Eyecam: Revealing Relations between Humans and Sensing Devices through an Anthropomorphic Webcam

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Figure 1: a) *Eyecam* is an alternative anthropomorphic design of conventional webcams, b) which draws inspiration from the human eye morphology to c) exaggerate the sensing capacities of webcams like face detection, and d) foster affective relationships.

ABSTRACT

We are surrounded by sensing devices. We are accustomed to them, appreciate their benefits, and even create affective bonds and might neglect the implications they might have for our daily life. By presenting *Eyecam*, an anthropomorphic webcam mimicking a human eye, we challenge conventional relationships with ubiquitous sensing devices and call to re-think how sensing devices might appear and behave. Inspired by critical design, *Eyecam* is an exaggeration of a familiar sensing device which allows for critical reflections on its perceived functionalities and its impact on human-human and human-device relations. We identify 5 different roles *Eyecam* can take: *Mediator*, *Observer*, *Mirror*, *Presence*, and *Agent*. Contributing design fictions and thinking prompts, we allow for articulation on *privacy awareness and intrusion*, *affect in mediated communication*, *agency* and *self-perception* along with speculation on potential futures. We envision this work to contribute to a bold and responsible design of ubiquitous sensing devices.

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CCS CONCEPTS

• **Human-centered computing** → **Interaction design theory, concepts and paradigms**; **Interaction devices**; • **Applied computing** → *Media arts.*

KEYWORDS

Critical Design, Anthropomorphism, Webcam, Ubiquitous computing, Sensing Devices

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1 INTRODUCTION

Today's interfaces have long transcended the traditional desktop setup and learned to sense and comprehend their environments. We are surrounding ourselves with an ever increasing number of sensing devices, ranging from cameras to smart speakers and motion sensing radar chips. They allow for object detection and recognition [55], natural interactions using speech [83], hand or body gestures [103], and for creating interactive rooms [40, 108], surfaces [100, 107] to furniture [92] and garments [34]. We encounter

these sensing devices everywhere: in public, at our workplace, and inside our homes and living spaces. They have become ubiquitous.

Simultaneously, ubiquitous sensing devices are becoming invisible and morph into our daily lives, up to a point where we are unaware of their presence and stop questioning how they look, sense, and act. This is alarming, because the way ubiquitous sensing devices are designed can have implications on

- how aware we are of what our surroundings,
- how we communicate with others,
- how we behave and how we perceive our selves,
- how comfortable and safe we feel in public and private surroundings, and
- how we interact with sensing devices and vice versa.

As a result, it is important to challenge conventional design assumptions and strategies to evaluate what other options of designing technology can be pursued to positively engage with everyday individual and societal life. In light of this, it is timely to rethink and reconceptualize the relationship between humans and sensing devices through novel design alternatives. To this end, we decided to single out one specific sensing device – the webcam. Everyone is highly familiar with this device, and it is widely-used, making it highly relatable. Hence, everybody can participate in a discussion about it and contribute with their personal experiences, thereby facilitating an inclusive discussion on the design of human-technology relations.

In addition, webcams, as image sensing devices, are interesting to study because of their ambiguity: they are both essential to (video) communication over a distance [63], as well as a potential cause of disturbance [86] and a privacy hazard [80]. We sought to re-think the conventional design of webcams (Figure 1-a) to emphasize the potential implications sensing has on its user and other people. For this purpose, we leveraged the similarity of its basic function with the human eye: seeing and observing.

Taking inspiration from critical design [5, 22] and anthropomorphic interfaces [93, 95], we created *Eyecam* as a physical instantiation of the implications an exemplary sensing device can have for a human. To this end, *Eyecam* exaggerates concealed functionalities using anthropomorphic metaphors (e.g., field of view, capturing turned on). Modeled on the human eye morphology (Figure 1 - b), *Eyecam* comprises an actuated eyeball with a pupil replaced with a camera, actuated eyelids and actuated eyebrows whose combined movements enable human-like behaviors. By making it physical, *Eyecam* makes abstract concepts more tangible and illustrative. The exaggeration of its appearance captures attention and triggers spontaneous reactions and critical reflections.

Our rationale behind designing *Eyecam* in this way was two-fold. Firstly, to create a contrast to the current trend of increasingly unobtrusive sensing devices, we aimed to learn from the opposite, a clearly seeing device. We achieve this by presenting a speculative, anthropomorphic instantiation based on the the human eye, thereby leverage the tacit knowledge we have of the human act of seeing. Secondly, *Eyecam* continues and joins prior research themes of the individual authors, including antropomorphism [93, 95], (self-)expression and perception [91] and privacy awareness [48, 90]. Originating from these diverse perspectives, this work broaches critical (social) issues around the ubiquity of sensing devices in breadth and by providing novel overview perspectives that is contextualized, compared, and contrasted with prior work. As a result, *Eyecam* does not directly explore the impact of anthropomorphic design, but proposes to use anthropomorphism as a new (uncanny) tool for speculation.

Our work falls in line with research efforts in HCI transcending mere usability of devices to encompass emotions, values and affects, and the increasing interest in ethical [77], social [46, 47], and privacy [2, 74, 80] issues with ubiquitous sensing devices. Yet, in contrast to prior work, we use anthropomorphic design to take a speculative turn, challenging the reader to imagine themselves interacting with *Eyecam*, actively contribute to the debate, and speculate and iterate on potential futures. To this end, we contribute *Eyecam* as a plug-and-play physical prototype that can be re-used, re-built, or re-purposed. We further contribute five provocative design fictions which explore different types of behavior of our prototype. These open up a debate on plausible and implausible ways future sensing devices might be designed.

Through these fictions, we identify five different roles of *Eyecam*'s design: *Eyecam* as an Observer, a Mediator in remote communications, a Mirror of the self, an Ambient Presence acting as Genius Loci, and an autonomous Agent. Through design scenarios revolving around the provocative design of *Eyecam*, we discuss the relevance of privacy awareness and intrusion, connect in mediated communication, self-perception, and agency beyond the realm of desktop working environments and video capturing systems, and sketch potential futures relating to ubiquitous sensing devices.

With this work we intend to broaden the discourse on sensing technologies to include affective aspects, allow to further articulate social and ethical challenges, and spark speculations on artifact aestheticism and function. Finally, we envision this work to contribute to both a bold and responsible design of cameras and other ubiquitous sensing devices.

2 BACKGROUND

While multiple relevant arguments presented by prior work are woven in with our design fictions, we opt to highlight the essential areas of contact here, in a dedicated background section. We outline relevant background information on webcams and other sensing devices in HCI, systems utilizing eye gaze for interaction, anthropomorphic interfaces as well as methods using artifact design for reflection.

2.1 Cameras and other Sensing Devices

The proliferation of sensing devices into diverse areas of daily life relates to research in HCI on sensing methods that enable novel ways of interacting [53, 100, 103, 107, 108]. In particular, cameras have a long history of being employed in interactive systems. For instance, they are used to realize visual tracking [43], object or face detection [101]. Camera-based assistance in everyday use cases, early-on envisioned and implemented by Mann as `Sixth Sense' [63], is nowadays ubiquitously available, e.g., as part of Google Lens [37] or Microsoft's Seeing AI [39]. In addition, interactive systems often employ cameras that exceed the visual range of the human eye. For instance, RGB-D cameras such as the Kinect (c.f., Jones et al. [40]) operate in the human perceptible and the near infrared

spectrum, thermal cameras [82] in the far infrared spectrum, invisible to the human eye. As a result, the line between cameras as human-operated, picture-taking device, and as a powerful sensor that actually `sees' its environment, become increasingly blurred. We elaborate on this theme using Eyecam as example.

As a second major area of interest, HCI has researched the effects ubiquitous sensing has on humans. Here, prior work looked into the use of wearable sensor devices, e.g., smart glasses in public spaces [18, 46, 86], lifelogging [45, 80], and ubiquitous sensing in smart home applications [16, 77, 88, 105]. Most related to our paper, a string of research by Pierce et al. [73, 77] sought to investigate network anxieties caused by always-on sensing in domestic environments using speculative design scenarios. His playful camera prototypes [73, 77] explore reassuring metaphors preventing information leaks, including curtains, cages and caps, as well as unpredictable autonomous sensing devices, e.g., a camera riding a Roomba [75]. These prototypes all have a clean, minimal and industrial aesthetic. By employing exaggeration and anthropomorphic design, Eyecam complements and extends this prior design research.

2.2 Privacy and Security Issues with Webcams

Webcams pose a potential privacy hazard as they might capture activities that their user (or other depicted persons) would not want to be recorded [16]. Their surreptitious and ubiquitous nature facilitates misuse including the secretive observation of others in the home, e.g., intimate partners or other family members [13, 51], as well as attacks on other internet service users, so-called webcam trolling [49]. These issues intensify, as effective locators or feedback mechanisms (as demanded by Song et al. [88]) are sparse and image masking techniques (e.g., blur filtration) fail to provide sufficient protection [64]. The webcam status LED, build-in with commodity notebooks, is the most common status indicator. Yet, it has been shown to be spoofable [11], and insufficiently noticeable and understandable [79]. In response to this danger of being surreptitiously watched, users have been observed to block their webcam's view with stickers or sliding covers [57, 58]. A guidebook of such countermeasures also extending to other, non-visual sensors has been proposed by Angus [59] who illustrates how to deceive a magnetometer and how to disable a smart phone's microphone using a manipulated audio jack. Similarly, the use of perceptually intuitive physical solutions using eye-lid or curtain metaphors has been proposed to improve understandability [15, 48, 77, 90]. Eyecam takes up these insights and implements the eye metaphor as design, following the Tangible Privacy [2] principles.

2.3 Eye Gaze for Interaction

The human eye gaze is crucial to convey non-verbal social cues. The temporal dynamics of gaze can improve communication, for instance by modulating social cognition and behaviour [14], influencing attention and engagement [84] and desire to communicate [24, 33]. Moreover, in combination with facial features such as eyebrow movements, eye gaze can convey pro-social emotions [56]. The importance of gaze has also been explored extensively in robotics [1] and with virtual agents [26]. The aesthetic and tangibility of the eyes are an important trait for anthropomorphism [21] and are beneficial for embodiment and familiarity. While social gaze communicates social engagement, a deictic gaze communicates task-related referential information [106] and can be used to guide the user's actions.

While human gaze was largely explored in the context of human-robot interactions, to the best of our knowledge, it was never explored in the context of ubiquitous sensing devices. With Eyecam we demonstrate how one can leverage the human gaze to better communicate the interaction design of ubiquitous sensors, and foster a effective communication with them.

2.4 Anthropomorphic Interfaces

Anthropomorphism in HCI relates to the attribution of human characteristics to inanimate objects with the goal to help us rationalise their actions [21]. Persson [70] considers anthropomorphism as being a multi-layered phenomenon, and highlight the fact that the aliveness perception of the interface is conveyed mainly through actuation and movement (look-and-feel) and through a perceived inner behaviour of the device. While using anthropomorphism is common for the design of social robots and can benefit interaction [12, 41, 52], explorations of anthropomorphic cues for the design of conventional everyday devices are less common.

In the HCI literature such examples are often encountered in the area of shape changing interfaces. Here, traditional objects are designed to communicate a sense of agency through movement [9, 96]. Research has shown that traditional non-verbal behaviour can be mimicked through simple actuation, such as communicating attention or aversion through body-posture inspired movements [31], convey aliveness through life-like signals such as breathing rhythms [30, 69] or present emotions through shape and shape dynamics [91]. Recent work proposed re-thinking or extending the form factor of usual interactive devices to produce an anthropomorphic look-and-feel. For instance, Teyssier et al. proposed to augment touch devices with artificial realistic human skin [95] or augment phones with realistic finger-shaped attachments [93], while Park et al. proposed to augment mobile devices with animal-like antennas [68]. These approaches leverage knowledge of human behavior to convey intuitive interactions. Similar to this approach, we argue that morphological cues are a key component for conveying and exacerbating interaction capabilities. In this paper, we use the term Anthropomorphic Affordances to refer to the tacit knowledge of the interaction cues and capabilities that are conveyed through a human-like appearance [25].

2.5 Artifact Design to Reflect on our Relationships with Sensing Devices

Historically, CHI has a tradition of using prototype design to perform empirical studies of firsthand use. However, there is a growing interest of using new artifacts to reflect on our relation with technology itself. While this perspective was traditionally deployed through the lens of philosophy [99], this practice can now thrive through design fiction, [10, 109] and critical and speculative design [22]. We opt for a different approach than speculative fictions through imaginary devices [10] by fabricating a proof-of-concept tangible and functional prototype. Creating a physical artifact allows researchers and users to experience the device and discuss

their experience with others to generate discussions [19]. With this approach, previous work demonstrated for instance the benefits of designing counter-functional interfaces [76], or even uncomfortable interactions [8].

Similar to the critique of Ubiquitous Computing through science fictions scenarios by Dourish and Bell [20], Eyecam aims to point out societal issues of the current challenges of technology, challenge the established conventions [5], while questioning implicit themes in sensor design research.

3 EYECAM, ANTHROPOMORPHIC WEBCAM

The physical design is central in our work. The artifact design and look and feel result from the coupling between functional and aesthetic considerations as well as technological constraints. In this section, we discuss our design considerations, and the physiological and behavioral design of Eyecam. We also provide insight on the iterative design process.

3.1 Design Considerations

We had the following three primary goals for the implementation of Eyecam: 1) fabricate a fully functional proof-of-concept tangible device to experience it, 2) preserve conventional webcam functionalities, 3) support anthropomorphic affordances through appearance and motions.

1. Tangible Proof-of-concept Artifact: Creating a physical prototype is not mandatory to reflect on the usage of a device, yet it is seen as a commitment to the idea [72]. The physical presence of an anthropomorphic agent has more impact on our behavior [52], hence a tangible prototype allowed us to experience it and concretely experiment with the look-and-feel of this device to foster discussion. Eyecam is not only a fully functional prototype, but all information for others to replicate it is freely available, making Eyecam an open platform for experimentation. We encourage designers and researchers to replicate our device, create novel interactions with it, and reflect on the relations they have with such a device to shape new experiences[1].

2. Preserve Conventional Webcam Functionalities: In the last decades, the form factors of USB Tethered webcams have marginally evolved. These devices are familiar to us, and we understand their roles in our computing space as well as their functionalities. To emphasize their role in our lives without radically changing it, the design of Eyecam crosses the traditional form-factor of a webcam with a human eye. Like traditional webcams, Eyecam can be placed on a computer, facing the user, or Eyecam could be used in a living room to enable remote social communications with relatives, integrating larger social circles. Either way, Eyecam behaves as expected of a commodity device. It plugs into a computer via USB and is recognized as a camera.

3. Provide Anthropomorphic Cues: To promote social interaction through human-likeness and to foster familiarity, we chose to reproduce the human eye. The eyes serve as social emotional display, hence are a critical trait for anthropomorphism [21]. We particularly want to emphasize on reactive human gaze dynamics and expressive eyebrow movements. An important consideration for anthropomorphism is the level of realism. Designers usually intend to avoid falling into the Uncanny Valley. In contrast, we embrace the uncanny valley by intentionally provoking it through an out-of-body and out-of-context body part, to shine a spotlight on critical issues hidden in ubiquitous sensing.

Figure 2: We manufactured Eyecam from a 3D-printed body (a), which we equipped with six servo motors for actuation (b). The servo motors are mechanically connected to the eyebrows and the eyeball (c). We created a realistic eyeball and iris encompassing the camera (d). The skin layer was molded in pigmented silicone (e), and augmented with hair implants (f) to generate a human-like impression (g). More details on the prototype hardware and material for replication can be found online [1].

The implementation of Eyecam follows high-level principles derived from the field of social robotics [21] and commonly used for anthropomorphic and human-like technologies. It comprises physiological and behavioral aspects.

3.2 Physiological Design: Fabricating a Human Eye

While anthropomorphic affordances can be present even in abstract representations [91], creating an artifact with high levels of realism removes levels of abstraction, fostering both a direct interpretation of anthropomorphic cues and a visceral response [36]. Consequently the physiological design of Eyecam replicates human characteristics and capabilities as realistically as possible, including the look-and-feel of the interface, the way it is actuated and the way it senses.

Human-like Appearance. Eyecam's form factor is inspired by a real-size human eye's anatomy (Figure 2g). It is composed of three main

[1] We provide our code and implementation materials at https://marcteys.github.io/eyecam/