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Anthropomorphic User Interfaces: Past, Present and Future of Anthropomorphic Aspects for Sustainable Digital Interface Design

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Interactions with computing systems and conversational services like ChatGPT are now integral to daily life. Surprisingly, user interfaces, the gateways to these systems, largely lack hedonic aspects. There is little attempt to intentionally make communication through user interfaces more like communication with humans. Anthropomorphic user interfaces, which integrate human-like attributes, can make interactions more pleasant and intuitive by allowing users to perceive and interact with interfaces as social actors. This enhances user experience, reduces the learning curve, and boosts adaption rates, but also holds the potential to make interfaces more sustainable, as they rely on familiar human interaction patterns. However, there is little consensus on how to build such interfaces. We conducted an extensive literature review on existing anthropomorphic user interfaces for software systems (*past*) to map and connect existing definitions and interpretations in an overarching taxonomy (*present*). The taxonomy and an accompanying web tool provide designers with a reference framework for analyzing and dissecting existing anthropomorphic user interfaces and designing new ones (*future*).

CCS Concepts: • **Human-centered computing → HCI design and evaluation methods**; *Interactive systems and tools.*

Additional Key Words and Phrases: Anthropomorphism, User interface design, Human-like interfaces, Taxonomy

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1 INTRODUCTION

Anthropomorphism, attributing human-like traits to entities, is widely used in media like comics and animations to engage audiences. It is increasingly applied in Human-Computer Interaction (HCI) to design interfaces that interact with users as social actors, aiming to motivate and influence behavior positively [7, 8]. Integrating these features in interfaces aims to motivate users and influence behavior positively, though designing effective anthropomorphic interfaces is challenging [23]. With the growing importance of large language models and generative AI, careful usage of anthropomorphic cues, both explicit (such as facial expressions) and implicit (like hesitating transitions between dialogs), is becoming even more crucial in interface design [2]. AI enhances machines with human-like cognition and interaction, adapting to human behavior to better meet needs and preferences. Anthropomorphic interfaces improve user engagement and satisfaction by fostering emotional connections and intuitive interactions, making technology more relatable and supportive. Nonetheless, it is imperative to carefully consider the appropriate level and combination of anthropomorphic cues, as excessive or mismatched use of such cues may lead to user (dis)trust in the system, underscoring the importance of determining optimal cue usage in specific contexts and situations.

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The user interface, the mediator between humans and machines, is a pivotal component in determining user experience metrics, with hedonic aspects being equally significant as usable functionality [14]. As technological advancements have reshaped the landscape of HCI, user experience has gained prominence beyond task-oriented approaches [11], placing a heightened emphasis on pleasure and enjoyment [10]. Hedonic aspects have become increasingly significant in HCI over time [6]. Recent work also shows that users experience human-like attributes such as perceived warmth and competence in AI systems [17], reinforcing the continuously growing importance of human-like AI in this evolution.

Establishing a clear nomenclature for emerging interface types is crucial for their advancement, as it provides a shared vocabulary and enables scalability within the domain. In HCI, structuring this nomenclature into a taxonomy with interconnecting relations is essential for comprehensively understanding and categorizing different aspects, particularly concerning anthropomorphic user interfaces (AUIs). As future interfaces are envisioned to integrate anthropomorphic elements, the objective is to formulate a taxonomy as a foundational framework for naming and classifying these interfaces. This taxonomy represents an initial step towards a more systematic and informed approach to designing and developing anthropomorphic user interfaces. Through a comprehensive literature review, we focused on dissecting the various dimensions of anthropomorphic user interfaces. By employing affinity diagramming in a workshop with HCI and psychology experts, we identified essential properties of AUIs, resulting in distinct clusters that form a taxonomy for their classification and analysis. We present the following contributions: (a) **state-of-the-art** of AUIs, (b) a **taxonomy** that serves as a reference framework for AUIs, (c) a **web tool** that allows for intuitive exploration of the literature and taxonomy.

2 THEORIES AND FORMER STUDIES ON ANTHROPOMORPHIC USER INTERFACES

The first empirical study on anthropomorphism was conducted by Heider and Simmel [12]. In this study, researchers showed an animation of different shapes (e.g., triangle, rectangle) moving around in several directions at varying speeds. They concluded that people see objects as intentional agents if there is no other obvious cause why objects are performing a certain behavior. More recently, another fundamental study on anthropomorphism was conducted by Epley et al. [7]. They defined a theory that predicts when people are more likely to anthropomorphize. This theory is based on three psychological determinants – “elicited agent knowledge, effectance motivation, and sociality motivation”. This theory has become widely accepted by the HCI community and is one of the standard definitions for anthropomorphism in interactive systems.

Nass et al. [18] were the first to study whether computers can act as social actors and if people perceive them as social actors. They found that people do not reply socially because they believe computers are human or human-like, but because social responses to computers are commonplace and easy to generate. Fogg [8] also investigated how computers can behave as social actors. He states that people cannot control their social responses at some level, because they are rather instinctive. People thus naturally respond socially when they perceive social pressure. Responding socially to computers is also supported by the *Ethopoeia* concept, which defines that social responses are triggered as soon as social cues are present and that people cannot avoid reacting socially when confronted with social cues [24]. A different perspective on anthropomorphism was set by Persson et al. [22], as they define it as “a phenomenon that arises in the interaction between a set of anthropomorphic user expectations and external reality (technology)". They also state that “anthropomorphism is not just one phenomenon, but it exists at different levels". Another study conducted by Osawa and Imai [21] concludes that when building user interfaces using an agent, the agent should have enough expressions that trigger people to express social behavior towards the user interface. These triggers include shapes, motions, behaviors, and auditory and visual changes. Nowacka and Kirk [19] created a framework based on how autonomous behavior in

tangible user interfaces can create a new way of interaction between computers and humans. Related research has shown that people apply social rules when autonomous behavior is present. Catrambone et al. [4] also states that research on anthropomorphic agent interfaces has yielded inconsistent results, likely due to inadequate consideration of key factors. They propose a framework that emphasizes agent features, user characteristics, and task nature, with initial experiments showing that tasks significantly influence agent perception more than agent appearance. Most research has focused on computers positively serving as social actors, although recent work on the negative consequences exists as well [1]. Within the context of persuasive design, we encounter using social interface characteristics as well, given the value of building and sustaining a long-term relationship with the user. Bickmore and Picard [3] proposes strategies to maintain a social relationship between a computer and a human. Oinas-Kukkonen and Harjumaa [20] also states that "people are more easily persuaded by people/entities that look similar to themselves". Cialdini [5] investigated the influence and persuasive effect of certain social factors on people in particular situations, which led to six principles. These principles reveal the strength of social and human influence in persuasion.

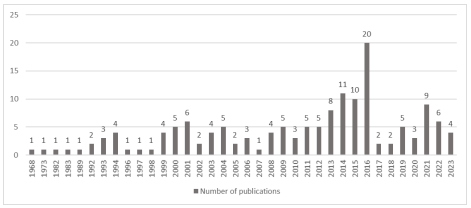
3 THE PAST: SYSTEMATIC REVIEW OF ANTHROPOMORPHIC USER INTERFACES

3.1 Affinity diagramming workshop on anthropomorphism

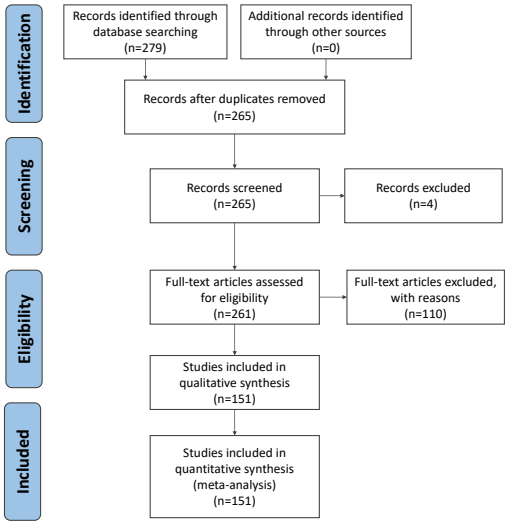
We organized an affinity diagramming [13] session to creatively generate keywords related to anthropomorphism using the tactile method of arranging post-it notes. This hands-on approach naturally guided us to group-related terms, enhancing our collaborative and intuitive exploration of ideas. Before we started with affinity diagramming, an introduction to anthropomorphism was provided to the four workshop participants. All participants have a background in HCI and are familiar with anthropomorphism. One participant also has a background in psychology. The introduction clarified the meaning of anthropomorphism (from the perspective of psychology and HCI) and different theories about anthropomorphism [7, 16, 22]. Afterwards, to help the participants brainstorm about anthropomorphism, six key questions were shared regarding human-likeness and anthropomorphism, focusing on revealing different human-like attributes: **1)**: *Describe different aspects or attributes of humans, physically as well as mentally.*, **2)**: *Which things can you anthropomorphize?*, **3)**: *Name all things you think about when you hear the word 'human-like'.*, **4)**: *Name all things you think about when you hear the word 'robot'?*, **5)**: *Imagine you have to create a human-like character for an application. On what different levels/aspects can you design this character?*, **6)**: *In what domains can a human-like virtual character or human-like robot be used?* These questions helped us to gather a comprehensive collection of anthropomorphic-related keywords, including anthropomorphic characteristics and application domains. Questions related to robots were also included to avoid narrowing the scope of anthropomorphism upfront and not to limit how the participants could brainstorm about anthropomorphism. Participants could write down all ideas that came to their mind for two minutes per question. Participants read each other's notes and add new notes afterward. Subsequently, the task was to pair notes that conceptually belong together or for which the participants felt they were related by moving them close together. After pairing all related notes, the participants had to create headers for the clusters they made. In this step, it was still possible to iterate over the clusters and split them into multiple clusters in case they felt this was appropriate. These steps resulted in 208 notes and 15 clusters (see Figure 1a). All clusters were explicitly validated with all participants to guarantee full consensus. The clusters resulting from the workshop are a representation of different properties of human-like aspects/characteristics: **Application Domain**, **Negative attitude toward others**, **Properties & attributes**, **Social skills**, **Feelings & emotions**, **Demographics**, **Reasoning**, **Abilities**, **Attached to objects**, **Attached to living entities**, **Physical traits**, **Instinct**, **Behavior**, **Expressions** and **Personality**. A thorough

discussion of all clusters individually was conducted to justify why certain elements belong together in one specific cluster. This resulted, for example, in a separate cluster for 'Negative attitude toward others' because all participants believe that this is a unique skill people can do (un)consciously. Trust, a factor in many anthropomorphism papers, was not included since the participants agreed that this is rather a result than a characteristic of an interface.

(a) Affinity diagram workshop results with 15 clusters (orange post-its) and 208 notes (yellow post-its)



(b) Publication years of the literature review's papers



(c) Flow diagram of literature selection for literature review

Fig. 1. Results from affinity diagramming workshop and literature review

3.2 Systematic literature review on anthropomorphism in HCI

We gathered an extensive list of papers related to *anthropomorphism* to review the literature systematically. The papers were retrieved from the ACM digital library by querying for papers with 'anthropomorphism' or 'anthropomorphic' in the title, abstract, or keywords until the end of 2023, resulting in 279 papers. By explicitly searching for these keywords in the aforementioned specific parts of the text, we verified that the authors of the resulting papers were conscious of using anthropomorphism in their work. Duplicate papers were removed from the resulting list of papers. Four other papers were left out because the full-text articles were inaccessible or not written in English. Afterward, appropriate papers were selected. After full-text screening, 94 papers were excluded, as they focused on technical aspects of robots (e.g., algorithms for robotic kinematics) or anthropomorphism in a different context unrelated to user interfaces. These exclusions resulted in a final set of 151 papers (see Figure 1c). Figure 1b shows the overview of publication years of the resulting set. The workshop's participants tagged the papers with the resulting clusters based on the content on the first page of the paper. Each paper was tagged by two participants. Many papers were not tagged by the same clusters. We concluded that some clusters were too closely related, resulting in fewer matching clusters per paper. We realized that not all papers were clear on what anthropomorphic elements they specifically investigated. We also found that some clusters needed extra sub-levels to specify certain properties. Therefore, we analyzed all papers and clusters again, together with existing theories on anthropomorphism from literature, and developed a taxonomy to guide the classification process better.

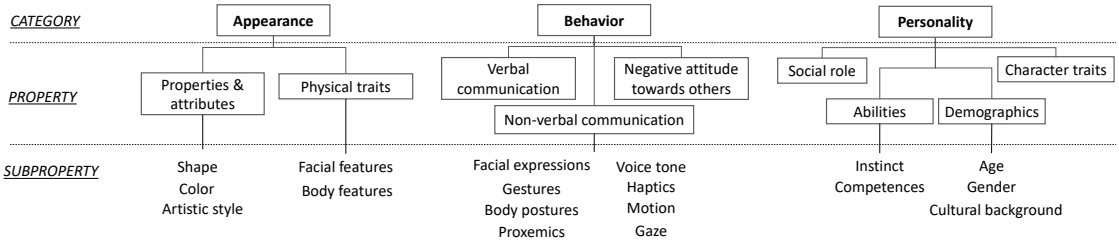


Fig. 2. Taxonomy of anthropomorphic user interface elements

4 THE PRESENT: TOWARD AN ACCESSIBLE CORPUS OF ANTHROPOMORPHISM IN USER INTERFACES

The taxonomy (see Figure 2) consists of three main categories: appearance, behavior, and personality, based on the definition of anthropomorphism as given in the Cambridge Dictionary: 'the showing or treating of animals, gods, and objects as if they are human in appearance, character, or behavior'. As 'personality' resulted from our affinity diagramming workshop, we used this term instead of 'character' as stated in the definition, but both have similar meanings. Each main category encompasses properties. Most of these properties are divided into subproperties. We define the value domain for each (sub)property (concrete examples of the property or subproperty based on the collected literature). Further refinement is based on existing theories and literature (e.g., [5, 8]) presented in Section 2. Relevant literature examples will be provided in an accessible tool in Section 5.

4.1 Appearance

Appearance is a purely visual feature of how someone or something looks. Properties in this category are related to the visual appearance of the anthropomorphic user interface. The category is subdivided into 'Properties & Attributes' and 'Physical traits'.

4.1.1 Properties & Attributes. Properties and attributes are related to visual or physical appearance and are not human-like or human-related but are still part of an anthropomorphic user interface. This property consists of three subproperties 'Shape', 'Color', and 'Artistic Style'. ***Shape*** defines the overall shape or representation in or of the interface. This can be very low-level, e.g., a rectangle, but this can also be a concrete representation of an existing object or animal, e.g., a pen or a dog. Value domain (description by example): rectangle, cat, dog, human, paperclip, etc. The subproperty ***Color*** describes the overall color scheme of the user interface; this can be a pattern of colors, e.g., grayscale, or a specific color, e.g., red, blue, or green. This is not a human-like attribute per se, but it should be considered as it influences the look and feel of the anthropomorphic representation. Value domain: blue, red, grayscale, pastel, etc. ***Artistic Style*** defines the style and level of lifelikeness used throughout the anthropomorphic user interface. The style can be represented by a simple 2D image or animation or a complex 3D representation, but it can also be a specific artistic style, such as 'Cartoon' or 'Realism'. Value domain: cartoon, realism, abstract, 2D, 3D, etc.

4.1.2 Physical traits. Physical traits encompasses all human physical appearance attributes, such as face, hair color, eyes, eye color, legs, etc. Physical traits provide users with a direct visual mapping of a human to a certain element in the user interface. This leads to two main categories, 'facial features' and 'body features'. ***Facial features*** focus on specific features present in a human's face. 'Facial features' is considered a separate subproperty next to 'body features' as it focuses more on the separate elements present in a human face. In contrast, 'body features' focuses more on other

parts of the human body that can be present in an interface. Value domain: eyes, mouth, hair, ears, teeth, etc. The subproperty ***Body features*** covers all elements that can be part of a human's body, except specific facial features as they are included in the previous subproperty 'Facial features'. Value domain: arms, legs, shoulders, body, face, toned figure, shoulders, etc.

4.2 Behavior

Behavior is how a person or animal acts in a certain situation. Behavior is influenced by personality and, at the same time, also exposes the underlying personality. It can be directed to another person or system, expressing an emotion or merely an action toward others. This category consists of three properties: verbal communication, non-verbal communication, and negative attitude towards others.

4.2.1 Verbal communication. Verbal communication is a way of sharing information between individuals by interacting in an oral or written manner. This property is not divided into subproperties. Examples are text or speech, but it can also be more concrete, such as praising or blaming. Value domain: text, speech, praise, blame, etc.

4.2.2 Non-verbal communication. Non-verbal communication covers different types of expressions that include visual cues, voice (paralanguage), or touch and is subdivided into a) facial expressions, b) gestures, c) body postures, d) proxemics, e) tone of voice, f) haptics, g) motion and h) gaze. ***Facial expressions*** can be shown voluntarily or non-voluntarily and are expressions of emotions visible on the face. Examples are smiling, crying, and looking surprised. Value domain: smile, sad, surprised, cry, annoyed, angry, etc. ***Gestures*** are a non-vocal way of communication in which arm or body actions express a certain message. This includes movement of hands, face, arms, and other body parts. Value domain: pointing, nodding, thumbs up, etc. ***Body postures*** refers to the way a person is sitting or standing and reveals information about a certain emotion. Value domain: sit, lay down, stand, etc. ***Proxemics*** is related to the use of space by humans. In this context, it describes the way people move toward other people. The way people move or reach toward others can influence the perception of the other person(s). This is an important aspect because a certain level of closeness can influence the level of trust and credibility. Value domain: intimate distance, personal distance, social distance, etc. ***Voice tone*** covers the group of non-verbal elements related to speech (paralanguage). This includes rhythm, volume, rate, and voice quality. Value domain: enthusiastic, empathetic, overwhelming, excited, etc. ***Haptics*** refers to the communication between humans or animals regarding touch, which is important for humans as it conveys physical intimacy. In an anthropomorphic user interface, haptics could be used as a form of feedback or as a certain texture to be perceived as a living entity by the user. Value domain: vibration, electric shock, etc. ***Motion*** is, in terms of anthropomorphism, the autonomous movement in position of a certain element or object. Motion is an important aspect highlighted by the research of Nowacka and Kirk [19]. Value domain: slow movement, fast movement, zigzag movement, etc. ***Gaze*** is a steady, intent look in a certain direction. This is an important factor in anthropomorphism as it will determine whether the user will feel addressed by the anthropomorphic user interface or not. Value domain: eye contact, no eye contact, looking upwards, looking downwards, etc.

4.2.3 Negative attitude towards others. Another property of behavior is *Negative attitude toward others*. It implies the ability of people to hurt other people consciously. This property is not divided into subproperties as it already covers a concrete, specific type of behavior. One could argue why this subproperty should not be more neutral in the form of 'Attitude', but given the papers we found in the literature focusing specifically on the negative intent and the outcomes of the workshop, we present the subproperty as is. Examples of negative attitudes are being able to lie, manipulating

people, and emotionally or physically injuring people. Anthropomorphic user interfaces must be designed carefully as they can also hurt people when performing the wrong behavior. Value domain: manipulate, lie, blame, etc.

4.3 Personality

Personality is the collection of unique and distinctive qualities that a person can encompass individually. Some people are more optimistic than others, while others can be rather stubborn. When designing an anthropomorphic user interface, we should consider what personality we want to assign to the character or entity in the anthropomorphic user interface and investigate if it should adapt its personality to the user‘s personality. The category ‘Personality’ consists of ‘Social role’, ‘Character traits’, ‘Abilities’, and ‘Demographics‘.

4.3.1 Abilities. Abilities are another aspect of someone‘s personality. Abilities can be divided in impulses almost all humans have (‘Instinct‘) and the capabilities humans can learn or improve (‘Competences‘). ***Instinct*** encompasses all abilities that (mostly) all people are capable of doing inherently, such as walking, talking, reasoning, or blinking with the eyes. Value domain: walk, talk, reason, blink eyes, etc. ***Competences*** are skills learned by doing, practicing, or by being taught how to do them. Value domain: dance, read, teach, write, drive a car, etc.

4.3.2 Social role. The anthropomorphic user interface can represent a certain *social role* such as a doctor or fitness coach. This property is not divided into subproperties. The role is a reflection of the personality, e.g., a doctor has more authority, while a fitness coach will be more positive and encouraging. Value domain: doctor, coach, teacher, student, police officer, etc.

4.3.3 Character traits. Character traits are an aspect of someone‘s personality. This property is not divided into subproperties. Character traits describe a person‘s traits specifically, such as being shy, dominant, or supportive. Value domain: shy, dominant, supporting, concerned, assertive, narcissistic, etc.

4.3.4 Demographics. Demographics encompasses the subproperties ‘Cultural background’, ‘Age’, and ‘Gender’. ***Cultural background*** is a reference to a certain culture. It can be represented in the anthropomorphic user interface by an individual or a group of individuals having character traits or visual characteristics related to this culture. The papers in our literature review do not report a clear study of the cultural background of anthropomorphic user interfaces. Nevertheless, this topic needs investigation as people can have certain preconceptions towards particular cultures and link certain character traits toward a specific population, both positive and negative. Value domain: Hispanic, Asian, Christian, etc. ***Age*** is not only related to the age perceived of/in the anthropomorphic user interface but can also represent a certain age group, such as children, elderly, or adults. Value domain: 21 years, 47 years, young adult, elderly, child, teenager etc. ***Gender*** relates to the perceived gender of the anthropomorphic user interface. Value domain: male, female, non-binary, transgender, etc.

4.4 Purpose of the taxonomy and literature classification

The taxonomy (see Figure 2) was created to assist designers and researchers in the process of designing anthropomorphic user interfaces. It will enable them to consciously select and define the different human-like elements contributing to a desired type of AUI. By providing different levels in the taxonomy, we can gradually assist designers and researchers in making selections according to their specific needs. High-level aspects of anthropomorphism can be selected first, e.g. appearance or behavior, after which the hierarchy guides the user toward concrete implementations. In most of the literature we investigated, we observed that anthropomorphic user interfaces are described generically. We hope

practitioners will utilize this taxonomy to describe and design anthropomorphic systems, thereby identifying distinct anthropomorphic elements. The literature was classified with the (sub)properties resulting from the taxonomy as a follow-up on our affinity diagramming workshop. Afterward, all the categories and properties were added to the tagged property or subproperty. Multiple categories, properties, and subproperties could be assigned to one paper. 15 papers were not tagged, as they do not investigate a specific aspect of anthropomorphism in terms of the design of AUIs, but rather discuss theory-related information or ethical issues.

5 THE FUTURE: A TOOL FOR TAXONOMY-DRIVEN QUERYING OF ANTHROPOMORPHIC UIS

To facilitate people in the design and classification of anthropomorphic user interfaces, and to use our taxonomy practically, we created an online tool[1], using Exhibit[2], that proposes literature on anthropomorphic interactive systems, structured according to our taxonomy. Using the various classification tags from the taxonomy enables faceted search through the vast collection of work on anthropomorphic user interfaces [9]. We assigned the corresponding categories and properties from the taxonomy to all papers and integrated other relevant information (e.g., the abstract and the year of publication). The tool allows users to filter and explore the dataset on different levels, including visual elements if available. With this approach, designers can find existing work on the specific aspects of anthropomorphic interfaces they seek. It turns the taxonomy itself into an operational tool and is especially useful during the early stages of design when exploring what properties to include when planning for engineering an anthropomorphic interactive system. Our online tool also enables us to grow the available content over time when new work appears and, when necessary, allows us to expand the taxonomy (e.g., add other properties, divide existing properties into new subproperties, etc.).

We evaluated our taxonomy and tool by classifying and analyzing the anthropomorphic aspects of a set of health apps in a study with five master-level computer science students specializing in HCI (P1-P5). The study consisted of two tasks using the online tool and taxonomy: 1) classify six mobile health apps, and 2) design an anthropomorphic user interface that supports cycling activity monitoring. All tasks were performed individually, and none of the participants was familiar with the tool, the taxonomy, or the concept of anthropomorphism.

Classifying health apps. We selected six apps[3] varying in popularity and targetting health behavior to focus on a certain scope: 1) Runkeeper, 2) Zombies, 3) Wokamon, 4) 8fit workout, 5) Fabulous, and 6) Lifesum. Participants were asked to classify the most common features of the apps and were informed upfront that not all apps necessarily have anthropomorphic aspects. All properties and subproperties that were classified by the participants were analyzed. We report a few frequently occurring combinations. Body features came often with facial features. Verbal communication is reported many times in combination with voice tone, social role, and gender, as these three subproperties contribute to verbal communication. Gaze was only mentioned a few times, but it was always combined with facial features and facial expressions. Age was usually reported in combination with many other subproperties, indicating that this subproperty needs multiple other subproperties to be notable in a user interface. Gender was noted often in combination with artistic style, verbal communication, and voice tone, suggesting that the overall appearance or audio reveals the gender of the anthropomorphic entity. Shape, color, and artistic style were reported many times, but this was also mentioned as more general characteristics of the user interface, rather than only in the anthropomorphic context.

Designing an anthropomorphic user interface. In the second task, participants had to report what sources they consulted in the tool next to designing an interface (for monitoring cycling activities). P5 did not make use of sources in the tool.

[1]https://anthropomorphic-ui.onrender.com/
[2]https://www.simile-widgets.org/exhibit3/
[3]https://runkeeper.com, https://zombiesrungame.com, https://www.wokamon.com, https://8fit.com, https://thefabulous.co, https://lifesum.com

P4 made, next to consulting papers in the tool, use of ideas from the apps (i.e. Runkeeper, and Lifesum) he classified in the other task. Three participants integrated a virtual coach in their user interface, supported by text dialogues to communicate with the user. Some properties occurred multiple times within the five designs that were created, e.g. facial features (5), verbal communication (4), artistic style (4), social role (3), and gender (3).

6 DISCUSSION

Our exploratory evaluation found that some anthropomorphic subproperties, as indicated in the taxonomy, were often reported as being present in the user interface. However, these characteristics did not contribute to the anthropomorphic nature of the application. We included subproperties such as color and artistic style as a feature of an anthropomorphic object, but these subproperties themselves do not always ensure that an interface is anthropomorphic. It must be clear that a subproperty is only relevant in the context of its parent property or classification in the taxonomy. Our study revealed that participants lacked experience using taxonomies as a classification tool, highlighting the need to familiarize them with the purpose and usage of taxonomies for effective application. Based on the findings of our evaluation, we also suggest integrating existing interfaces in the tool, and not only examples from literature. It is also crucial to consider the context in which the interface will be used. While the taxonomy provides inspiration and suggestions for anthropomorphic aspects, it is the responsibility of interface designers to tailor these elements to the context's specific needs. For instance, the design requirements for an application intended for use in a hospital setting will differ significantly from those for a mobile game.

In developing our taxonomy for anthropomorphic user interfaces, we consciously navigated the balance between breadth and specificity. By limiting the scope to exclude a significant portion of robotics-related literature, we aimed to maintain a clear focus on interfaces that leverage human-like characteristics without the direct influence of physical robotics. This scope means that our taxonomy might not encompass the full spectrum of anthropomorphic design principles and applications in the wider field, and is only applicable for digital user interfaces.

As large language models humanize our perception of system intelligence [15, 17], there is a growing need for interfaces that communicate effectively with human-like nuances. This development highlights the importance of our research in creating sustainable, anthropomorphic interfaces that meet evolving user expectations for intuitive and empathetic interactions. Consequently, our taxonomy is intended not as a final model but as a starting point for ongoing dialogue in designing interfaces with human-like qualities. We hope our work inspires further innovation, inviting designers and researchers to build on, refine, or question our taxonomy. This collaborative effort is crucial as we advance toward more human-centric interface designs, driven by the fact that advanced technologies acting more human-like are becoming more common.

7 CONCLUSION

We conducted a literature review and developed a taxonomy to aid in designing, comparing, and exploring anthropomorphic user interfaces based on insights from 151 papers and a workshop with HCI and psychology experts. We identified properties for classifying these interfaces using affinity diagramming, which were then incorporated into our taxonomy. This taxonomy not only helps designing new anthropomorphic interfaces but also facilitates the comparison and exploration of existing ones. We have also introduced an online tool that categorizes literature according to the taxonomy, enhancing its practical use. Additionally, a study involving five participants evaluated the taxonomy and tool's effectiveness in classifying health apps and designing anthropomorphic interfaces, highlighting the need to integrate more diverse resources, such as existing apps, into the tool.

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REFERENCES

[1] Lize Alberts, Ulrik Lyngs, and Max Van Kleek. 2024. Computers as Bad Social Actors: Dark Patterns and Anti-Patterns in Interfaces that Act Socially. *Proc. ACM Hum.-Comput. Interact.* 8, CSCW1, Article 202 (apr 2024), 25 pages. https://doi.org/10.1145/3653693

[2] Nanyi Bi and Janet Yi-Ching Huang. 2023. I create, therefore I agree: Exploring the effect of AI anthropomorphism on human decision-making *(CSCW '23 Companion)*. Association for Computing Machinery, New York, NY, USA, 241–244. https://doi.org/10.1145/3584931.3606990

[3] Timothy W. Bickmore and Rosalind W. Picard. 2005. Establishing and maintaining long-term human-computer relationships. *ACM Transactions on Computer-Human Interaction* 12, 2 (2005), 293–327. https://doi.org/10.1145/1067860.1067867

[4] Richard Catrambone, John Stasko, and Jun Xiao. 2002. Anthropomorphic agents as a user interface paradigm: Experimental findings and a framework for research. *Proceedings of the 24th Annual Conference of the Cognitive Science Society* (2002), 166–171.

[5] Robert B. Cialdini. 2007. *Influence: The Psychology of Persuasion.* 1–263 pages. https://doi.org/10.1017/CBO9781107415324.004

[6] Sarah Diefenbach, Nina Kolb, and Marc Hassenzahl. 2014. The 'hedonic' in human-computer interaction: history, contributions, and future research directions. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. Association for Computing Machinery, New York, NY, USA, 305–314. https://doi.org/10.1145/2598510.2598549

[7] Nicholas Epley, Adam Waytz, and John T Cacioppo. 2007. On Seeing Human : A Three-Factor Theory of Anthropomorphism. *Psychological Review* 114, 4 (2007), 864–886. https://doi.org/10.1037/0033-295X.114.4.864

[8] B. J. Fogg. 2003. Using computers to change what we think and do. *Persuasive Technology* 5, December (2003), 89–120. https://doi.org/10.1016/j.amepre.2008.09.040

[9] Jonas Geuens, Ine D'haeseleer, Luc Geurts, and Vero Vanden Abeele. 2016. Lenses of Motivational Design for mHealth. In *Proceedings of the 2016 Annual Symposium on Computer-Human Interaction in Play Companion Extended Abstracts* (Austin, Texas, USA) *(CHI PLAY Companion '16)*. Association for Computing Machinery, New York, NY, USA, 165–171. https://doi.org/10.1145/2968120.2987722

[10] Marc Hassenzahl, Axel Platz, Michael Burmester, and Katrin Lehner. 2000. Hedonic and ergonomic quality aspects determine a software's appeal. *Proceedings of the SIGCHI conference on Human factors in computing systems - CHI '00* 2, 1 (2000), 201–208. https://doi.org/10.1145/332040.332432

[11] Marc Hassenzahl and Noam Tractinsky. 2006. User experience - A research agenda. *Behaviour and Information Technology* 25, 2 (2006), 91–97. https://doi.org/10.1080/01449290500330331

[12] Fritz Heider and Marianne Simmel. 1944. An experimental study of apparent behavior. *The American Journal of Psychology* 57, 2 (1944), 243–259.

[13] Karen Holtzblatt, Jessamyn Burns Wendell, and Shelley Wood. 2005. Rapid Contextual Design: A How-to Guide to Key Techniques for User-Centered Design. *Elsevier* 2005, March (2005), 3. https://doi.org/10.1145/1066322.1066325

[14] Sari Kujala, Virpi Roto, Kaisa Väänänen-Vainio-Mattila, and Arto Sinnelä. 2012. Identifying hedonic factors in long-term user experience. *Proceedings of the 2011 Conference on Designing Pleasurable Products and Interfaces* (2012), 1. https://doi.org/10.1145/2347504.2347523

[15] Pratyush Kumar. 2023. Large Language Models Humanize Technology. arXiv:2305.05576 [cs.CY] https://arxiv.org/abs/2305.05576

[16] Jae-Gil Lee, Jihyang Gu, and Dong-Hee Shin. 2015. Trust In Unmanned Driving System *(HRI'15 Extended Abstracts)*. Association for Computing Machinery, New York, NY, USA, 7–8. https://doi.org/10.1145/2701973.2702023

[17] Kevin R McKee, Xuechunzi Bai, and Susan T Fiske. 2023. Humans perceive warmth and competence in artificial intelligence. *Iscience* 26, 8 (2023).

[18] Clifford Nass, Jonathan Steuer, and Ellen R. Tauber. 1994. Computers are social actors. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (Boston, Massachusetts, USA) *(CHI '94)*. Association for Computing Machinery, New York, NY, USA, 72–78. https://doi.org/10.1145/191666.191703

[19] Diana Nowacka and David Kirk. 2014. Tangible autonomous interfaces (TAIs): exploring autonomous behaviours in TUIs. In *Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction* (Munich, Germany) *(TEI '14)*. Association for Computing Machinery, New York, NY, USA, 1–8. https://doi.org/10.1145/2540930.2540942

[20] Harri Oinas-Kukkonen and Marja Harjumaa. 2008. A Systematic Framework for Designing and Evaluating Persuasive Systems. In *Proceedings of the 3rd International Conference on Persuasive Technology* (Oulu, Finland) *(PERSUASIVE '08)*. Springer-Verlag, Berlin, Heidelberg, 164–176. https://doi.org/10.1007/978-3-540-68504-3_15

[21] Hirotaka Osawa and Michita Imai. 2013. Morphing agency: deconstruction of an agent with transformative agential triggers. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (Paris, France) *(CHI EA '13)*. Association for Computing Machinery, New York, NY, USA, 2237–2246. https://doi.org/10.1145/2468356.2468745

[22] Per Persson, Jarmo Laaksolahti, and Peter Lönnqvist. 2000. Anthropomorphism-a multi-layered phenomenon. *AAAI Fall symposium, Socially Intelligent Agents: The Human in the Loop* (2000), 131– 135.

[23] Nicolas Pfeuffer, Alexander Benlian, Henner Gimpel, and Oliver Hinz. 2019. Anthropomorphic information systems. *Business & Information Systems Engineering* 61 (2019), 523–533.

[24] Byron Reeves and Clifford Nass. 1996. *The Media Equation: How People Treat Computers, Television, and New Media Like Real People and Places.* Cambridge University Press, New York, NY, USA.