The Uncanny Valley Effect

- An ET driven project

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Introduction

Uncanny Valley refers to the phenomenon where human replicas, such as robots or digital avatars, become increasingly unsettling as they approach but do not quite achieve a perfect resemblance to human beings.
Earlier studies revealed that objects in the humanoid category along the Mechano-Humanness dimension are likelier to evoke the uncanny valley effect.

Our study investigates the distribution of attention (operationalised by gaze fixation density) towards different regions of the face in human, robotic and humanoid stimuli. Participants, upon presentation, rate the likeability and mechano-humanness of the face.

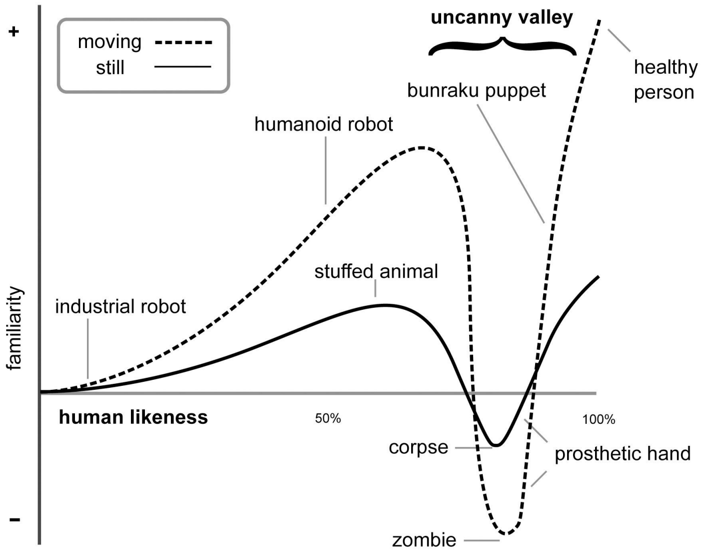


Figure 1: Uncanny Valley Hypothesis

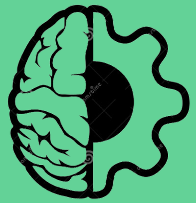
Hypotheses for causes of UVE

Dead Body Hypothesis: Suggests that the Uncanny Valley Effect arises because human-like robots or virtual characters trigger our evolved response to avoid corpses or dead bodies.

Predictive Coding Hypothesis: According to this hypothesis, the Uncanny Valley Effect arises from a mismatch between our perceptual expectations and the actual sensory information that we receive.

Ambiguous Categorization Hypothesis: This hypothesis suggests that the Uncanny Valley Effect arises from a confusion or uncertainty about how to categorize robots or virtual characters that closely resemble humans.

Moral Considerations Hypothesis: The Uncanny Valley Effect arises from a sense of unease about the use of robots or virtual characters in roles that are traditionally reserved for humans, such as caring for the elderly or working in customer service.



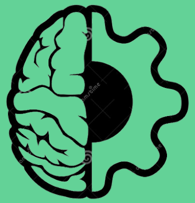
Hypothesis of our Experiment

Humanoid images that elicit negative-valence effect (Uncanny Valley Effect) show a deviant distribution pattern of gaze concentration between the facial features when compared to humanoid images with no UVE present.

1. This hypothesis seeks to challenge the Moral Consideration Hypothesis as it uses images in context independent setting.

2. As we are using still images, we challenge the Dead Body hypothesis as well. Though, it is important to note that a control protocol with corpse images has not been used in the experiment.

3. The experiment hypothesis directly relates to the Ambiguous Categorization Hypothesis. The participant is unable to place the humanoid image in Robotic and Human categories due to deviant attention distribution and processing.



Related Work

Uncanny Valley Hypothesis and hierarchy of facial features in the human likeness continua: An Eye Tracking Approach

- Ivan Grebot, Pedro Cintra, Emilly Lima, Michella Castro, Rui Jr.

The study examined whether perceptual ambiguity affects the hierarchical processing of facial features. Participants categorized female and male faces as real or artificial, and behavioral measures were taken to determine the categorization threshold and response time. Eye tracking analysis showed that boundary faces received more attention in the nose area compared to avatar and human faces. The study suggests that perceptual ambiguity can alter the allocation of attentional resources and impact the processing of artificial faces.

Literature Review

“The Role of the eyes in the uncanny valley effect: Does incongruence between eyes and face influence uncanniness?” explores the role of the eyes in the Uncanny Valley effect, specifically whether incongruence between the eyes and the face increases the perceived uncanniness of human-like entities. Using a rating scale and eye-tracking technology, participants rated the uncanniness of faces with varying degrees of eye-face congruence. The results suggest that incongruence between the eyes and the face does increase perceived uncanniness, and that eye-tracking can provide valuable insights into the factors contributing to the Uncanny Valley effect. The study highlights the importance of eye design in the creation of more lifelike robots and digital avatars.

“Category processing and the human likeness dimension of the uncanny valley hypothesis: eye-tracking data” investigates how the human likeness dimension of the Uncanny Valley hypothesis affects categorical perception of artificial faces. Using eye-tracking technology, the study measured participants' gaze patterns when categorizing female and male faces along the human likeness continuum. The results showed that faces in the uncanny region received less attention in the eyes and mouth areas and more attention in the nose area. The study suggests that the Uncanny Valley effect is driven by changes in the salience of facial features and that the effect is modulated by the categorical processing of artificial faces.

Literature Review

"The other-race effect in the uncanny valley" investigates the other-race effect (ORE) in the context of the Uncanny Valley phenomenon. The ORE refers to the tendency for individuals to recognize and remember faces of their own race better than faces of other races. Using a behavioral experiment, the study examined whether the ORE is exacerbated when viewing human-like robots with varying degrees of resemblance to human faces. The results showed that the ORE was greater in response to robots that were highly human-like, suggesting that the Uncanny Valley effect interacts with the ORE.

"Overcoming the Uncanny Valley" examines the Uncanny Valley phenomenon in relation to the design of human-like robots and avatars. The study proposes a design strategy for overcoming the Uncanny Valley by utilizing a combination of visual and behavioral cues that align with human expectations. The strategy involves reducing the realism of the entity in areas that are likely to trigger the Uncanny Valley effect while maintaining a high degree of realism in areas that are crucial for communication and social interaction. The study's findings offer practical guidelines for designing human-like entities that can avoid eliciting negative reactions from humans and promote positive social interactions.

Methodology

We used **Eye Tracking modality** to record participants' Behavioral response to the images.

Pupil Core, a product of Pupil Labs, was used for the experiments.

Figure 2(a): Pupil Core Eye Tracking Headset Front View

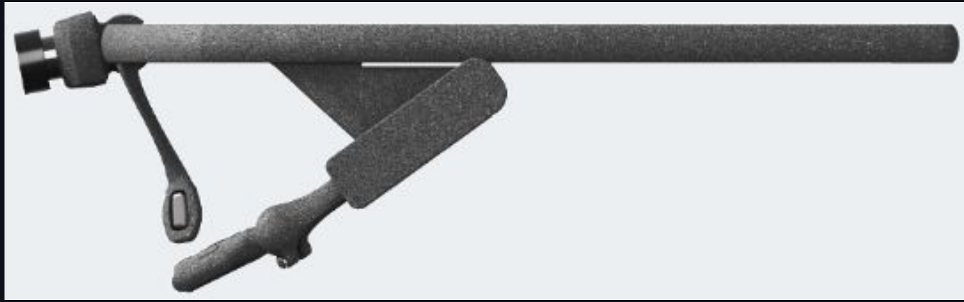


Figure 2(b): Pupil Core Eye Tracking Headset Side View

Participants

- Nine students took part in the experiment with no previous knowledge of the investigation topic and the study’s goals out of which data of **Four** participants has been used (mean age = 20.5 years, range = 20–22 years).
- The participants had normal and reported no history of ocular, psychiatric or neurological disorders.
- All participants read and signed a statement of consent approved by the local research ethics committee.

Stimuli

- All the stimuli data were taken from repositories online and modified for our convenience and experimental goals.
- The original images were grayscaled and resized to 400 x 400 pixels in dimension, then the stimuli is filtered with a low pass gaussian filter with cut-off freq 8 cycles/width (LSF) since it gives holistic face representation and coarse details, High pass gaussian filter with cut-off freq 32 cycles/width (HSF) and provide information about face details, and grayscale image with all frequencies (BSF).
- Each stimulus has three variants of spatial frequency namely LSF, HSF and BSF, (Human: Total, LSF, BSF, HSF: 45,15,15,15; Mechanical: Total, LSF, BSF, HSF: 90,30,30,30).

Figure 3: Same Stimulus was presented in 3 different Spatial Frequencies

Figure 4: ROI was made for each stimulus

Procedure

- Participants were tested in a single session for approximately 30 minutes. Each session comprised four experiments to record Likeability and Mechano-Humanness for both human and mechanical stimuli.
- Instructions were conveyed to the participants before the experiment, followed by a 5-point calibration of Eye Tracker. After calibration, the experimental task began, comprised of randomly ordered trials (45 for Humans and 90 for Mechanical). A break of 2-3 minutes was given after each experiment.
- Each trial started with a fixation point (‘+’ sign) in the centre of the screen (1000 ms), which was followed by the stimulus (1000 ms). Then a slider was presented to record the response, after which the participant had to click the “Continue” button to proceed to the next stimulus.
- The participants were asked to rate the Mechano-Humannes score (range:0 to 100), which relates to the extent of mechanical or human particular stimuli from “Least” to “Most” and the likeability (range: -100 to 100) for each stimulus and relates to the likeability of particular stimuli between “Creepy” to “Friendly”.

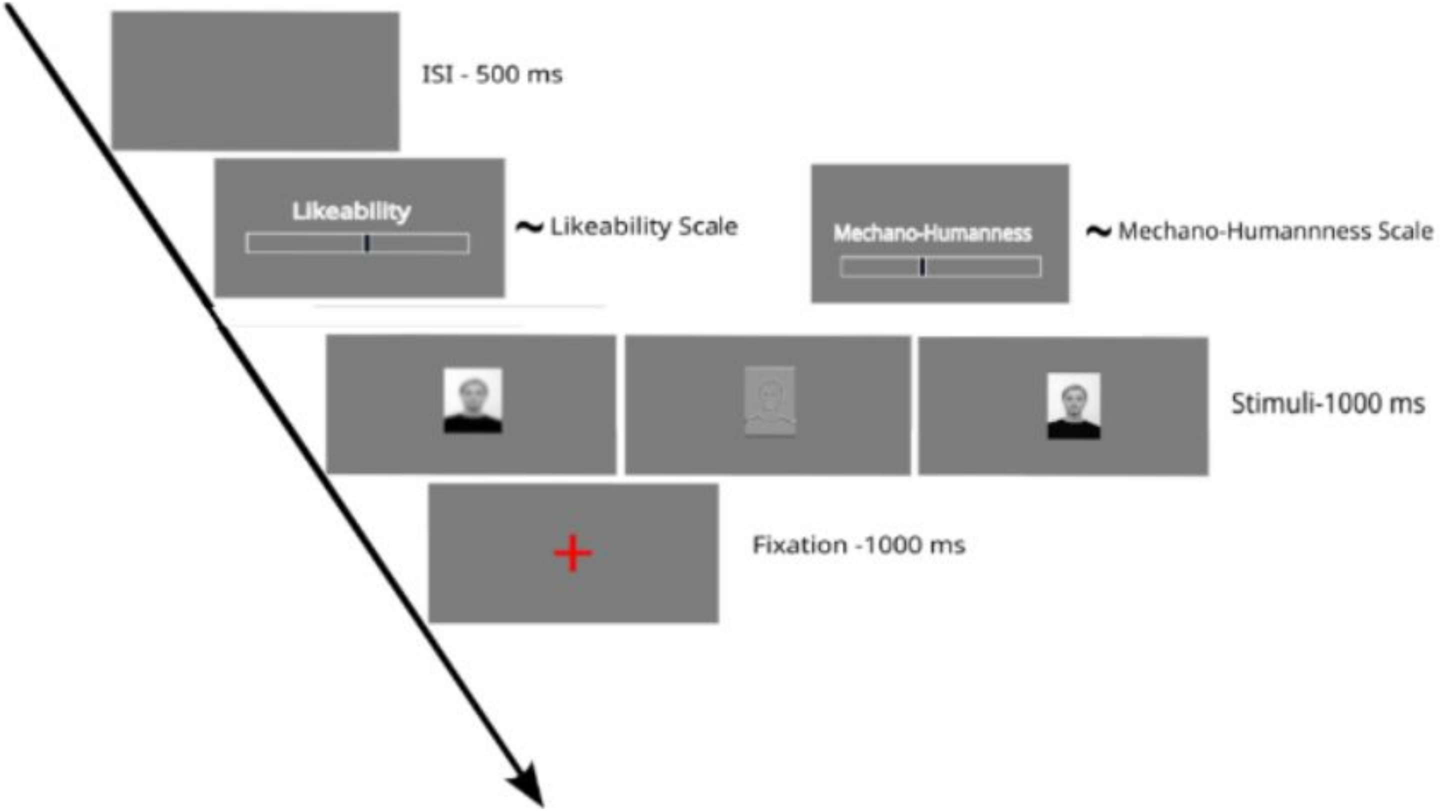


Figure 5: Workflow of our experiments

Results

Based on Gaze plots for Humans, Robots and Humanoids

Gaze plots show that Eye region had most of the gaze points in all the three categories and for all three spatial frequencies.

Other than Eye region Forehead region in Humans, Nose region in Humanoids and Mouth region in Robots had most of the gaze points.

Results

Gaze plots for Humans, Robots and Humanoids

Gaze plots were made by plotting the participants' gaze positions on each ROI-identified stimuli image.*

These plots help us to understand and analyse the regions of the face that people tend to notice before making any decision about likeability and mechano-humanness.

**Figure 6 shows a sample of each category.*

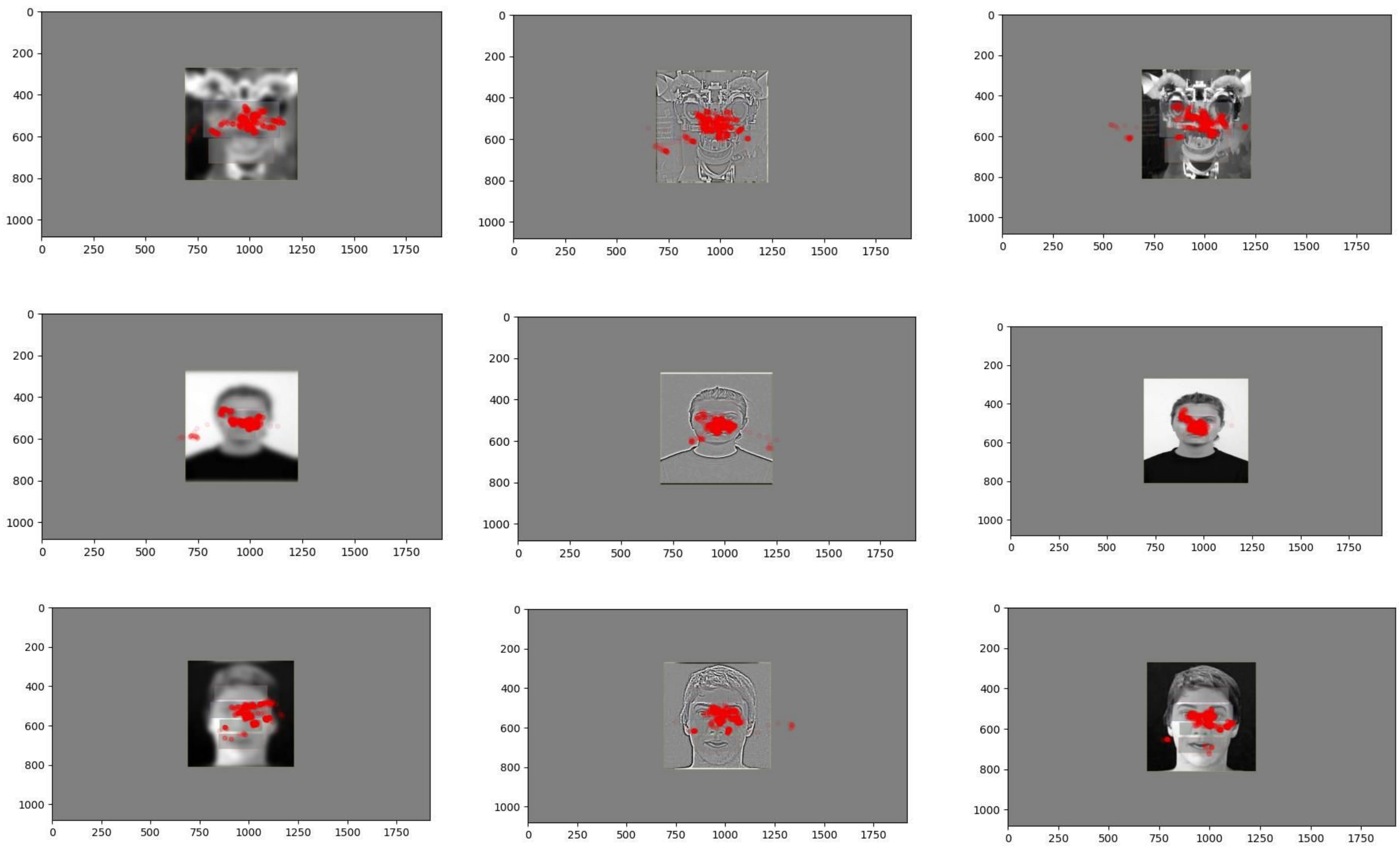


Figure 6: Gaze Plots for Robot, Human and Humanoid for 3 spatial frequencies

Results

Figure 7 shows the plot summarising the average gaze positions corresponding to the facial region for Humans.

We can see that most of the gaze falls in the eye region, which tells us that participants look at the eyes most of the time for the Humans category.

The forehead region has the highest gaze after the eye region.

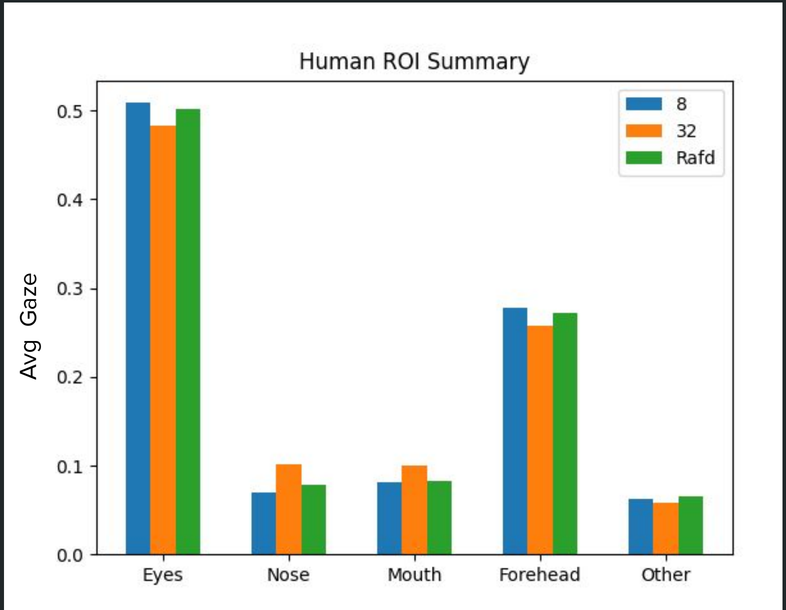


Figure 7: ROI Summary for Humans

Results

Figure 8 shows the plot summarising the average gaze positions corresponding to the facial region for Humanoids.

We can see that most of the gaze falls in the eye region, which tells us that participants look at the eyes most of the time for the Humanoids category.

The nose region has the highest gaze after the eye region.

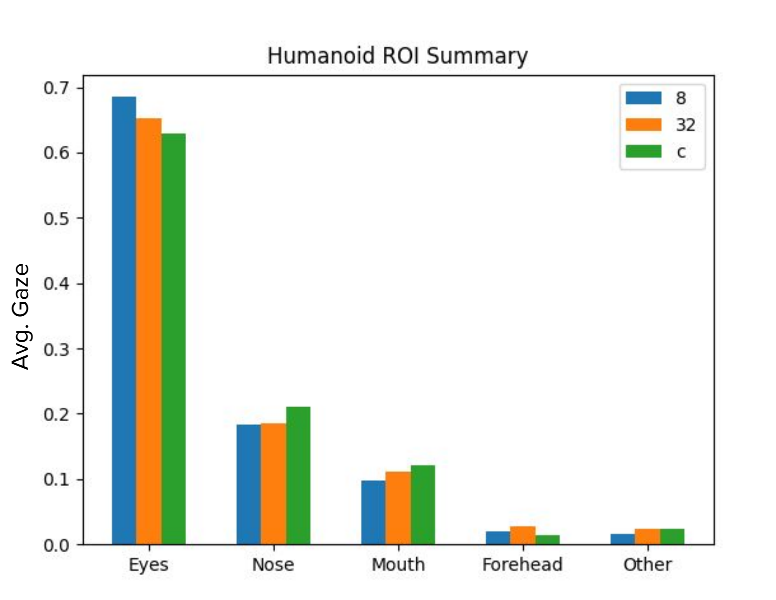


Figure 8: ROI Summary for Humanoids

Results

Figure 9 shows the plot summarising the average gaze positions corresponding to the facial region for Robots.

We can see that most of the gaze falls in the eye region, which tells us that participants look at the eyes most of the time for the Robots category.

The mouth region has the highest gaze after the eye region.*

**Due to lack of data a clear depiction was not shown; otherwise, eye and mouth region would have had a similar gaze plotting*

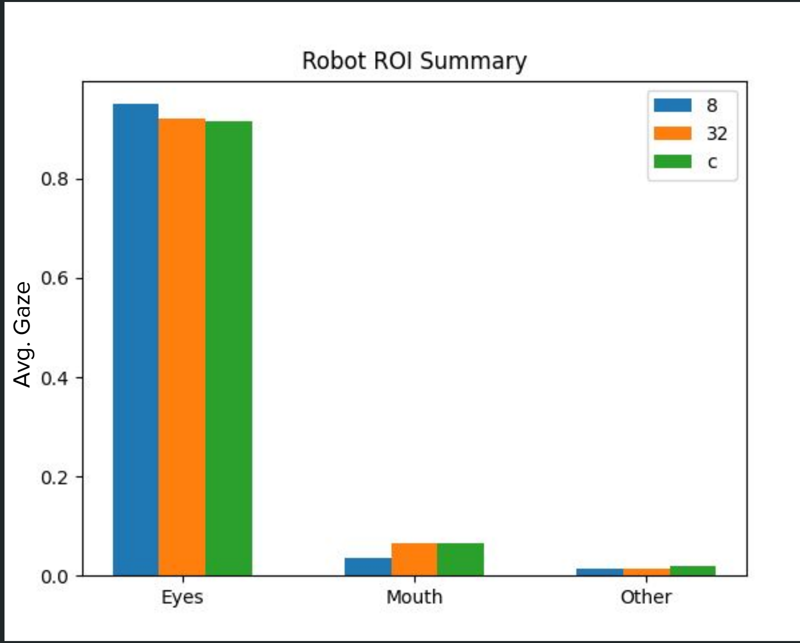


Figure 9: ROI Summary for Robots

Results

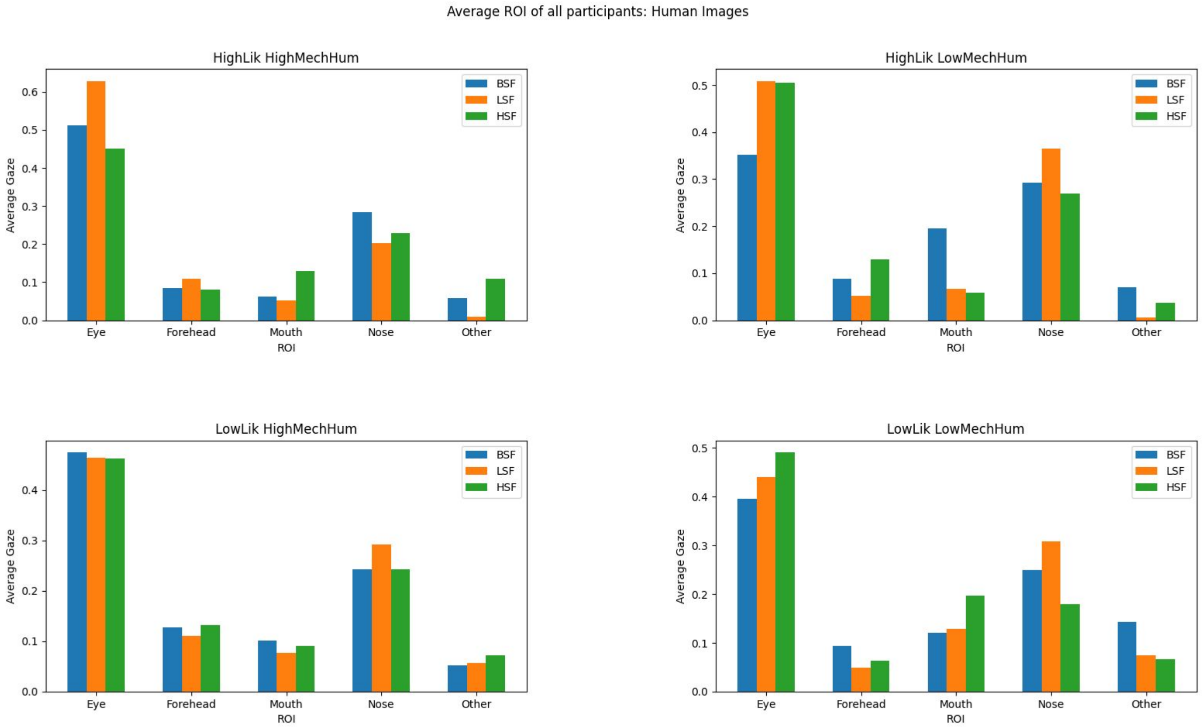


Figure 10: Human Stimuli Classification into 4 categories

(*High Likeability High Mechano-Humanness*, *High Likeability Low Mechano-Humanness*, *Low Likeability High Mechano-Humanness*, *Low Likeability Low Mechano-Humanness*)

Results

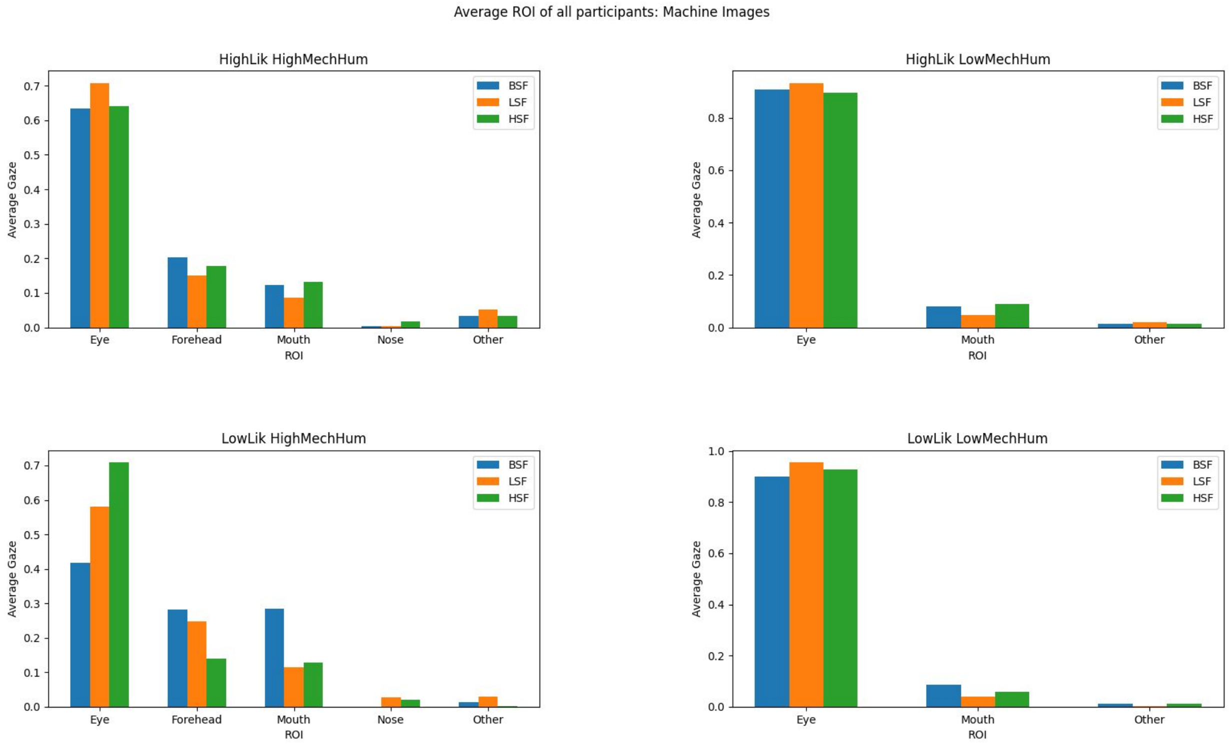


Figure 11: Mechanical Stimuli Classification into 4 categories

(*High Likeability High Mechano-Humanness*, *High Likeability Low Mechano-Humanness*, *Low Likeability High Mechano-Humanness*, *Low Likeability Low Mechano-Humanness*)

Analysis

Human Images:

- We see greatest density of gaze in the **eyes**.
- **Nose** also show substantial gaze concentration.
- In **Low Spatial Frequency** images, we see that the **gaze is highly concentrated** in eyes and nose (due to lack of fine feature clarity in these images). Whereas, in **High SF** observes some distribution, albeit a small proportion being **dissipated into other facial features**.
- Distribution of gaze for **BSF** images usually lie somewhere **between LSF and HSF** due to mutual interaction/interference of both Spatial Frequency bands.

Mechanical Images:

- We see that Low Likeability High Mechano-Humanness images have a distributed gaze concentration between eyes, nose, mouth and other features(in BSF). This corresponds to **humanoid images**(BSF) that **evoke the Uncanny Valley effect** in the participant.
  So, UVE is characterized by a more distributed gaze concentration(see **Fig 11**).

Conclusion & Implications

Due to small sample size, it is important to note that inferences made with respect to the data needs further validation. Nonetheless, we do see a trend in **BSF** experimental stimuli.

BSF images represent stimuli that model real world percepts. For **humanoid images**, we see that **UVE eliciting images** observe a more **distributed density of gaze fixations** between the ROI(facial features). *This seeks to confirm our experiment* hypothesis.

Also, since UVE is observed in these **still, context independent** images, this challenges the Moral Consideration and Dead Body hypothesis for causes of UVE. The Dead Body hypothesis could still bear weight in the context of **modulating the extent of UVE**(moving humanoids may elicit stronger UVE).

Further research activities with this experiment are deemed to reveal trends in HSF and LSF images as well.

Discussion

The eye-tracking data we collected revealed interesting insights into the mechanisms underlying the Uncanny Valley effect. Participants gazed more at the forehead and eyes of the human stimuli and eyes and nose of the humanoid stimuli. This pattern of gaze allocation may reflect participants' attempts to find cues of human-like emotions and intentions, which are typically expressed through the forehead, eyes.

These findings suggest that facial features play an important role in determining the perceived likability and mechano-humanness of human-like entities. In particular, the eyes may be a critical factor in generating a sense of familiarity and emotional connection with human-like stimuli.

Our findings also have **important implications for the design** of more engaging and user-friendly human-like machines. Exaggerating non-human features, adding unique personality traits, and increasing interactivity can help overcome the Uncanny Valley and increase user engagement and likability. However, it is also important to strike a balance between human-like features and non-human features to avoid crossing the Uncanny Valley threshold.

Our study also has practical implications for the design of human-like machines. By identifying specific areas of the face that elicit greater attention, designers can focus on improving the realism and expressiveness of those features to increase likability and reduce the Uncanny Valley effect.

Limitations

1. The sample size was small and may not be representative of the general population. Future research with larger and more diverse samples would help to confirm and extend our findings.

2. The stimuli were limited to static images and did not include dynamic movements or speech, which may have different effects on the perception of human-like stimuli.

3. The study was based only on visual perception and did not explore other modalities, such as auditory or haptic feedback, which may also influence the perception of human-like machines.

Limitations

4. Since the experiments were **blocked** rather than interleaved using a randomised scheme, the user may strategise as to which block to give lower MH ratings to and which block to automatically score higher. Apart from that, the user can also adapt toward better processing of experimental images over time (training).

Through the lens of categorization Hypothesis, after some trials, users can get better at object classification through learning. This can impact task performance and mitigate UVE to some extent(dampening).

Hence, altering the sequencing of images in the Experimental Design can offer alternate behavioral and cognitive data, which would richen the inferences that can be drawn for this phenomenon.

Supplementary Work Done

- **Saliency Maps** for images using opencv library - It normalises the image pixel matrix to highlight the high contrast regions of the face.

  Supposedly, these “salient” features would capture more attention, hence denser gaze concentration around these features is hypothesized. By overlaying our gaze plots we can test this hypothesis for deviation in experimental image stimuli while controlling using Human Images.

- **ML based ROI** using machine learning models(pre-trained). Although the model generates accurate isolated feature ROI Bounds for human images, it is not very effective for experimental image stimuli (Humanoid and Robotic).

Future Research Areas

- **Saliency Maps**: By overlaying our gaze plots we can test whether gaze positions deviate from the saliency map in experimental image stimuli while also verifying the hypothesis for Human images(control).

- We can use **Pupil Dynamics** to measure user arousal in all 4 experiments. This can help us correlate the participants cognitive state and the gaze distribution with ratings given on the Mechano-Humanness and Likeability scales.

References

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Questions?