FaceVis: Exploring a Robot's Face for Affective Visualisation Design

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Figure 1: Exemplified designs on how to leverage robot faces as affective visualisation design to convey environmental data by incorporating agency: (left) Robot face as graphical user interface, (middle) metaphorical representation of environmental data via loss of leaves as a symbol of death or dripping oil [19] combined with an aging face, (right) blazing fire combined with negative facial expressions.

ABSTRACT

In this paper we examine the use of a robot's face as an interface for affective visualisation design, a concept that we name FaceVis. We conducted a design workshop with 9 experts to explore metaphorical ideas on how to leverage a robot's physicality, appearance and agency to convey data and communicate emotion. We present insights on potential challenges, benefits and pitfalls when using a robot's face to visualise data. Our results show that this approach has the potential to enhance user engagement, support self-reflection and elicit empathic concern. We contribute three design considerations and provide future research directions to investigate a robot's face as an interface for visualisation design.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**; **User studies**.

KEYWORDS

social robot, affective visualisation design, faces, data visualisation

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1 INTRODUCTION

The human face has long been a focus of attention in affective computing [20, 22], HCI [15] and Human-Robot Interaction (HRI) [6, 34] due to its expressiveness and association with emotions. A human face tells stories and can communicate without the need for spoken language. However, it has yet to be explored as an interface for information visualisation. Human faces offer a variety of attributes and features that can be manipulated and used to map data. From the skin as its surface, with all its wrinkles, shadows and colours, to eyes - the windows to the soul, which can convey emotions that words struggle to articulate. In this work, we explore affective visualisation designs using a robot's face.

Contrary to the stream of rationalism, affective visualisation design acknowledges the user's subjective experience when interacting with visualisations [12, 17, 19]. Moreover, past research in the context of data humanism and anthropographics has focused on conveying the people behind the data to bridge the gap between visualisations and their true meaning [5, 8]. According to their argumentation, showing data about topics like death rates or violence through simple visualisations (e.g., line graphs) does not reflect the underlying essence of the data nor serves the intended purposes, namely to inform, to engage and to provoke [18]. Lupi [21] states that "we have to bring data to life - human life". We argue that robots have the power to do so.

Social robots are increasingly equipped with human-like faces and can be perceived as social agents as a consequence of their embodiment [27, 31], anthropomorphic appearance [25] and continuously advancing interactivity, autonomy, and adaptability [9]. They collect and generate a large amount of data, and increasingly interact with humans in various social settings, e.g. healthcare, education, service. Thus, social robots offer diverse opportunities to map and visualise data - from simply using a robot's face as a 2D graphical interface to display traditional information visualisations to embodying the data through metaphorical representations, see Figure 1. These visualisations could foster reflection and introspection through the additional dimension of agency and physical embodiment. Moreover, robot faces offer an easy way to convey demographically diverse data, which recently has been identified as a challenge in the area of anthropographics [5].

In this paper we explore affective visualisation designs using a robot's face as a visualisation canvas, a concept which we name FaceVis. FaceVis is our first step to push the boundaries of information visualisation and to communicate data "face-to-face". To tackle these ideas, we conducted a workshop with 9 experts. We provided all experts with a set of non-human, human-related and human data, and asked them to visualise the respective data using a robot's face. From the workshop, we collected a total of 23 metaphorical ideas as design outcomes. Based on a thematic analysis of a subsequently conducted group discussion, we identified challenges and opportunities for FaceVis and robot-driven affective visualisation design. We further implemented 8 metaphorical ideas as a proof of concept prototype, using the Furhat robot [26]. Our design corpus and implemented prototype can be accessed here: https://sites.google.com/view/facevis/home.

We offer three key contributions. First, we conducted a design workshop to explore a robot's face as an interface to visualise data. We present initial design outcomes for the three most common design domains in the scope of affective visualisation design, previously identified by Lan et al. [18], and a proof of concept prototype. Second, we deepen the understanding of the relationship between affective visualisation design and robots, highlighting challenges and benefits based on our qualitative data. Third, we offer three design considerations to guide future explorations in the context of FaceVis.

2 RELATED WORK

2.1 Affective Visualisation Design

We define affective visualisation design as "data visualisations that are designed to communicate and influence emotion" [18]. Designing data visualisations with the intention to communicate emotions is an emerging field in HCI [1, 2, 14, 19]. A recent paper by Lan et al. [18] offers convincing perspectives on why it is important to consider emotion as a result of information visualisation and sheds light on various design opportunities, including data tasks and applications. Among others, the design space aims to *inform*, *engage*, *educate*, and to *provoke* [18]. The authors hereby contribute to the long-lasting debate on whether information visualisation has to chase objectivity and rationalism [11] or shall embrace the opportunity of evoking emotion as a result of visualizing data [1, 17, 19]. Importantly, affective visualisation design can increase expressiveness in data stories without sacrificing data comprehension [12, 17] and improve user engagement [17]. The communication of negative emotions, in particular, facilitates thoughtful reflection and introspection, and can challenge to think and focus attention [19]. Interestingly, the research by Lan et al. [19] shows that people may not recall specific details of data stories, but do retain the negative emotions connected to it.

Various design choices can be made to design for emotions - varying from colour [1], anthropomorphism [2, 8], to metaphorical representations [14, 36] and motion [17]. For instance, a bouncing or swaying pie and line chart are interpreted as joy, while undulating or breathing charts are perceived as tender [17]. Anthropographics, on the other side, aim to convey the "real people behind the data" by using primarily human-shaped visualisations with the purpose to increase empathic concern and engagement with human-related data [2, 5, 24].

2.2 Metaphorical Representations

Metaphors act as encoders that build bridges to connect the unfamiliar with the familiar, enabling users to easily understand abstract data. To do so, metaphors often make use of people's prior knowledge and experience to draw associations and to contextualise information [38]. "Data mapping describes the process of translating data values to representations using metaphors" [38]. Yu et al. [36] used a tree representation to encourage participants to reduce stress. Participants' physiological data was mapped onto a tree visualisation that reflected their heart rate data, with variations in growth, form, and color. Other metaphorical representations visualise traffic data as a 2D net of blood vessels [4], or convey heart rate data as 3D printed chocolate treats that adapt their affective message to incentivise a healthy lifestyle [14].

Data physicalisations bring data from the 2D into the 3D space [10], where data attributes are mapped onto physical representations to make data tangible. In an early paper, Zhao and Vande Moere [38] stressed the importance of physicality to enrich user experience. Recent work by Morais et al. [23] explored situated data physicalisations to visualise harassment cases in Brazil. The authors mapped the type and number of harassment, time of day, and detailed stories onto a plant's attributes, e.g. colour or stem height. Interestingly, their "Harassment Plants" resulted in significantly more pro-social behaviour compared to verbal descriptions of the respective data.

2.3 Robots as Visualisation Agents

Built upon previous work, we argue that a robot's face can serve as an interface to successfully visualise data and to communicate data affectively. Contrary to data physicalisations, a robot's increased autonomy, interactivity and adaptability makes it to be perceived as a social agent [9]. Moreover, people tend to name their robots, build a relationship with their robots [33], and respond emotionally towards them [25, 31], which could support the effectiveness of affective visualisation design. Thus, social robots offer new opportunities, i.e. agency and physical presence, to design visualisations, map and represent data to make people feel, think and reflect. Besides non-human data, we envision FaceVis to visualise the human behind the data - beyond the traditional anthropographics approach. This work aims to explore new possibilities in affective visualisation design by raising questions like *What challenges and opportunities arise when using a robot's face for affective data visualisation?*, and *Does an anthropomorphic robot constrain the design space to solely visualising human-related data?*

3 METHOD

We conducted an in-person design workshop with 9 experts to explore a robot's face as an affective visualisation design tool [13, 19]. A design workshop is a common practice in HCI and provides the opportunity to collaboratively generate a multitude of visualisations, to exchange ideas, and to unveil potential constraints [7, 18]. The workshop consisted of a brainstorming phase and a follow-up group discussion, targeting the experts' experience, challenges and thoughts on leveraging robots for affective visualisation design. The design workshop was approved by the University's ethics committee.

3.1 Stimuli for Design Workshop

We provided participants with three stimuli five days prior to the workshop to help them better understand the design task and to constrain the workshop as proposed by Kerzner et al. [13]. We carefully selected each example of affective visualisation design from the corpus proposed by Lan et al. [18]. Our examples cover the three most common design domains of affective visualisation design: *environmental science & ecology*, *social issues*, and *health & well-being* [18]. This allowed us to investigate *non-human data*, *human-related data* and *human data*. The first example was based on research by Kuznetsov et al. [16] who visualised air pollution using sensor-based balloons that change their colour depending on three pollutants, e.g. diesel. The second stimulus showed "Harassment Plants" designed by Morais et al. [24] to visualise different data related to harassment cases in Brazil, e.g. time of the day. The third example was based on research by Khot et al. [14] who visualised heart rate data using 3D-printed chocolate treats that adapt their message depending on the level of physical exercise.

3.2 Participants

We recruited 9 ($6F$, $3M$) participants for the workshop. Prior to the workshop, participants filled out a survey to determine their eligibility; ensuring a certain level of experience and diversity. We recruited experts with work, research and teaching experience ($M = 4.3$ years) in HCI related fields, e.g. user experience, prototyping, data analysis or interface design.

3.3 Procedure

We allocated the experts to groups of three (see Figure 2 in Appendix A) avoiding gender homogeneous groups and guaranteeing diversity in regard to the experts' backgrounds [7]. We gave a 10-minute workshop introduction, including an ice-breaker to encourage self-expression and to foster trust among the experts [13]. We introduced the design task and explained relevant concepts to avoid misunderstandings or knowledge imbalance. In the second phase, we provided participants with a 5-minute demo of the Furhat robot [26], an anthropomorphic robot head. During this phase, participants were able to acquaint themselves with the robot's face and facial features, aiming to ignite inspiration and to show the robot's capabilities. The Furhat robot is known for its customizable appearance, facial movements and expressiveness, which makes it particularly suitable for FaceVis.

The third stage of the workshop consisted of the actual design task. We asked participants to brainstorm affective visualisation designs to convey data using a robot's face as the interface. Participants were instructed to visualise three distinct stimuli using the robot's face, see section 3.1. To guide the design process, we instructed participants within each group to (1.) understand the data they need to visualise (2.) set a timer (3 min.) for individual brainstorming to generate as many ideas as they can and (3.) choose, refine and annotate their favourite designs collaboratively using the workshop material. We provided all groups with printed photocopies of different robot faces, sticky notes, and other crafting materials. Participants were given 45 minutes in total. We informed participants at 15-minute intervals to provide an anchor for time management. After the brainstorming phase, each group was asked to pick and briefly explain their favorite design outcomes.

We closed the design workshop with a semi-structured group discussion led by the first author. This included an opening question based on Lan et al. [19] to initiate the discussion ("Which design impressed you most?'), an introductory question targeting the overall design experience ("How did you proceed to map data onto a robot's face?') and 3 key questions to investigate the experts' thoughts on challenges, benefits and pitfalls for robots utilised as affective visualisation design ("Please describe challenges you have faced during your design-process, e.g. design constraints when using a robot's face to visualise affective data?'; "Could you please elaborate why you think a robot's face could be useful in conveying affective data and if you can think of potential pitfalls?'; "We gave you one specific robot - what did you miss to better convey data?'). The group discussion took 30 minutes and was audio-recorded.

4 RESULTS

We collected 23 affective visualisation designs and many ideas written down on sticky notes. We transcribed our audio recordings and analysed the transcription using a deductive thematic analysis [3]. After developing a coding scheme, two authors first analysed the transcription independently, followed by an in-person meeting to compare codes, discuss low and high level themes, and to address any discrepancies. This approach allowed us to gain nuanced insights on expert's design ideas, challenges, and thoughts on benefits and pitfalls of employing a robot for affective visualisation design.

4.1 Workshop Design Outcomes

During the workshop, all participants were able to brainstorm metaphors to visualise each stimuli using the robot's face. For exemplified design outcomes see Appendix B and for an exhaustive list: https://sites.google.com/view/facevis/home.

Metaphors for Environmental Data. Participants had different ideas to convey air pollution (see Appendix B.1 Figure 3), from using the face as an *"artistic landscape that reflects the three different gases"* (E2), including *"growing leaves"* that turn into *"cracks"* or a *"Terminator"* like appearance, to colour-coded skin reactions. E7 explained that the robot *"would have a rash and pimples if it's pesticides"* or *"red eyes"* for pollution caused by *"the coal factory"*. Other visualisations involved more provoking ideas, including *"choking"* (E3), *"eye balls falling out of their socket"* to visualise intense air pollution or *"a child's face to make it even worse"* (E7). Several designs further include the idea of a face mask, wherein the type of mask dynamically adjusts to the varying levels of air pollution. *"Because of COVID, we thought of using face masks and almost like a respirator towards the very end of the [pollution] spectrum"* (E3).

Metaphors for Social Issue Data. Similar to environmental data, participants explored different metaphorical representations to convey distinct harassment types, their frequency and the time of the day they occurred (see Appendix B.2 Figure 4). One of the groups used *"eye movements"* (E1) to convey stalking and *"mouth muttering"* (E1) to convey verbal assault. E1 further explained that *"the tiredness in the eyes"* (E1) visualises the time of day, whereas *"how many cases could be represented by head shakes"*. To better convey time, one group decided to divide the face into regions that mimic a clock. *"Instead of a real clock, we can have different parts of that quadrant light up when it's happening during that time of day"* (E5). Besides, E4, E5, and E6 emphasised on facial expressions. *"It could start with a wrinkle and then blood vessels and then watering eyes and, in the end, explode into crying"* (E4). Beyond facial expressions, E6 elaborated that one of their designs *"has these flowers that bloom around the face and each type of flower is a type of harassment"*. The participant highlighted *"every time a case happens, a petal falls like a tear down her face [...] and every morning, afternoon, night, new flowers bloom. But the dead heads stay on their face"* (E6).

Metaphors for Health & Well-being Data. To convey heart rate data, E2 explained that their group experimented with different types of smiles and *"faces for praising or motivating"*; see Appendix Figure 5a in B.3. Further, they envisioned that *"the head would shake if [the heart rate] reaches dangerous levels"* (E2). E4 emphasised that one of their designs is *"inspired by the Tamagotchi concept"*; Figure 5b in B.3. E5 added that their Tamagotchi inspired robot *"starts small and cute and the more you exercise, the more you feed it, it gets bigger. If you don't exercise, it dies"*. E8 explained that the robot either looks *"lethargic"*, or, *"if you exercise a lot, it's a happy and lively face"*. One of their group's design was also inspired by the battery level. *"If you don't exercise, you have low batteries, a red color"* (E8).

4.2 Data Mapping Logic

Participants described a multitude of different approaches to map the respective data onto the robot's face. E1 and E2 started with a list of potential facial features that can be used to map data. *"So I had eye color, face color, facial hair. Head movement, expression movement, freckles, masks, tears, a list"*. (E1). In the contrary, E3 reported that their group started by first *"looking at the data types. So whether it's categorical, continuous, whatever. And then we tried to find out facets of the face to accurately map to that"*. Alternatively, E7 elaborated that they first identified a fitting metaphor, which they then deconstructed to map the associated data attributes. *"It was more top-down. Getting inspiration from what we knew and then saying how could we translate it onto [the robot faces]"*. To visualise heart rate data, the expert elaborated that the idea of a battery *"just came naturally"*, since it *"expresses energy"* and is *"used in so many places"* (E7). In a similar sense, E3 first reflected on *"what is causing an effect, so the source of the data [...] and then how the human or robot face reacts to it [...], whether it's pollution, harassment or lack of exercise"*.

4.3 Challenges

We identified 4 challenges for using a robot's face as affective visualisation design.

C1: Balancing Storytelling and Data Precision. Data comprehension is a common concern in the affective visualisation space [19]. Several participants experienced a trade-off between telling the overall story of the data versus being accurate and precise in their data mapping. *"You can get some really elegant things that make you feel when it's just one thing, like the petals falling. It's so impactful. The more you pile on, [...] the more complicated it gets and potentially the less impactful"* (E2). Further, the expert explained *"what got us caught up sometimes, was really trying to map every single data variable onto the face at once"*. Two experts expressed to have spend *"a little bit too much time thinking how to represent the time of day"* (E5), calling it *"a harder choice"* (E1).

C2: Navigating Ambiguities. Some participants encountered the challenge that traditional encodings of data could not be transferred to the robot's face. They emphasised an awareness of ambiguous interpretations and *"conflicting effects"* (E4) based on the robot drawing on human-related associations. *"I was especially noticing it with the battery idea [...] I would think, why is the face green? That doesn't look good, a green face is usually disgust so there's a conflict when you map these more traditional color metaphors to a face"* (E4). E2 elaborated that a *"higher heart rate doesn't necessarily mean good and a lower heart rate doesn't necessarily mean bad. There's a lot of like nuances involved in fitness"*.

C3: Beyond Facial Boundaries. Some participants elaborated robot-related challenge due the face restrictions. *"Facial expressions, it's very rich in emotion, but it's only one element of communication"* (E6). Thus, participants expressed that it could be useful to have *"arms"* (E7), *"some hair"* (E8) or *"shape changing"* (E4) abilities to better convey data. E2 elaborated tactile features to improve their design, such as *"temperature"* or *"moisture"*, since *"so much can happen with tears [and] sweat"*. E7 and E1 emphasised to utilize a robot's motion to better convey data through *"gestures"* and *"body language"* (E7). *"It would be good to have the whole bust animate. You could lean in and lean out"* (E1). E3, E7 and E4 highlighted audio to better visualise data, e.g. through *"coughing"*, *"peaceful breathing"* or *"a rusty voice"* (E3) in case of air pollution, and to *"make it more immersive"* (E7). In line, E4 added that a robot's voice enables users to *"have a conversation with [the robot] about the data it's reviewing"* (E4). Several participants were interested in making the robot *"respond to environmental impact"* (E4), and to use projection or AR (E3,E4,E6,E7) to make the experience more immersive. Contradicting, E4 highlights that *"it can also be powerful that [the robot is] limited to a head"* since *"it triggers the imagination"*.

C4: A Robot's Face shapes Context. One expert expressed that the robot's face shapes expectations due to its appearance and presence. *"You can't use it as a screen because anyone ingesting the presence of a robot like that is going to expect human features. And so you are kind of restricted in that"* (E1). Following the thought, the expert argues that you cannot simply *"project a line graph on there and hope for the best"* (E1). Building upon the presence of a robot, E2 voiced ethical apprehensions regarding the possibility of the robot being overly provocative and triggering, as well as its potential to manipulate emotions. *"I think there's ethical issues with demonstrating certain emotions in the face. It can also be really triggering. You have to be really mindful and very immersed in that context to even begin to dictate who feels what"* (E2).

4.4 Benefits

Participants highlighted potential benefits when using a robot for affective visualisation design.

B1: From User Engagement to Self-reflection. E2 emphasised that using a robot as visualisation ensures a sustained and captivating user experience by making the visualisation *"interesting to look at each time"*. E1 further elaborated that using a robot's face can *"amplify certain situations"*. The expert highlighted that a robot's face *"is going to leave a more lasting impact"* (E1) compared to a graph [19]. Reflecting on the heart rate visualisation, E4 explained that visualising data using a robot's face might foster self-reflection [18] and empower user to take on a more active role in managing their own health [36]. *"[The robot] could convey the expression that communicates how poor your heart rate is in relation to an activity. So if you just did a walk and it's super exhausting, that's not good, right? You shouldn't be super exhausted"* (E4).

B2: From Mimicry to Empathy. Interestingly, participants expressed that the robot's human-likeness encouraged empathic concern with the underlying data. *"I think the idea of exploring that [the robot is] a human [is] compelling because it can help you as the viewer to empathise"* (E4). Moreover, participants felt inclined to mimic the robot. *"The first thing I did when you showed the [robot demo] was mimicking the expression"* (E2). In line, E1 explained *"this is a "Monkey See, Monkey Do" effect and looking at a particular target state of a facial expression set is going to make me want to mimic it, without knowing it so"*. Building upon mimicry, E2 questioned what *"it means for us to look at a robot's face"* and whether the robot is *"reflecting to us what we should be feeling?"* or rather what the robot itself is feeling. *"Or is this what [the robot] is feeling in observing us?"* (E2). Moreover, E4 expressed to have experienced mutual gaze with the robot. *"It is also weird, it's a visualisation that's looking at you. Like I've caught mutual gaze with it"* (E4). Similarly, E7 elaborates *"[the robot is] looking into the future"*, conveying *"what it would look like if you'd have continued [polluting air]"* (E7).

5 DISCUSSION

Participants successfully generated a multitude of affective visualisation designs to represent different types of data, employing a robot's face as the interface. Interestingly, our findings show that a robot's face is not restricted to visualise data solely related to the human, i.e. physiological data. In addition, participants used a varying degree of embodiment and metaphorical distance to convey the respective data [38]. From animated wrinkles to represent heart rate data to falling flower petals to convey harassment cases and frequencies. Notably, participants employed either a symbolic or an indexical relationships to visualise data. In a symbolic approach, the visual representation does not resemble the data, as seen in examples like flower petals representing harassment data. In contrast, an indexical relationship involves a direct connection between the representation and the respective data, such as smoke covering the face to visualise air pollution or sweat to convey heart rate data [38]. Further, we identified two main approaches for mapping data onto the robot's face: bottom-up and top-down. In the bottom-up approach, participants listed the robot's facial features and capabilities to connect them to specific data parameters. In the top-down approach, participants began by contemplating the overall cause and impact of the data, considering human responses and generic metaphors to convey the underlying meaning of data, such as a battery to visualise energy.

5.1 Between Ambiguity, Precision and Storytelling

We identified several challenges associated with utilising a robot's face as an interface for affective visualisation design. First, participants expressed concern in regard to balancing storytelling and data precision. Affective visualisation designs should aim to engage without causing distraction and inform without compromising the integrity of the information. Past research has shown that the expressiveness of affective visualisation designs does not hinder data comprehension [19].

Further, participants were eager to explore robot inspired designs beyond facial restrictions. Interestingly, participants wished to explore tactile sensations, gestures, body language, motion and audio to better map data onto a robot agent which presents an under-explored research area [28]. Schömbs et al. [30] investigated information visualisations and their effects on decision-making using either the robot's behaviour to convey data or a graphical user interface attached to the robot. **Both, extending information visualisation to a robot's embodiment and integrating sound present new directions for future investigations**. For instance, audio enables the robot to talk about data. It also offers the opportunity to create a more immersive visualisation experience by using sounds, e.g. breathing. A recent study showed that turning heartbeats into sounds as an expressive biosignal can elicit empathy [35]. A recent review shows that sounds in HRI can be used to explicitly convey emotions [37]. Nevertheless, this study intentionally excluded speech to prioritize accessibility and to explore implicit information visualisation.

Thirdly, participants expressed concerns about ambiguous interpretations and conflicting effects arising from the robot's face and its human-related interpretation since conventional encodings might not apply to FaceVis. Indeed, the robot's face contextualises and frames the room of interpretation based on its high human-likeness and social agency - which opens up pitfalls as well as opportunities.

5.2 The Power of Agency: Monkey See, Monkey Do

The robot's agency has been both identified as pitfall and opportunity. One participant raised ethical concerns since the design could bee too provocative and triggering given the robot's human-likeness and perceivable agency. Lan et al. [18] identified provoking as an objective and data task in the affective visualisation space. However, designers have to find the sweet spot between provoking - to foster reflection, increase attention and challenge viewers to think - and visualisations causing emotional stress and harm. Notably, our results propose the robot's agency as a catalyst for user interest, engagement and self-reflection, which can be particularly interesting for applications such as risk communication. Nevertheless, we highlight that further evaluation is needed in order to quantify these first impressions and to establish FaceVis in the affective visualisation design space. Interestingly, our findings show that using a robot as visualisation interface can potentially enhance emphathic concern. Whereas past research on anthropographics provide inconclusive findings on people's empathy [23, 24], research in HRI shows that anthropomorphic robots can be used to facilitate empathic concern [25, 29]. **Future research should examine the relationship between the additional dimension of physical presence and agency and their effect on empathy in a data visualisation context**. Referring to the *"Monkey Do, Monkey See"* (E1) effect, our results show that participants felt inclined to mirror the robot's expressions. In social interactions, mimicry is known as an indicator for interpersonal relationships and an influencing factor for building rapport [32]. These findings align with our vision that robots have the potential to bring data alive, as *"a visualisation that's looking at you"* (E4).

5.3 The Future of FaceVis

Based on our findings, we offer three design considerations for FaceVis:

- FaceVis can be used to communicate emotion and visualise human-related and non-human data. This includes metaphorical representations with a varying degree of metaphorical distance, from symbolic to indexical [38].
- Designers have to carefully navigate ambiguities as a highly anthropomorphic robot face frames the room of interpretation and draws on human-related associations.
- The high degree of a robot's agency can result in triggering and provoking visualisations, and has the potential to elicit empathic concern and facial mirroring. Designers have to be aware of the power of agency.

FaceVis is a powerful avenue to visualise data and to expand the space of affective visualisation design. As a next step, we aim to refine and evaluate our prototype[1] in regard to expressiveness, data comprehension, and empathic concern. We envision that FaceVis can be applied to information visualisation challenges such as risk communication, and implemented in people's homes, workplaces, and public spaces to enrich data experiences, to better communicate emotion and to spark interest from a broader audience.

[1]https://sites.google.com/view/facevis/home

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A DESIGN WORKSHOP

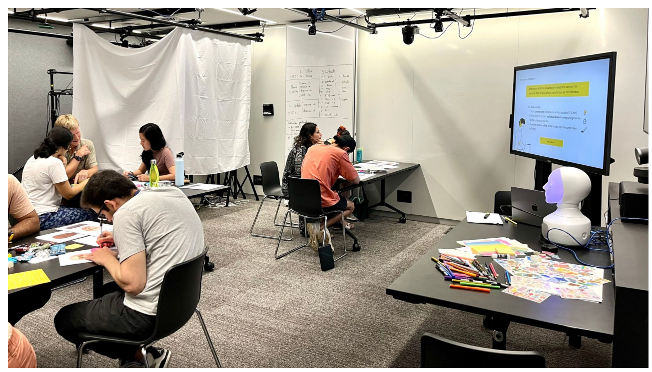
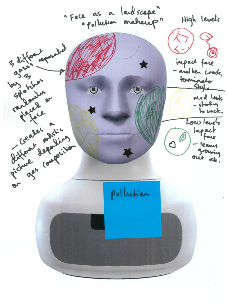


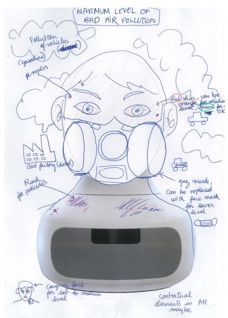
Figure 2: In person design workshop to brainstorm metaphorical representations using a robot's face as the interface.

B EXEMPLIFIED DESIGN OUTCOMES

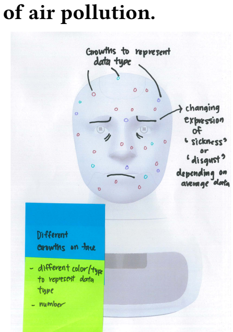
B.1 Environment & Ecology



(a) This design introduces "pollution make-up" and shows the robot's face as an artistic landscape, with dedicated facial regions to visualise each air pollutant. Depending on the degree of air pollution, the face is either covered by leaves, starts to crack or transitions into a Terminator like appearance.



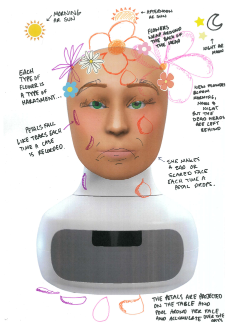
(b) The design experiments with projected smoke, a spreading skin rash and pimples to convey each type of air pollutant, i.e., diesel conveyed by smoke. The design includes various types of face masks to convey the degree of air pollution.



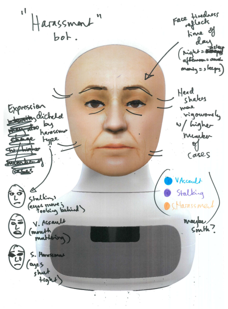
(c) The design introduces pimples as a human response to air pollution. Each colour represents a specific pollutant type. The growth of the eczema is according to the level of air pollution. Further, the design plays with facial expressions such as disgust or sadness.

Figure 3: Exemplified design outcomes to convey air pollution data [16] using the robot's face as visualisation interface.

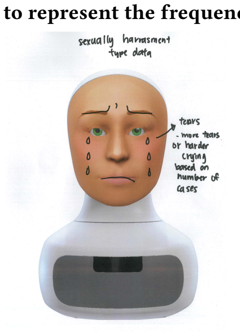
B.2 Social Issue



(a) The design explores flowers as metaphorical representation for each harassment type. The falling flower petals symbolise the frequency of the respective harassment type, whereas the projected light intensity conveys the time of day. Besides, the design experiments with facial expressions, conveying sadness each time a petal falls.



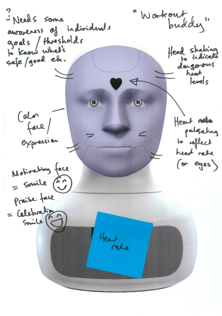
(b) The design assigns facial features and movements to represent harassment types. For instance, eye movement conveys stalking, whereas mouth muttering represents verbal assault. The time of day is represented through the tiredness of the eyes. The design explores head shakes as a way to represent the frequency of harassment.



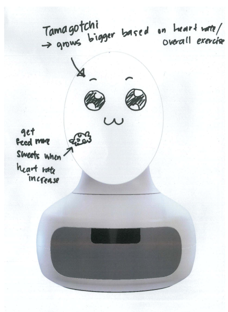
(c) The design uses different type of robot faces for each type of harassment case. The number of tears falling down the robot's face represent the frequency of harassment. The design further explores facials expressions to elicit a stronger emotional response.

Figure 4: Exemplified design outcomes to convey harassment data [23] data using the robot's face as visualisation interface.

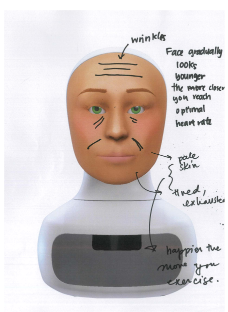
B.3 Health & Well-being Data



(a) The design explores smiles and celebrating faces as a means to encourage physical exercise. The design further includes a pulsing face to mimic the user's heart rate and includes head shakes to signal dangerous heart rate levels.



(b) The design uses the "Tamagotchi" concept to visualise user's physiological data as a means to incentivise physical exercise. An increased heart rate data functions as way of taking care and feeding the Tamagotchi like robot. It either grows tall, healthy and strong according to your physical exercise or stays week and eventually dies.



(c) The design explores wrinkles as a sign of aging to visualise heart rate data. The less physical exercise, the faster the aging process. The more physical exercise, the younger the robot's appearance. Paired with a healthy and happier facial expression.

Figure 5: Exemplified design outcomes to convey heart rate data [14] data using the robot's face as visualisation interface.