) Does the robot have a mind? Mind perception and attitudes towards robots predict use of an eldercare robot. Int J Soc Robot. doi:10.1007/s12369-013-0186-y
7. Matsumoto N, Fujii H, Okada M (2006) Minimal design for human–agent communication. Artif Life Robot 10(1):49–54. doi:10.1007/s10015-005-0377-1
8. Blow MP, Dautenhahn K, Appleby A et al (2006) Perception of robot smiles and dimensions for human–robot interaction design. In: Proceedings of the 15th IEEE international workshop on robot and human interactive communication (RO-MAN 2006), pp 469–474
9. Ishiguro H (2006) Interactive humanoids and androids as ideal interfaces for humans. In: Paris CL, Sidner CL, Edmonds E et al (eds) Proceedings of the 11th international conference on intelligent user interfaces, IUI '06. ACM Press, New York, pp 2–9
10. Mori M (1970) The uncanny valley. Energy 7(4):33–35
11. MacDorman KF, Ishiguro H (2006) The uncanny advantage of using androids in cognitive and social science research. Interact Stud 7(3):297–337. doi:10.1075/is.7.3.03mac
12. MacDorman KF (2006) Subjective ratings of robot video clips for human likeness, familarity, and eeriness: an exploration of the uncanny valley. In: Proceedings of the cog sci 2006 workshop on android science, pp 26–29
13. Hanson D, Olney A, Pereira IA et al (2005) Upending the uncanny valley. In: Proceedings of the national conference on artificial intelligence, vol 20, pp 1728–1729
14. Brenton M, Gillies M, Ballin D et al (2005) The uncanny valley: does it exist? In: Proceedings of the conference of human computer interaction, workshop on human animated character interaction
15. Hanson D (2006) Exploring the aesthetic range for humanoid robots. In: Proceedings of the cog sci 2006 workshop on android science, pp 16–20
16. Pollick FE (2010) In search of the uncanny valley. In: Daras P, Ibarra OM (eds) Proceedings of the first international conference on user centric media, UCMedia 2009, Venice, Italy, December 9–11, 2009. Revised selected papers. Springer, Berlin, pp 69–78
17. Gee FC, Browne WN, Kawamura K (2005) Uncanny valley revisited. In: Proceedings of the 14th IEEE workshop ro-man, pp 151–157
18. Bartneck C, Kanda T, Ishiguro H et al (2007) Is the uncanny valley an uncanny cliff? In: Proceedings of the 16th IEEE international workshop on robot and human interactive communication (RO-MAN 2007), pp 368–373
19. Shimada M, Minato T, Itakura S et al (2006) Evaluation of android using unconscious recognition. In: Proceedings of the 6th IEEE-RAS international conference on humanoid robots (Humanoids 2006), pp 157–162. doi:10.1109/ICHR.2006.321378

20. Minato T, Shimada M, Itakura S et al (2005) Does gaze reveal the human likeness of an android? In: Proceedings of the 4th international conference on development and learning, pp 106–111
21. Minato T, Shimada M, Itakura S et al (2006) Evaluating the human likeness of an android by comparing gaze behaviors elicited by the android and a person. Adv Robot 20(10):1147–1163. doi:10.1163/156855306778522505
22. von der Pütten AM, Eimler SC, Krämer NC (2011) Living with a robot companion. empirical study on the interaction with an artificial health advisor. In: Proceedings of the 2011 ACM international conference on multimodal interaction, ICMI'11. ACM Press, New York, pp 327–334
23. Sung J (2009) Robots in the wild: understanding long-term use. In: Proceedings of the 4th ACM/IEEE international conference on human–robot interaction, HRI'09. ACM Press, New York, pp 45–52
24. Sung J, Grinter RE, Christensen HI (2010) Domestic robot ecology. Int J Soc Robot. doi:10.1007/s12369-010-0065-8
25. Weiss A, Igelsböck J, Tscheligi M et al (2010) Robots asking for directions: the willingness of passers-by to support robots. In: Proceedings of the 5th ACM/IEEE international conference on human–robot interaction, HRI 2010. IEEE, Piscataway, pp 23–30
26. Hayashi K, Sakamoto D, Kanda T et al (2007) Humanoid robots as a passive-social medium. In: Breazeal CL, Schultz AC, Fong T et al (eds) Proceedings of the 2nd ACM/IEEE international conference on human–robot interaction, HRI'07. ACM, New York, pp 137–144
27. Shiomi M, Kanda T, Ishiguro H et al (2007) Interactive humanoid robots for a science museum. Intell Syst 22(2):25–32
28. Kanda T, Sato R, Saiwaki N et al (2007) A two-month field trial in an elementary school for long-term human–robot interaction. IEEE Trans Robot 23(5):962–971. doi:10.1109/TRO.2007.904904
29. Bartneck C, Takayuki K, Ishiguro H et al (2009) My robotic doppelgänger—a critical look at the uncanny valley theory. In: Proceedings of the 18th IEEE international workshop on robot and human interactive communication (RO-MAN 2009), pp 269–276
30. Mori M, MacDorman K, Kageki N (2012) The uncanny valley. IEEE Robot Autom Mag 19(2):98–100. doi:10.1109/MRA.2012.2192811
31. Hara F (2004) Artificial emotion of face robot through learning in communicative interactions with human. In: Proceedings of the 13th IEEE international workshop on robot and human interactive communication, (RO-MAN 2004), pp 7–15. doi:10.1109/ROMAN.2004.1374712
32. Walters ML, Dautenhahn K, te Boekhorst R et al (2007) Exploring the design space of robot appearance and behavior in an attention-seeking 'Living room' scenario for a robot companion. In: IEEE symposium on artificial life (ALIFE '07), pp 341–347. doi:10.1109/ALIFE.2007.367815
33. Kanda T, Miyashita T, Osada T et al (2008) Analysis of humanoid appearances in human–robot interaction. IEEE Trans Robot 24(3):725–735. doi:10.1109/TRO.2008.921566
34. Tondu B, Bardou N (2011) A new interpretation of Mori's uncanny valley for future humanoid robots. Int J Robot Autom. doi:10.2316/Journal.206.2011.3.206-3348
35. Gray K, Wegner DM (2012) Feeling robots and human zombies: mind perception and the uncanny valley. Cognition 125(1):125–130. doi:10.1016/j.cognition.2012.06.007
36. McDorman KF (2005) Mortality salience and the uncanny valley. In: Proceedings of the 5th IEEE-RAS international conference on humanoid robots, pp 399–405
37. Greenberg J, Pyszczynski T, Solomon S et al (1990) Evidence for terror management theory II: The effects of mortality salience on reactions to those who threaten or bolster the cultural worldview. J Pers Soc Psychol 58(2):308–318. doi:10.1037/0022-3514.58.2.308
38. Ho C, MacDorman KF, Pramono Z (2008) Human emotion and the uncanny valley: a GLM, MDS, and isomap analysis of robot video ratings. In: Proceedings of the 3rd ACM/IEEE international conference on human–robot interaction (HRI 2008), pp 169–176
39. Noma M, Saiwaki N, Itakura S et al (2006) Composition and evaluation of the humanlike motions of an android. In: 6th IEEE-RAS international conference on humanoid robots, pp 163–168
40. Turing AM (1950) Computing machinery and intelligence. Mind 59(336):433–460
41. French RM (1990) Subcognition and the limits of the TuringTest. Mind XCIX(393):53–65. doi:10.1093/mind/XCIX.393.53
42. Straub I, Nishio S, Ishiguro H (2010) Incorporated identity in interaction with a teleoperated android robot: a case study. In: Proceedings of the 19th IEEE international workshop on robot and human interactive communication (RO-MAN 2010), pp 119–144. doi:10.1109/ROMAN.2010.5598695
43. Nass C, Steuer J, Tauber ER (1994) Computers are social actors. In: Proceedings of the SIGCHI conference of human factors in computing systems (CHI 1994), pp 72–78
44. Nass C, Moon Y, Morkes J et al (1997) Computers are social actors: a review of current research. In: Friedman B (ed) Human values and the design of computer technology, vol 72. CSLI Publications, Cambridge, pp 137–162
45. Ramey CH (2006) An inventory of reported characteristics for home computers, robots, and human beings: applications for android science and the uncanny valley. In: MacDorman KF, Ishiguro H (eds) Proceedings of the ICCS/CogSci-2006 long symposium "Toward social mechanisms of android science", pp 21–25
46. Becker-Asano C, Ogawa K, Nishio S et al (2010) Exploring the uncanny valley with geminoid HI-1 in a real world application. In: Blashki K (ed) Proceedings of the IADIS international conference on interfaces and human computer interaction, IHCI 2010, pp 121–128
47. Ortony A, Norman D, Revelle W (2005) Affect and proto-affect in effective functioning. In: Fellous J, Arbib MA (eds) Who needs emotions: the brain meets the robot. Oxford University Press, Oxford, pp 173–202
48. Cowley JS, McDorman KF (2006) What baboons, babies, and Tetris players tell us about interaction: a biosocial view of norm-based social learning. Connect Sci 18(4):363–378
49. Minsky M (1975) A framework for representing knowledge. In: Winston PH (ed) The psychology of computer vision. McGraw-Hill, New York, pp 211–277
50. Ramey CH (2005) The uncanny valley of similarities concerning abortion, baldness, heaps of sand, and humanlike robots. In: Proceedings of views of the uncanny valley workshop: IEEE-RAS international conference on humanoid robots, Tsukuba, Japan, pp 8–13
51. Rozin P, Fallon AE (1987) A perspective on disgust. Psychol Rev 94(1):23–41
52. Rozin P, Haidt J, McCauley C et al (1999) Individual differences in disgust sensitivity: comparisons and evaluations of paper-and-pencil versus behavioral measures. J Res Pers 33(3):330–351
53. Blow MP, Dautenhahn K, Appleby A et al (2006) The art of designing robot faces—dimensions for human–robot interaction. In: Goodrich MA, Schultz AC, Bruemmer DJ (eds) Proceedings of ACM SIGCHI/SIGART 2nd conference on human robot interaction (HRI2006). ACM, New York, pp 321–332
54. Nass C, Fogg BJ, Moon Y (1996) Can computers be teammates? Int J Hum-Comput Stud 45:669–678
55. von der Pütten AM, Krämer NC (2012) A survey on robot appearances. In: Proceedings of the 7th ACM/IEEE international conference on human–robot interaction (HRI 2012), pp 267–268
56. Nishio S, Ishiguro H, Hagita N (2007) Geminoid: teleoperated android of an existing person. In: de Pina Filho AC (ed) Humanoid Robots: New Developments. I-Tech Education and Publishing, Rijeka, pp 343–352

57. OpenCV Wiki FaceDetection. http://opencv.willowgarage.com/wiki/FaceDetection
58. Wittenburg P, Brugman H, Russel A et al (2006) Elan: a professional framework for multimodality research. In: Proceedings of language resources and evaluation conference (LREC)
59. Hall ET (1982) The hidden dimension. An anthropologist examines humans' use of space in public and private. Anchor, New York
60. Hall ET (1974) Handbook for proxemics research. In: Society for the anthropology of visual communication, Washington DC
61. Howell DC (2010) Statistical methods for psychology, 7th edn. Thomson Wadsworth, Belmont

Astrid M. Rosenthal-von der Pütten works as a research associate at the University of Duisburg-Essen, Faculty of Engineering, Department for Social Psychology: Media and Communication. She holds a Master's degree in Applied Cognitive and Media Science. Since 2011 she is a PhD fellowship holder of the German National Academic Foundation for her work on the uncanny valley hypothesis. Her research interests include social effects of artificial entities, especially the uncanny valley, linguistic alignment with robots and virtual agents, presence, and crisis communication in social media.

Nicole C. Krämer is Professor for "Social Psychology—Media and Communication" at the University Duisburg-Essen since 2007. She finished her PhD in Psychology at the University of Cologne in 2001. In the academic year 2003/2004 she was visiting scholar and visiting lecturer at the University of Cambridge, Faculty of Social and Political Sciences. In 2006 she received the venia legendi for psychology with a habilitation thesis on "Social effects of embodied conversational agents" at the University of Cologne. Her research interests include human–computer-interaction, social psychological aspects of web 2.0, nonverbal behaviour and computer supported instructional communication.

Christian Becker-Asano received his diploma in computer science in 2003 and his doctor's degree (Dr. rer. nat.) in 2008 both from the University of Bielefeld, Germany. He was pre-doctoral JSPS fellow at the National Institute of Informatics (NII) in Tokyo, Japan and from 2008 until 2010 he joined the Advanced Telecommunications Research Institute International (ATR) in Kyoto, Japan, as post-doctoral JSPS fellow. After his return to Germany he joined the University of Freiburg pursuing Affective Computing research, first, in virtual reality scenarios and, since 2011, also in the domain of robotic tele-presence systems. Since 2012 he is Lecturer in the Foundations of Artificial Intelligence group of the University of Freiburg, Germany.

Kohei Ogawa received his PhD from Future-University Hakodate, Hokkaido, Japan, in 2010. From 2008 to 2010, he worked as an Intern Researcher in the Intelligent Robotics and Communication Laboratory, ATR, Kyoto, Japan and started research in android science. From 2010 to 2012, he worked in the Hiroshi Ishiguro Laboratory, ATR, Kyoto, Japan as researcher. He is now an assistant professor in the Department of Engineering Science, Osaka University. His research interests include human–robot interaction, human–agent interaction, and interaction design.

Shuichi Nishio received his MSc in computer science from Kyoto University in 1994, D. Eng. from Osaka University in 2010 and is currently a Senior Researcher at the Advanced Telecommunications Research Institute International (ATR) in Kyoto, Japan.

Hiroshi Ishiguro received his PhD degree in engineering from Osaka University, Japan in 1991. He was Research Associate (1992–1994) in the Graduate School of Engineering Science at Osaka University and Associate Professor (1998–2000) in the Department of Social Informatics at Kyoto University. He was also Visiting Scholar (1998–1999) at the University of California, San Diego, USA. He was Associate Professor (2000–2001) and Professor (2001–2002) in the Department of Computer and Communication Sciences at Wakayama University. He then moved to Department of Adaptive Machine Systems in the Graduate School of Engineering Science at Osaka University as a Professor (2002–2009). He is currently Professor of Department of Systems Innovation in the Graduate School of Engineering Science at Osaka University (2009–) and Group Leader (2011–) of Hiroshi Ishiguro Laboratory at the Advanced Telecommunications Research Institute International (ATR). His research interests include distributed sensor systems, interactive robotics, and android science.