



The Uncanny Valley

How human-like should an agent look and behave?

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Papers

Based on the papers:

- 1 Minato, T., Shimada, M., Ishiguro, H., and Itakura, S. (2004). *Development of an Android Robot for Studying Human-Robot Interaction*. *Innovations in Applied Artificial Intelligence* 3029/2004:424-434.
- 2 Tinwell, A. and Grimshaw, M. (2009). *Bridging the Uncanny: An Impossible Traverse?* *Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era*, pages 66-73, October 2009.



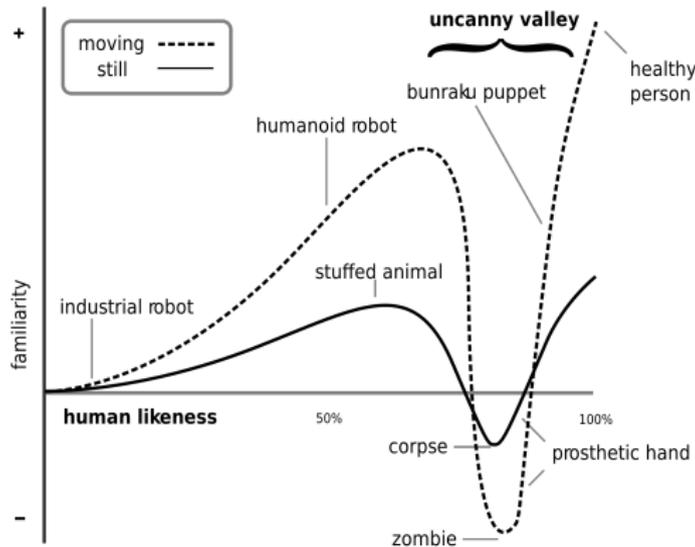
Outline

- 1 Introduction: What is the “Uncanny valley”
- 2 Minato et al. paper; development of an android and experiments
 - theoretical assumptions
 - the experiment
 - discussion
 - conclusions
- 3 Tinwell&Grimshaw paper; uncanniness of virtual agents
 - theoretical assumptions
 - the experiment
 - discussion
 - conclusions
- 4 Overall Conclusions



The Uncanny Valley

- Masahiro Mori in 1970
- plot emotional response against similarity to human:





Factors

- Modulation of
 - **appearance** given a certain degree of movement or
 - **movement** given a specific human-like appearance



Factors

- Modulation of
 - **appearance** given a certain degree of movement or
 - **movement** given a specific human-like appearance
- How would people perceive each agent?
- Can the uncanny valley be experimentally supported?



Minato et al. (2004)



Motivation

- Goal: human robot interaction for facilitating everyday life
- Emphasis on **communication**
- Need for robot “intelligence”



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Study of human-robot and human-human communication





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reveal a principle of **interaction**





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Study of human-robot and human-human communication



reveal a principle of **interaction**



develop a partner robot and **realize** its intelligence



Focus on two factors of HRI

Behavior (includes movement, responses) of a robot clearly affects HRI - communication

Appearance can modulate the interaction by raising or lowering our expectations towards the robot

behavior and appearance :

- two different functions of the robot
- should be studied “independently”
- cannot be easily differentiated experimentally



Approaches to behavior vs. appearance problem

- 1 Bottom-up approach: start simple, incrementally enhance the behavior or appearance of the robot



Approaches to behavior vs. appearance problem

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- 2 Top-down approach: initially build a human-like robot, evaluate interaction while removing some aspects of behavior or appearance



Approaches to behavior vs. appearance problem

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“close resemblance to humans removes the effect of the robot’s dissimilar appearance and enables an investigation purely of the effect of behavior”

human-like appearance - modulate behavior



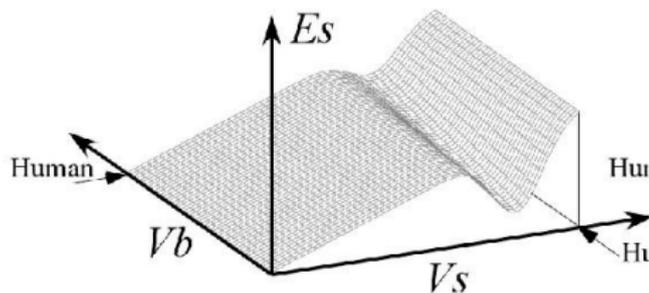
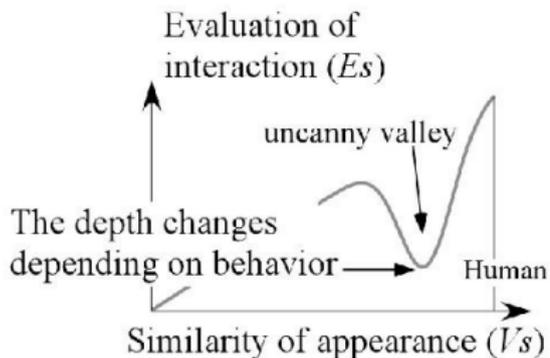
Appearance hypothesis (1)

- “Evaluation” of interaction increases with similarity of robot's appearance
- Close resemblance to humans - uncanny valley

“subtle imperfection of appearance and motion becomes repulsive”



Appearance hypothesis (2)



(a)



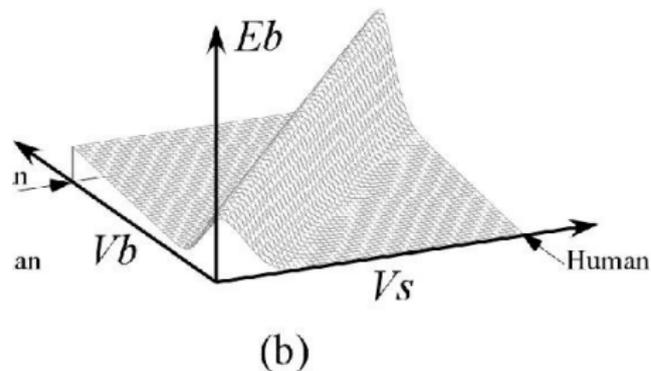
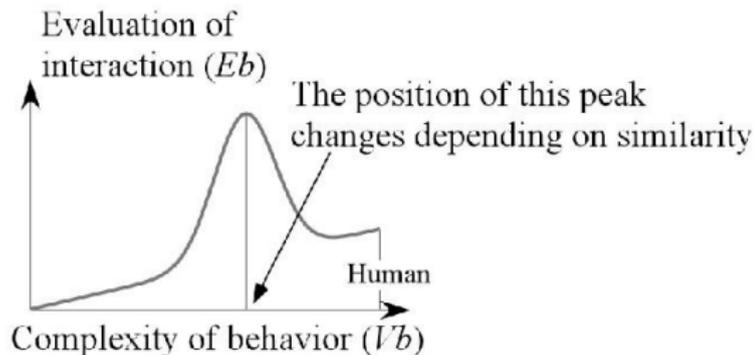
Behavior hypothesis (1)

Based on the “matching hypothesis”

- human-like behavior does not always make a good impression, unless the appearance of the agent supports it
- synergy effect: behavior matching appearance

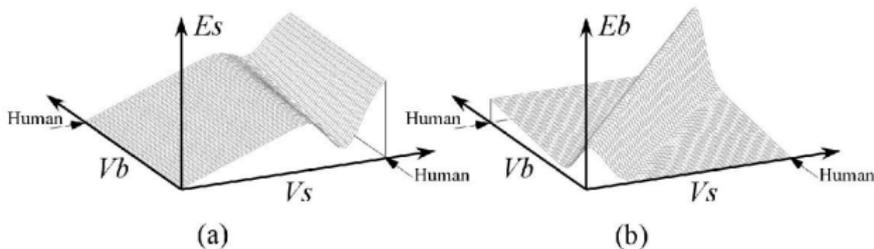


Behavior hypothesis (2)

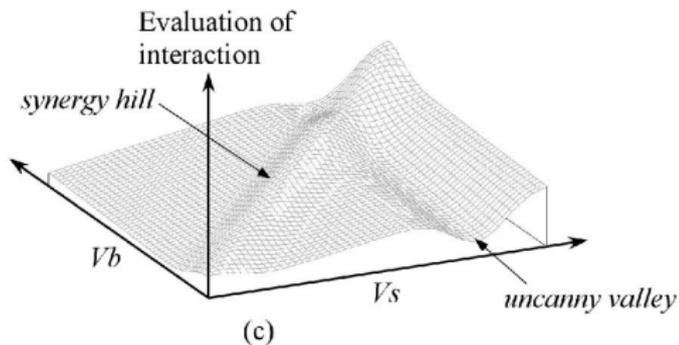




Synthesizing the hypotheses

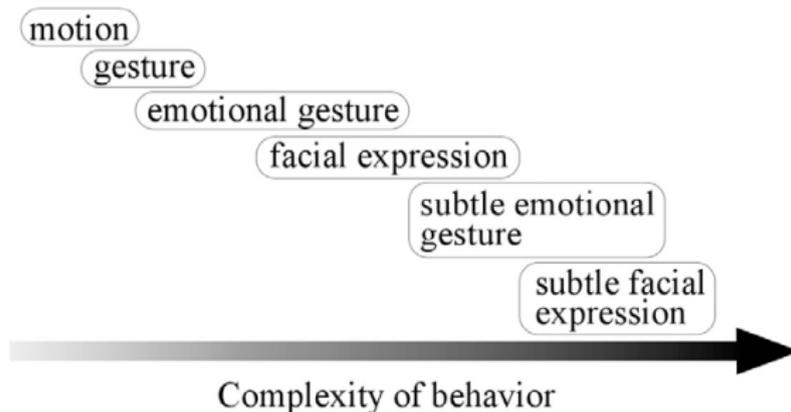


Synthesizing





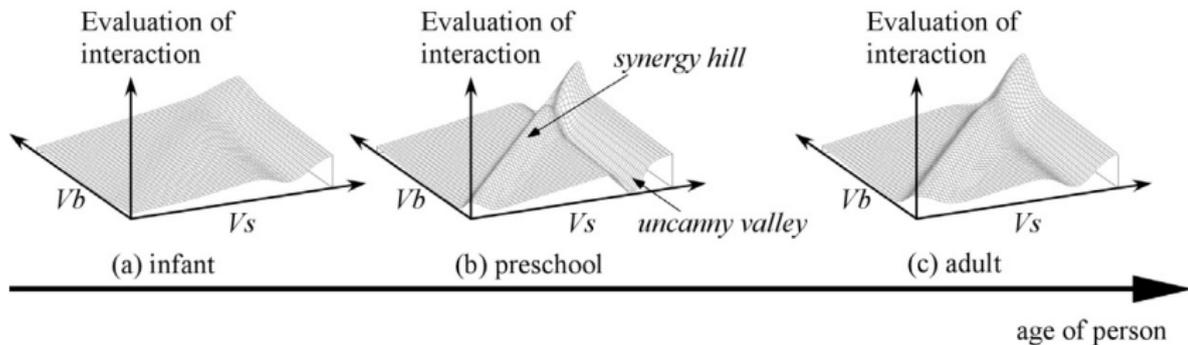
Hypothesis about Complexity of behavior



- Subtle emotional behaviors including facial expressions are human-like behaviors.

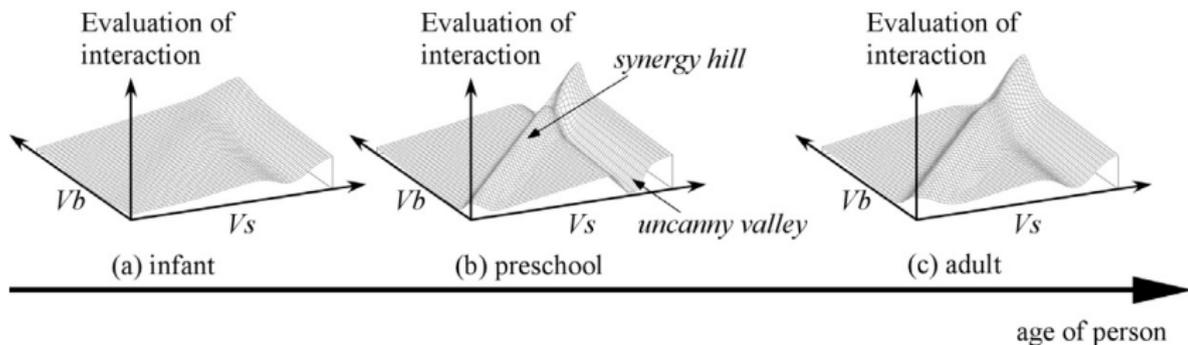


Hypothesis about person's age





Hypothesis about person's age



The uncanny valley seems to change owing to person's age:

- deepest in early childhood and shallower in adulthood
- a synergy hill becomes the steepest at younger children and smoother at adults



The Android Robot

Repliee R1 - external appearance, head skeleton, skin and body, tactile sensors



http://www.youtube.com/watch?v=_ZxvYhwIvyk



Experiment

Study of Gaze Behavior

- Quantitative evaluation of interaction
- Investigate eye motion of people during a conversation with the android

Prediction gaze behavior varies owing to the **similarity** of a robot's appearance and the **complexity** of its behavior during communication



Experimental Setup (1)

- 1 Types of actors:
 - A1: human girl
 - A2: android with eye, mouth and neck motions
 - A3: still android
- 2 All subjects had a brief conversation with each actor
random order of actors



Experimental Setup (2)

- Conversation Script (an English translation)

Actor: Hi, I'm [name].

Subject: [answers]

Actor: Let's play together! I'll give you a quiz. Are you ready?

Actor: What is a word starting with [any alphabetic character]?

Subject: [answers]

Actor: That's right! Well, what is a word starting with [any alphabetic character]?

Subject: [answers]

Actor: No! Well, then, what is a word starting with [any alphabetic character]?

Subject: [answers]

Actor: That's right! That was fun! Bye-bye!



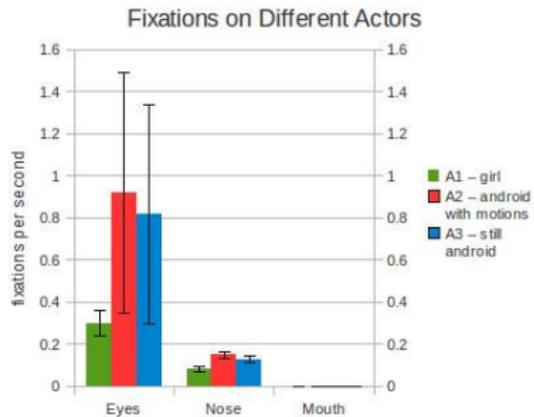
Experimental Setup (3)



- Gaze fixation: a gaze fixed for more than four frames (133ms)
- count frequency of fixations on actor's eyes, nose and mouth
- Participants also answered an open questionnaire about their impression of the actor

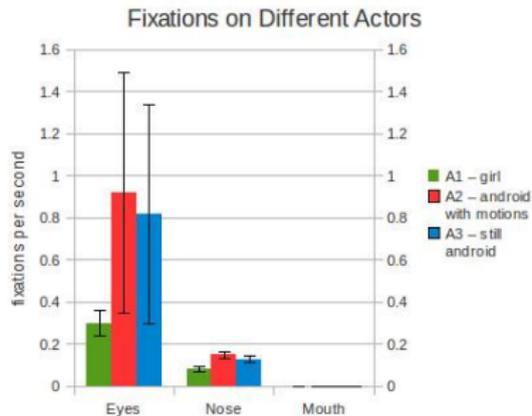


Results





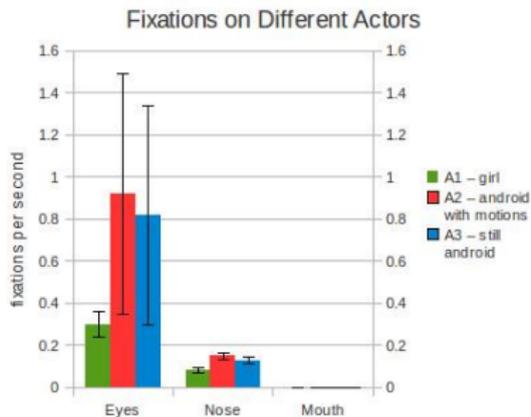
Results



- Subjects look at android's eyes more frequently than girl's



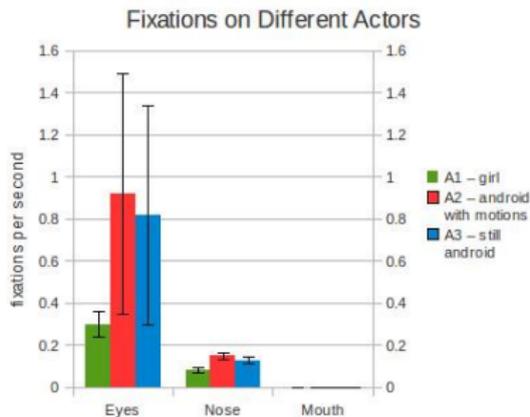
Analyzing the results



- Possible explanations:



Analyzing the results

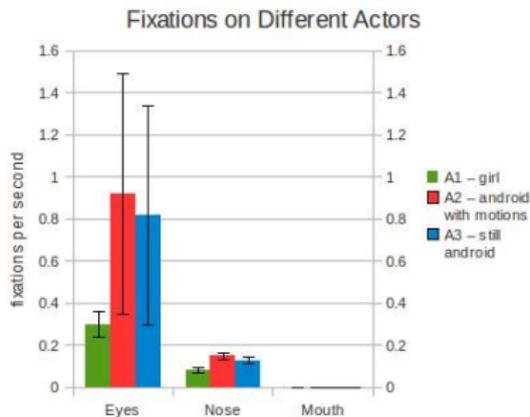


- Possible explanations:

- 1 attempt for **mutual understanding**



Analyzing the results

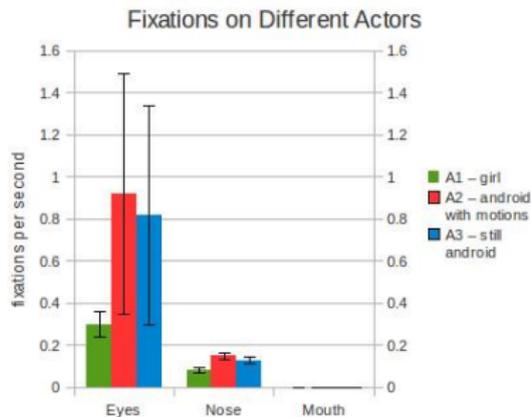


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- ① attempt for **mutual understanding**
- ② **artificiality** on eye- rather than mouth-movement



Analyzing the results

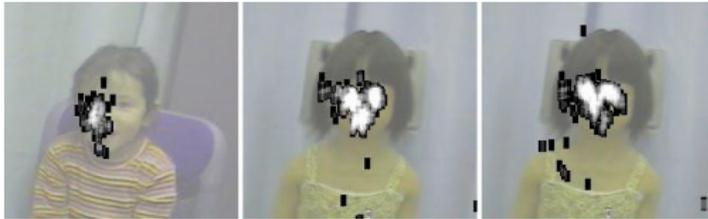


- Possible explanations:

- ① attempt for **mutual understanding**
- ② **artificiality** on eye- rather than mouth-movement
- ③ difference between how **people gaze at people** in contrast to how **people gaze at robots**.



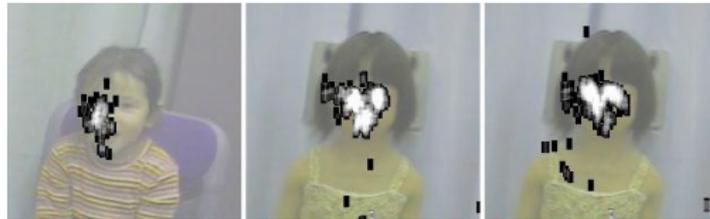
Discussion



- Prediction: difference on the gazes between A2 and A3



Discussion



- Prediction: difference on the gazes between A2 and A3
- **No significant difference found**
- **Why?**



Discussion: Additional Factors

Uncanniness/Eye contact

- **Uncanny valley**

- ① artificiality of appearance and behavior
- ② imbalance between appearance and behavior

- test on a robot with robotic appearance: fewer fixations?

hypothesis the higher the evaluation of the communication
the lower the frequency of the fixations



Discussion: Additional Factors

Uncanniness/Eye contact

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- test on a robot with robotic appearance: fewer fixations?

hypothesis the higher the evaluation of the communication
the lower the frequency of the fixations

- **Eye contact**

- ① subjects could not achieve eye contact
- ② eye contact should work synergistically to enhance communication

- check with a robot with robotic appearance and no eye contact behavior



Discussion: Additional Factors

Contingent/Involuntary motion

- **Contingent motion:** estimated to work in synergy with human-like appearance
 - 1 in-contingent motion of A2
 - 2 repeating the same behavior of the android was considered unnatural



Discussion: Additional Factors

Contingent/Involuntary motion

- **Contingent motion:** estimated to work in synergy with human-like appearance
 - ① in-contingent motion of A2
 - ② repeating the same behavior of the android was considered unnatural
- Involuntary waving **motion:** animate living effect
 - ① A2 was moving only the head
 - ② A1 always moved the whole body slightly



Discussion: Additional Factors

Habituation effect

- **Habituation effect**

- ① people:

- ① in the first conversation with the android - surprised

- ② in the second conversation - already kind of familiar with it

- ② frequency of fixations on eyes decreased in second conversation

Habituation to the android seems to affect the interaction



Discussion: Additional Factors

Habituation effect

- **Habituation effect**

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Habituation to the android seems to affect the interaction

→ **Investigate** the short-term change of interaction



Conclusions - critics

- Appearance and behavior modulate our **expectations** from the robot
- **Evaluation** of the interaction is difficult, requires taking into account both our *expectations* and the specific *task* of the social agent
- **Experimental setup** is really important, questions remain open mainly because of insufficient initial assumptions



Summary

- Attempt to reveal a principle of human robot interaction
- Difficulty of isolating the effect of behavior from that of appearance
- Methodology for robot design
- Experiment
- Human reactions to android
- Conclusions

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Tinwell&Grimshaw (2009)



Motivation

“Sophistication in technology allows for increasing realism for both androids and virtual characters”

- Focus on **virtual characters**:
 - which **characteristics** make a character more human-like?
 - does technological experience of the **viewer** affect the perception of a virtual character?
 - if yes, **how**?



Connection to the uncanny

- Very little research on the uncanny valley with regard to virtual agents
- So far mostly use of still images as stimuli
- Need for investigation: how will sound and motion modulate uncanniness?



Connection to the uncanny

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- Need for investigation: how will sound and motion modulate uncanniness?

Tinwell&Grimshaw attempt to plot the uncanny for virtual agents -
use of videos



Specific property of virtual agents

- For virtual agents, a viewer's response is likely to change over time:

characters will appear less uncanny as viewers grow accustomed to them



Specific property of virtual agents

- For virtual agents, a viewer's response is likely to change over time:

characters will appear less uncanny as viewers grow accustomed to them

- Is it at all possible to overcome the uncanny?



Experimental setup

- 1 Participants were presented with 15 video clips in total (14 of virtual agents, 1 human)
 - placed in different settings
 - engaged in different activities
 - presented in random order



The presented agents



- | | | | | | |
|---|---------------|----|--------------|----|------------|
| 1 | Emily | 6 | Francis | 11 | Zombie 1 |
| 2 | Warrior | 7 | A Smoker | 12 | Chatbot |
| 3 | Mary Smith | 8 | The Tank | 13 | Lara Croft |
| 4 | Alex Shepherd | 9 | The Infected | 14 | Mario |
| 5 | Louis | 10 | The Witch | 15 | Human |



The task

- Participants were asked to **rate the agents** for
 - ① **human-likeness**
 - ② **familiarity/eeriness**
 - ③ **behavior - based on character's appearance**
(appearance-to-task correspondence)

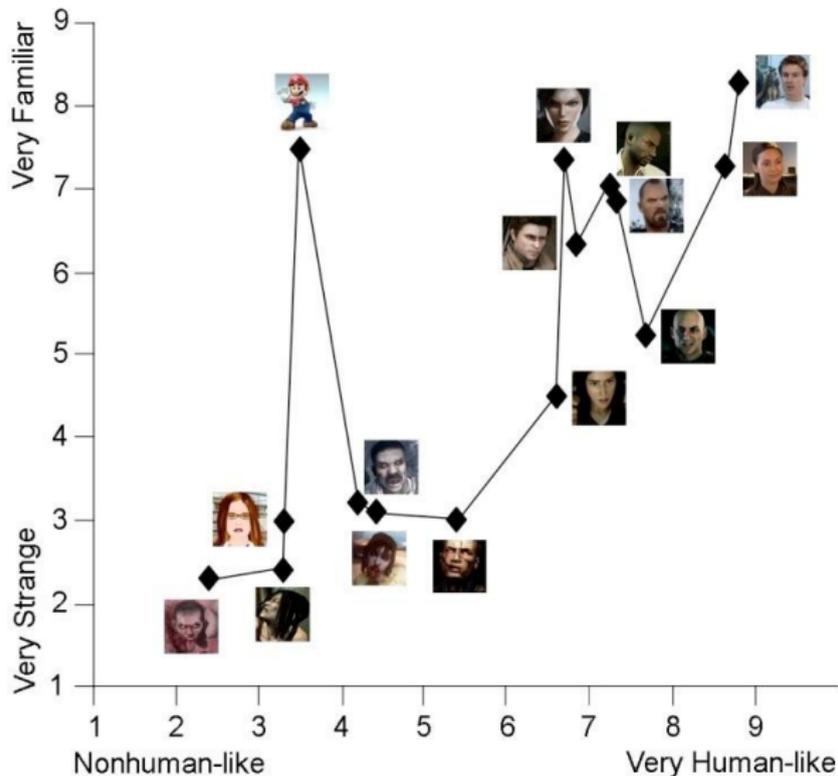


The task

- Participants were asked to **rate the agents** for
 - ① **human-likeness**
 - ② **familiarity/eeriness**
 - ③ **behavior - based on character's appearance**
(appearance-to-task correspondence)
- Rate **level of experience** in
 - ① playing video games and
 - ② using 3D modeling software



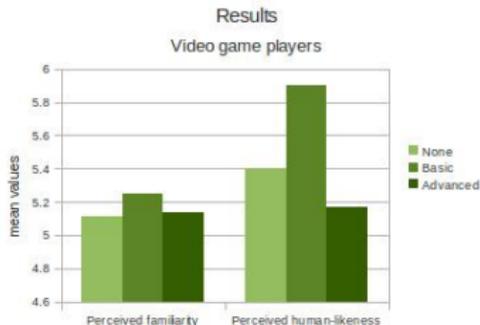
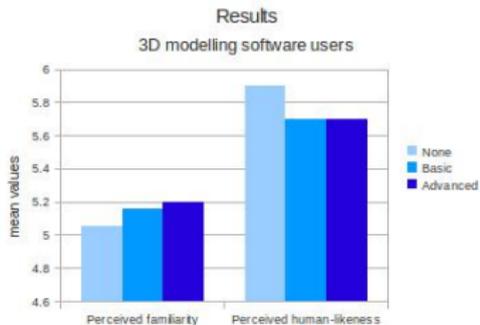
Results; familiarity and human-likeness





Results

3D modeling software users, Video game players





Results

3D modeling software users, Video game players

- **no clear evidence** for habituation effect

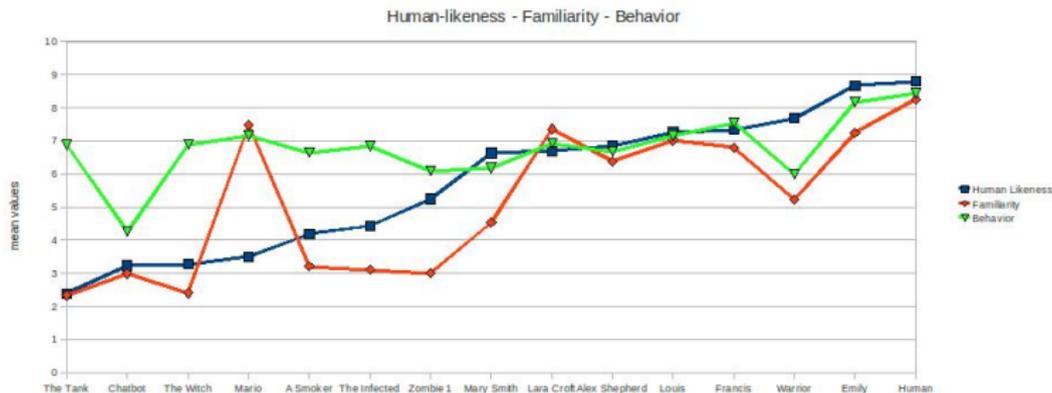
Proposal “increasing level of technological discernment on the part of viewers maintains the uncanny”

However, habituation effect could be also tested in on-line experiments



Results

Behavior judgments



- Familiarity and human-likeness in general tend to go together
- Single exceptional case: Mario (→ test more anthropomorphic cartoons)
- Other interesting cases: Chatbot, Warrior, Alex Shepherd - Louis - Francis



Discussion

Criticism on Mori's uncanny valley

- Mori: uncanniness emerges at 80-85% of human likeness
- Mac Dorman: nadir of the valley at approx. 35-40% human likeness

However, Mac Dorman used still images, whereas Mori refers mainly to robotic agents

Also, Mori's plot for a **still agent** corresponds better to the Mac Dorman results



Where is the valley?

- No clear evidence found in favor of the uncanny valley as defined by Mori

Instead, there was a significant valley bounded:

- anthropomorphic cartoon Mario
- photo-realistic Lara Croft

nadir centered around 50-55% human likeness - again far from Mori's prediction



How important are vocalizations?

- Increased uncanniness was found in:
 - ① lack of lip and sound synchronization
 - ② lack of human likeness of the voice
 - ③ increasing exaggeration of mouth articulation while vocalizing
- What about appropriateness of the voice? - based on “experience”



The role of context

- Important factor: **appropriateness of agent in a given context**

Example

Young Frankenstein

Antics of the monster or prior knowledge that the film is a comedy can cause laughter?



How do cartoons differ?

- Cartoons do not attempt to deceive the audience to believe they are real humans
- No cognitive dissonance
- No feeling of unease

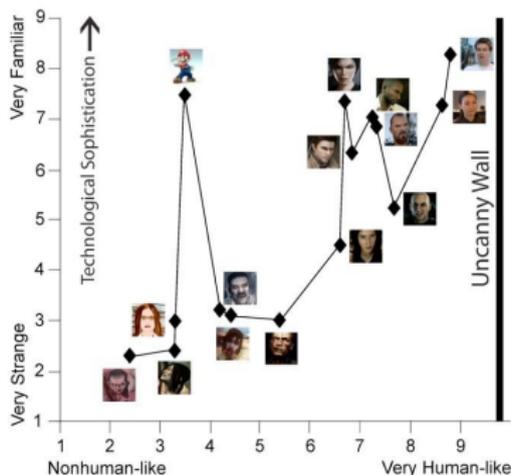


Connection to Minato et al.

- Habituation in Minato et al.(2004): may affect a participants interaction with an android over time, **leading to acceptance**
- Tinwell&Grimshaw:
 - propose **differentiation between acceptance and perceived familiarity**
 - suggest that toleration against an overall uncanny agent will be damaged by the next technological breakthrough



The Uncanny Wall



“technological discernment on the part of the audience generally keeps pace with technological developments used in the attempt to create realistic human-like characters such that ultimately, the perception of uncanniness for such characters is inevitable”



Comparison of the studies

Minato et al.

- focus on androids and modulate factors as motion to find the golden mean of HRI.
- accept Mori's concept of the uncanny valley, modify it slightly by plotting appearance and motion together
- ultimate goal: overcome the uncanny

Tinwell&Grimshaw

- focus on virtual agents and try to plot the uncanny for them
- no evidence for uncanny valley
- conclude an “uncanny wall” after incorporating other views to their study



Critics on experimental setup

Minato et al.

1 appearance:

- the android looks very human, although there is definitely room for improvement

2 behavior:

- not strongly controlled - android standing vs. girl sitting
- movements were random (except mouth-speech)
- communication during the task is questionable (recall yes and no responses)

3 ratings:

- open questionnaire reveals a lot about people's opinions, but
- no clear results about the modulation of factors



Critics on experimental setup

Tinwell & Grimshaw

- 1 characters:
 - no clear categorization of the characters,
 - no control on the amount of same type of characters (e.g. only one cartoon agent)
- 2 not clear how they manipulated the videos:
 - settings behind the characters
 - activities of the agents
- 3 no clear definition of familiarity:
 - “I feel good against this character”
 - “I know this character”
- 4 perhaps, very well-known agents as Mario and Lara Croft should be studied separately



General Conclusion

- 1 It seems that the uncanny phenomenon depends on many and different kind of factors
- 2 When studying the uncanny, start from what could cause an eerie feeling to people and then turn to virtual or robotic agents
- 3 Experiments on different agents:
 - more fine grained distinction of factors
 - clear control and modulation of factors

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Thanks
Ευχαριστώ





Discussion

What is the most important difference between robots and virtual characters?

- How is it connected to the uncanny phenomenon?
- Could that have had an impact on the results and the conclusions?

Questions?

Opinions?



Bibliography

- 1 Minato, T., Shimada, M., Ishiguro, H., and Itakura, S. (2004). *Development of an Android Robot for Studying Human-Robot Interaction*. *Innovations in Applied Artificial Intelligence* 3029/2004:424-434.
- 2 Tinwell, A. and Grimshaw, M. (2009). *Bridging the Uncanny: An Impossible Traverse?* Proceedings of the 13th International MindTrek Conference: Everyday Life in the Ubiquitous Era, pages 66-73, October 2009.
- 3 <http://www.androidscience.com/theuncannyvalley/proceedings2005/>