# Your Smart Glasses' Camera bothers me! - Exploring Opt-in and Opt-out Gestures for Privacy Mediation

**Marion Koelle**[1], **Swamy Ananthanarayan**[1], **Simon Czupalla**[1], **Wilko Heuten**[2], **Susanne Boll**[1]
[1] Media Informatics and Multimedia Systems, University of Oldenburg, Oldenburg, Germany
[2] OFFIS – Institute for Information Technology, Oldenburg, Germany
firstname.lastname@uol.de, firstname.lastname@offis.de

## ABSTRACT
Bystanders have little say in whether they are being recorded by "always-on" cameras. One approach is to use gestural interaction to enable bystanders to signal their preference to camera devices. Since there is no established gestural vocabulary for this use case, we explored gestures to explicitly express consent (Opt-in) or disapproval (Opt-out) in a particular recording. We started with a gesture elicitation study, where we invited 15 users to envision potential Opt-in and Opt-out gestures. Subsequently, we conducted a large-scale online survey (N=127) investigating ambiguity, representativeness, understandability, social acceptability, and comfort of a subset of gestures derived from the elicitation study. Our results indicate that it is feasible to find gestures that are suitable, understandable, and socially acceptable. Gestures should be illustrative, complementary, and extendable (e.g., through sequential linkage) to account for more granular control, as well as not be beset with common meaning. Moreover, we discuss ethicality and legal implications in the context of GDPR.

### Author Keywords
Privacy; smart glasses; wearable camera; gestures.

### ACM Classification Keywords
H.5.2. Information Interfaces and Presentation (e.g. HCI): User Interfaces

## INTRODUCTION
Bystanders of mobile camera devices often have no option of providing consent or expressing their disagreement with being recorded, except by directly addressing the camera user. This is however, not always possible, especially since "always-on" cameras, such as life logging devices, or smart glasses, are often ambiguous about their recording status.

Our work aims to give back control to the bystander, and enable them to consciously decide their recording preference. As suggested by Denning et al. [6], we distinguish between two types of consent mechanisms:



*NordiCHI'18,* September 29-October 3, 2018, Oslo, Norway



ISBN 978-1-4503-6437-9/18/09…$15.00

DOI: https://doi.org/10.1145/3240167.3240174

**Figure 1: Free-hand gestures might enable device-less communication of privacy preferences. We collected various gestures for Opt-in (left) and Opt-out (right) in an elicitation study.**

**Opt-in** bystanders are by-default anonymized, e.g., by blurring their faces, or are removed from the imagery. If they wish to be recorded they have to explicitly provide consent.

**Opt-out** in the default case, everyone is recorded. Any bystander who wants to be excluded from the recorded imagery has to explicitly express their disagreement.

Opt-in and Opt-out procedures that rely on wireless communication, using BLE or Wi-Fi, or visual markers (c.f. [27, 29]), require the bystander to own a particular device or token. Blocking technologies, such as Yamada's "Privacy Visor" or Harvey's "CV Dazzle" also require the bystander to wear tags, particular accessories [32, 35] or make-up [8]. These approaches however, require bystanders to own and use specific technologies.

In contrast, mechanisms following the "come-as-you-are" paradigm do not require additional adornments on the bystander's side. They could provide him/her with control over the image, e.g., using gesture or voice commands [13]. With the increasing popularity of Voice User Interfaces (c.f., Porcheron et al. [20]), voice commands, such as "Stop recording!", or "Camera off", might be considered an intuitive choice. However, Reis et al. [24] report that the user's willingness to use voice commands decreases with an increasing number of strangers in the surroundings. Thus, requiring bystanders to use speech to opt-in or opt-out of an "always-on" camera's recording might create barriers: Williamson et al. [33] found gesture-based interactions to be considered more socially acceptable than voice-based interactions when interacting in

**Figure 2: Our participants suggested dynamic gestures that encode information in the direction of movement: e.g., chin to forehead: Opt-in (middle), forehead to chin: Opt-out. Alternatively, concatenations of static gestures might have a different meaning depending on the order in which they are performed: fist opening: Opt-in (left), open hand closing to fist: Opt-out.**

public. Thus, in this work, we explore a "come-as-you-are" approach where bystanders utilize **free-hand gestures** as Opt-in, and Opt-out mechanisms.

The use of gestural interaction between primary users and their smart glasses has been explored for both hand-to-face [28] as well as free-hand gestures [10]. In contrast, (gestural) interaction between secondary users (e.g., bystanders) and a primary user's body-worn device (e.g., their Smart Watches [19] or Virtual Reality glasses [5]) has not been fully explored.

While a comprehensive line of research has investigated the usage [9], social acceptability [25, 26, 2] and learnability [1] of free-hand gestural human-machine communication in public, using gestures for privacy mediation with smart glasses and/or body-worn cameras has only sparsely been covered. Shu et al. [29] explore visual tags, gestures, and their combinations, and Jung et al. [11] suggest an off-the-record gesture for imposing privacy preferences to a third person's body-worn camera. Both however, do not delve into the choice of gestures. Prior work targeting other Opt-in and Opt-out scenarios (e.g., Barhm et al. [4]) are also not conclusive about what gestures are suitable, i.e., applicable, easy to learn and execute, and unambiguously distinguishable in a variety of contexts.

We aim to close this gap and contribute the results of a gesture elicitation study (N=15) exploring options for free-hand Opt-in and Opt-out gestures, as well as results of a large-scale online survey (N=127) tackling ambiguity, understandability, representativeness, social acceptability and comfort. In light of our findings, we discuss the selection of Opt-in and Opt-out, and critically reflect on the concept of privacy mediation using Opt-in and Opt-out concluding with directions for future work.

## EXPERIMENT 1: ELICITATION STUDY

In our work, we employ Kendon's [12] definition of gesture as a movement that is intended to convey information. Particularly, we explored hand movements suitable for encapsulating "Opt-in" or"Opt-out" intent. In order to collect as many potential candidates for Opt-in and Opt-out gestures, we conducted a guessability-style elicitation study [34]. This method has been successfully used in prior research [22] to generate easy to learn and remember gesture vocabularies. Moreover, it involves users in the early stages of concept development.

### Method

After granting informed consent, participants filled out a brief demographic questionnaire that also assessed their experience with free-hand gestural interaction and symbolic languages such as international sign language, referee hand signals, and diver communications. Subsequently, participants were invited to envision and perform potential Opt-in, and Opt-out gestures. The Opt-in and Opt-out principles were visualized using explanatory cards that contained a textual and graphic description. The order of Opt-in, and Opt-out, respectively, was randomized between participants based on a lottery system. The gestures were video-recorded for further analysis. The guessability session was followed by a brief exit questionnaire, where participants reflected on Opt-in or Opt-out procedures in different real-world hypothetical situations. We post-processed and anonymized (e.g., blurring faces) all videos directly after the session and deleted the raw images. These procedures were approved by our internal review board.

### Participants

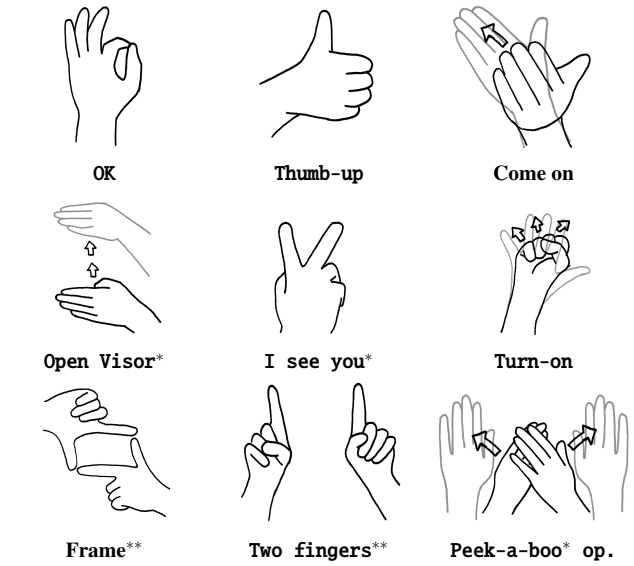
We recruited 15 unpaid participants (5 female) via campus mailing lists and social networks. They were aged between 24 – 61 (M=28, SD=9) years. The majority of participants were students in different majors, including computer science, education, biology, and social sciences. Three of them were working (engineer, care-giver, and one server).

### Results

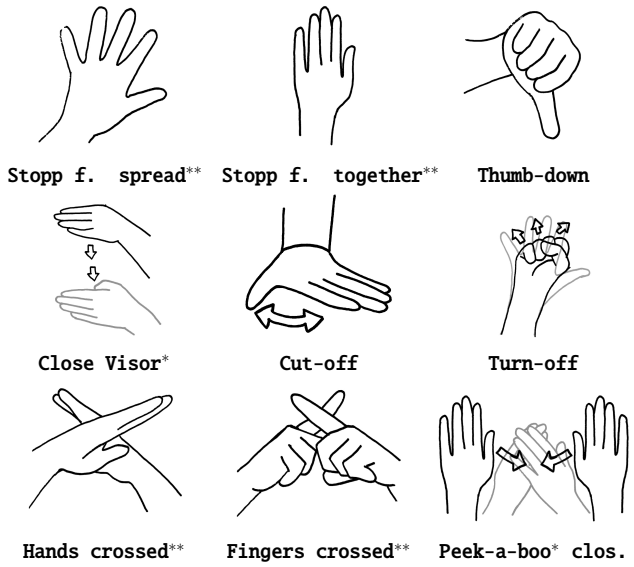
We collected 94 gesture samples in total where each participant suggested between 4 and 9 (M=6 , SD=1) distinct gestures. In the following subsections we delve into these gestures, and discuss underlying metaphors and analogies.

#### *Suggested Gestures*

After removing duplicates and grouping similar gestures, we obtained 60 distinct gestures, 32 of which were suggested for Opt-out and 28 for Opt-in. Participants suggested both, static (Figure 1) and dynamic gestures (Figure 2). For some gestures, such as `Peek-a-boo`, shown in Figure 2 (right) we recorded both one-handed and two-handed variants. Some also suggested combinations where multiple static gestures were sequentially linked, e.g., `I see you` followed by `Thumbs-up` or covering both eyes followed by a `Thumbs-down` movement.




**Opt-in gestures evaluated in experiment 2.**




**Opt-out gestures evaluated in experiment 2.**

**Figure 3: Overview of evaluated Opt-in gestures (top) and Opt-out gestures (bottom). Some gestures employ metaphors that refer to the eyes or face. Thus these are mostly carried out in front of the face (indicated as *, faces not shown for visual clarity). Dynamic gestures are indicated using arrows, where the grayed out hand posture indicates the end of the movement.**

*) **typically carried out in front of the face.**
**) **might be carried out either in front of the face or chest**

*Metaphors & Analogies*

While envisioning suitable gestures for Opt-in and Opt-out, most participants utilized metaphors or analogies. Opt-in was used synonymous with *agreeing* (e.g., Nodding, or the `Thumb-up` gesture), and Opt-out with *disagreeing* (e.g., shaking ones head, or `Thumb-down`). Other suggested gestures borrowed movements, artifacts or postures from reality: e.g., the "picture taking" movement that imitates pressing the camera trigger, or the `Frame` gesture that mimics the physical dimensions of a photograph. The `Open visor` and `Close visor` gestures simulate the actions performed on a motorcycle helmet's visor or an ancient suit of armor. Aptly, participants used the human eye as a metaphor for the camera *seeing and not seeing*. They suggested multiple gestures covering and uncovering the eyes, the face (e.g., `Peek-a-boo`, or directly referring to the eyes (e.g., `I see you`, Figure 3). In conclusion, illustrating the abstract concepts of Opt-in and Opt-out using real-life analogies might support intuitive understanding.

*Complementary Gestures*

Wherever possible, participants tried to come up with complementary pairs of Opt-in and Opt-out gestures. For concatenated (dynamic) gestures this often meant a reversal of order (c.f., `Turn-off` and `Turn-on`, Figure 2, left). For kinematic gestures, that indicated a directional movement (e.g., up for Opt-in) they simply showed the same movement in the opposite direction (e.g., down for Opt-out). Similarly, static gestures such as `Thumb-up`, had a reverse `Thumb-down` corollary. These observations indicate, that pairs of Opt-in/Opt-out gestures referring to antithetical concepts, have complementary kinesthetic counterparts. These kinesthetic pairs might be preferred by users, and also easier to learn and remember.

## EXPERIMENT 2: ONLINE SURVEY

How a gesture is interpreted may largely vary between regions, e.g., within Europe (c.f., Morris [17]). To better understand how gestures are interpreted in western regions, we conducted an online survey with 127 participants from Europe and North America using a subset of gestures from the elicitation study. We selected the 18 most frequently used Opt-in and Opt-out gestures (Figure 3). In the cases where participants suggested a one-handed and a two-handed version of the gesture, we included the more frequently used version in the survey.

### Method and Study Materials

We used abstract renderings of a virtual, androgynous character to showcase the gestures. We avoided real-world footage, to prevent cultural or gender bias. Each of the 18 gestures (9 opt-in, 9 opt-out) was named at least twice during the elicitation study. We generated a three seconds (72 frames) video clip comprising of the virtual character performing each gesture (c.f., Figure 4). Static gestures were held for 7 frames; dynamic gestures were performed in 28 frames. To clearly delineate start and end of each gesture, the character started and ended in the same position, with both hands casually on the side. The video clips were looped indefinitely in the online questionnaire, to allow the participant to thoroughly judge each gesture. All clips were piloted and tested independently by two researchers other than the authors.


**Figure 4: Sample frames taken from the animated gesture sequences used in the online survey. To clearly delineate start and end of each gesture, all rendered animations started in the same pose (A). Then, one of the pre-selected 18 gestures (e.g., B, C, D, E) was performed by the virtual character before ending with the start pose (A) again.**

The online survey first gathered demographic information and participants' prior experiences with gesture-based languages, manual communication (e.g., ASL), and gesture-controlled human-machine interfaces. Subsequently, they were presented with the gesture videos in randomized order. Participants were asked to explore alternative meanings for each gesture (*"What does the gesture shown in the video above mean to you?"*) and objectively decide whether it meant an "Opt-in", "Opt-out", or *"something completely different"*. Then, on a 7-pt Kunin Scale [15], they were asked to rate the gesture's representativeness for Opt-in, and Opt-out as well as its social acceptability (*"How acceptable would it be to perform the presented gesture in public?"*). They were also asked to indicate their confidence in performing the gesture in public (*"How comfortable would you feel performing this gesture in an everyday public setting, such as a busy sidewalk?"*, c.f., [33].

### Participants

Participants were recruited via quota-sampling on Prolific[1]. Overall 127 participants (59 female) from Europe (63, 50%), and North America (64, 50%) took part in the study. Table 1 lists the country of origin (COO) and country of residence (COR) as an indicator of cultural background. Participants were aged between 18 and 71 (M=34, SD=12). Nineteen (15%) of them indicated that they had experience with manual communications (e.g., diver communications/RTSC); 11 (9%) of them knew ASL[2]. Only few had ever used free-hand gestures to operate a human-machine interface such as the Microsoft Kinect (13, 10%).

Around half the participants had a University or college degree (66, 52%), and a few (3, 2%) had doctorate/postdoctoral lecture qualification as highest level of education (ISCED[3] level 6 and above). Twenty-four (19%) participants had obtained a High School Diploma or Associate degree (level 5), 14 (11%) had a vocational or technical school diploma (level 4), and overall 18 (14%) indicatedlevels 3 or below.

### Results

Overall, 71 participants (56%) left optional qualitative comments at the end of the questionnaire. In this section, we selectively report comments on specific gestures together with the quantitative results. Other quotations, e.g., concerning ethical or social issues are included in the discussion section.

[1]Prolific, https://prolific.ac, accessed 14.03.2018

[2]American Sign Language, c.f., https://www.handspeak.com, accessed 18/04/06

[3]International Standard Classification of Education (ISCED), http://uis.unesco.org/en/isced-mapping, accessed 14.03.2018

*Meaning and Ambiguity*

Participants listed 0 to 7 distinct meanings for each proposed gesture. We grouped the meanings and removed all occurrences of "Opt-in" (n=16) and "Opt-out" (n=39) from this part of our analysis to mitigate interviewer bias, since they might not reflect how the gestures would have been understood outside our study.

Unsurprisingly, many of the gestures marked as Opt-in by our participants from experiment 1 showed an inherent positive connotation, e.g., `Thumb-up`: "OK"(n=75), "Good"(n=41), "yes"(n=24). Many Opt-out gestures were inherently negative, e.g., `Fingers crossed`: "Stop" (n=48), "No"(n=27).

As suggested during the elicitation study, the `Frame` gesture was understood as a metaphorical representation for "Picture taking" "Photography" or "Camera" (n=117). Additions, such as "look at my smile" and "I feel sexy" indicate that the gesture communicates a positive attitude towards photography. The Two fingers gesture, which the participants in experiment 1 also intended to represent the boundaries of a frame or picture, was understood by some participants ("Picture taking", n=24), but oftentimes misunderstood as "Deer" resp. "Animal with horns" (n=16) or directional command: "Up" (n=13). While the `I see you` gesture was understood as a reference to eyes and/or watching (n=88), participants were indecisive whether the gesture referred to an ego perspective "I am watching what you do" or a third person "Look at me".

While thirty participants assigned "Hiding" or "Hide" to the closing variant of the `Peek-a-boo` gesture (n=30), the opening variant was perceived as confusing: participants named "Hide" (n=8) as well as open (n=11), or stated "Nothing" (n=9) or "No idea" (n=11). Similarly, participants were inconclusive

| Country | Participants' COR* | COO** |
|---|---|---|
| US | 59 (46%) | 58 (46%) |
| Italy | 21 (17%) | 19(15%) |
| UK | 12(9%) | 9(7%) |
| Spain | 8(6%) | 7(6%) |
| Germany | 6(5%) | 6(5%) |
| Canada | 5(4%) | 6(5%) |
| Netherlands | 4(3%) | 4(3%) |
| Ireland | 4(3%) | 3(2%) |
| Others | 8(6%) | 15(12%) |

*) **In which country do you currently live and work?**
**) **In which country did you grow up?**

**Table 1: Participants were recruited via quota-sampling from North America and Europe. Number of participants per country of residence (COR) and country of origin (COO).**

about the Turn-on and Turn-off gestures, where they suggested (amongst others) "Vomit", "Bad breath", "Grabbing", and "Stop talking". This ambiguity was also reflected in the lower understandability and representativity ratings (see next section) of these gestures.

### *Understandability and Representativeness*

Participants perceived the Thumb-up gesture as most representative (Mdn=7, SD=1.3, significant[4] with p<0.01), and a large majority interpreted it as Opt-in (110, 87%). This leads us to conclude that it is also well understandable as Opt-in gesture, along with the Frame (80%), OK (80%), and Come on (74%) gestures. Similarly, the Thumb-down gesture was rated most representative (Mdn=7, SD=1.8) and clearly understood as Opt-out (79%). However, the gestures Hands crossed (Mdn=6, SD=1.7) and Fingers crossed (Mdn=6, SD=1.7) were also equally well understood (both 80%). There was no significant difference with regard to representativeness between Thumb-up and the other two gestures.

Surprisingly, both Stopp gestures, which had been suggested most frequently (10 times) in experiment 1, underperformed amoungst the static Opt-out gestures with regard to representativeness (both Mdn=5, SD=1.7), and understandability (c.f., Figure 5), where the version with spread fingers (76%) was slightly harder to understand than its relative (71%). Dynamic gestures were not generally rated less representative then static gestures. However, they were significantly[5] more often misinterpreted which points to a lack of understandability: $\chi^2$ (8, N = 18) = 35.2 , p<0.05. This might partially be attributed to their novelty: *"I think the obvious gestures would be more efficient, but I think the hand going up or down the face would be cool if it's clearly established which means which. I saw it as the hand going down would be covering the face and the hand going up would be 'opening' up the face to opt-in."* (P45) Nevertheless, dynamic gestures that encode "Opt-in" respectively "Opt-out" in a directional movement, might also require more attention, and cognitive resources from the observer, and thus be harder to understand at a single glance.

### *Social Acceptability and Comfort*

In general, participants stated that they would feel comfortable when performing the suggested gestures in public (av. Mdn=5.2), and that the suggested gestures were socially acceptable (av. Mdn=5.4). However, P62 also noted, that unfamiliarity with a certain gesture might have affected her rating: *"If I had seen people do them in public before I would have rated more so as highly acceptable [...]"* (P62)

On average participants rated the set of proposed Opt-in (Mean score =5.2, SD=1.1), and Opt-out (Mean score=5.3, SD=1.1) as equally acceptable in public; there were no significant[6] differences (Z=1.3, p=0.1, r=0.08). However, Opt-in gestures that did have a directionally complementary Opt-out gesture were rated significantly more acceptable than their counterpart: participants perceived the Thumbs-up (Mdn=7, SD=1.0) gesture as significantly more acceptable than the Thumbs-down (Mdn=6, SD=1.5) gesture (Z=4.6, p<0.05, r=0.28), and would feel significantly more comfortable performing the Thumbs-up gesture in public (Z=5.0, p<0.05, r=0.31). A smaller, but similar effect can be observed for the Open Visor and Close Visor (Z=1.8, p<0.05, r=0.1).

[4]Friedman Test plus Post-hoc Wilcoxon Signed Rank Test with Bonferroni Correction, p<0.01

[5]Chi-Square Test

[6]Wilcoxon Signed Rank Test for paired samples

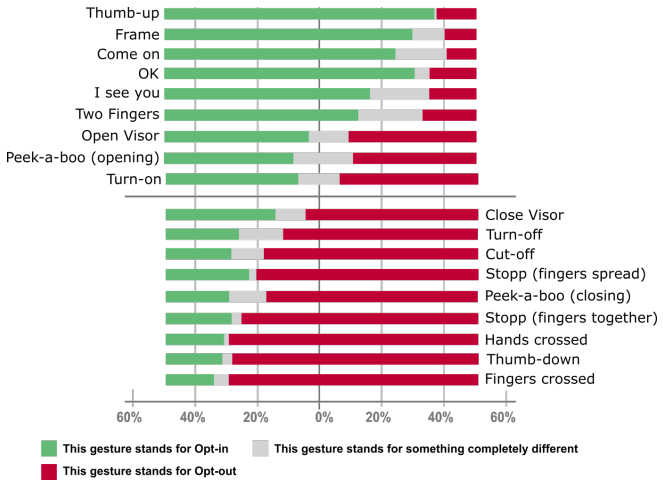



**Figure 5: For each gesture participants decided whether they would understand it as Opt-in (green), Opt-out (red) or neither (grey). Gestures intended to be Opt-in are shown in the upper half, gestures intended as Opt-out in the lower half. The most distinct are the top (Opt-in) and the bottom (Opt-out) gestures.**

We did find no significant difference regarding acceptability for the Peek-a-boo (opening) and the corresponding Peek-a-boo (closing) gesture (Z=1.5, p=0.07, r=0.01). This might, however, be attributed to the lack of understandability (c.f., Figure 5) and representativeness (Mdn=3) of the uncovering (opening) variant along with 24 (19%) participants indicating that the gesture stood for neither Opt-in nor Opt-out. This matches that, from the list of collected meanings (see above) the gesture seems not to have a strong positive connotation. The same applies to the Turn-off and Turn-on gestures (Z=1.5, p=0.07, r=0.1) which are, as discussed above, also more ambiguous than the other proposed gestures.

With regard to comfort and acceptability there were no differences between static and dynamic, and one-handed as well as two-handed gestures. However, two participants also commented on the practicability of two-handed gestures: *"I don't think two-handed gestures are a good idea. What if you're carrying something (e.g., groceries)?"* (P57)

## DISCUSSION

Designing command sets for gesture-based interaction is a well researched area in HCI. Quality criteria for gesture vocabularies include *cognitive*, *articulatory*, and *technological aspects* (c.f., Lenman et al. [16]). The main focus of this work were *cognitive aspects*, i.e., which gestures are perceived as natural and intuitive (c.f., Barclay et al. [3]) in a certain context: does a gesture that was intended as Opt-in, or Opt-out,

respectively, inherently make sense to the user? Would (s)he feel natural using it for opting-in or opting-out?

In the following we discuss if and how a decision for a gesture set for privacy mediation, comprising an Opt-in, and Opt-out gesture, could be made based on the results of our experiments.

### Selecting Gestures

We demonstrated that it is possible to find gestures that are (1) representative for Opt-in and Opt-out, as well as (2) understandable and easy to interpret. Our results show that some of the evaluated gestures were already beset with meaning, which increases ambiguity but also makes them easier to interpret. On the other hand, existing gestures that are frequently used in other contexts (e.g., `Thumb-up`) might cause false positive interpretations. P33 highlights that *"several [gestures] did not appear to have any generic use. It would be difficult to find an action that is not used in everyday life for opting in and out [...] without having unintentional signs sent to the camera operator."* P31 was worried *"[..] they may opt-in accidentally*.

Consequently, when designing systems that intend to use Opt-in and Opt-out gestures, we should carefully consider whether to re-appropriate an existing gesture or establish a new gesture. To envision new gestures for Opt-in and Opt-out, metaphors and analogies associated with photography (e.g., the `Frame` gesture) can provide a starting point. Establishing a new gesture might succeed for widely deployed mainstream systems, but be difficult for niche or prototypical applications.

Furthermore, our results indicate that gestures with a positive connotation (1) would typically be used as Opt-in gesture, and (2) would be perceived more socially acceptable than a potential counterpart with a negative connotation (i.e, Opt-out). Our participants indicated that, in public, they would feel more comfortable performing an affirmative gesture, such as `Thumb-up`, than performing a dissenting gesture, such as `Thumb-down`. In the context of privacy mediation this is problematic. Similarly to acquiescence effects, secondary users (i.e., bystanders) might be hesitant performing an Opt-out gesture, if they feel uncomfortable doing so, and thus silently accept privacy infringements. The perfomative nature of gestures (c.f., [33]) might add up to this effect, as P43 states *"People who want to opt out should only have to do something subtle, they shouldn't have to make any kind of grand, flamboyant gesture to opt out."* (P43). In consequence, to avoid unwanted bias and acquiescence, gesture sets for Opt-in and Opt-out would have to be consciously designed and carefully selected, as well as critically (re-)evaluated in-situ.

### Ethicality and Legal Issues

Multiple participants raised the question whether it should not rather be the user, instead of the bystanders who takes care of privacy protection: *"Placing the onus of having to opt out on people who may not even be aware of the recording taking place is inadequate."* (P63) This issue has also been tackled by Denning et al. [6] who also discussed the burden of registering, and noted that a number of their participants expressed a desire for camera blocking technologies. Participant 21 doubts *"whether such devices with just an 'opt-out' mechanism would even be legal."* (P21). In fact, the General Data Protection Regulation (GDPR – EU 2016/679 [23]), which recently came into effect, requires "privacy-by-default", i.e., bystander privacy would have to be implemented in all cases, except where (s)he had explicitly Opted-in. In practice however, most body-worn cameras do not provide any privacy mediating procedure. Thus, to date the de facto procedure is Opt-out, i.e., (verbally) asking the device user to turn the camera off.

In contrast to blocking or wirelessly communicating artifacts.g., BLE tokens, that allow secondary users to remain *passive*, gestures would require the bystander to *proactively* Opt-in, or Opt-out. P36 imagines *"I cannot imagine having to do this either way. There is getting to be a little too much stress in our everyday walking around. I don't like the idea of the glasses with cameras."* P21 adds *"You would be forced to constantly be aware of any person wearing such a device and take care to always 'opt-out'."* which they would perceive as inconvenience.

Alternatively, body-worn cameras might react automatically and adjust to contextual privacy requirements (e.g., based on location [31], content [14], or activity [30]), thus taking the burden of both, primary and secondary users.

Considering individual contexts could be beneficial, as legally (e.g., in GDPR) it strongly depends on the situation, whether the use of a body-worn camera would be unregulated (e.g., at home), based on proportionality (e.g., in (touristic) city centers), or prohibited (e.g., in a clinic). In addition, how users and bystanders perceive privacy is also highly individual (c.f., Price at al. [21]). Thus, combining both approaches could be highly advantageous: utilizing a default automatic, context-sensitive approach could provide comfort and reliability. A gesture-based approach (e.g., to Opt-in) for special cases or more individual and granular control would increase flexibility, and offer a viable control mechanism to bystanders. In this context, any implementation would have to accept both, Opt-in as well as Opt-out gestures, to provide flexible and reversible choices (c.f., Nielsen et al. [18]). With our work, we demonstrated that complementary gestures for Opt-in, and Opt-out can be found, e.g., by reversing the order or direction of movements in dynamic gestures or altering the directionality of deictic gestures. Nevertheless, our qualitative results also highlight that the moral and legal implications of smart glasses and body-worn cameras, as well as GDPR's implications for such camera devices, are not talked through yet.

### Limitations

Our work provides first assessment of which gestures are representative for Opt-in, and Opt-out, in the context of smart glasses with integrated "always-on" cameras. As the choice of the "right" gesture, might not only depend on the individual gesture, but also on the interaction design (default or specialized use case) and the dissemination of the intended application or device, we do not explicitly propose a concrete set of gestures. Moreover, our analysis is most likely limited to how the proposed gestures are perceived in western regions. However, future work could fill this gap building upon our methodology and using our study materials. Due to timing and format of the online survey, we did not test for rememberability and appropriation, two factors that might also affect the

effectiveness of Opt-in, and Opt-out gestures. Nevertheless, our results provide the necessary ground work for systems design and future long-term studies.

Furthermore, our work only considered gestures for Opt-in/Opt-out. In practice, privacy preferences might not be binary, but require more granular distinctions. This aspect is relevant, as – in addition to privacy-by-default and privacy-by-design – the GDPR names the granularity of consent as key principle. Our work can serve as a baseline and stating point for creating more extensive gesture vocabularies including granular consent, e.g., defining consent for recording, but no consent for sharing. In addition, the GDPR also requires consent to be informed, which is not covered in this paper. However, design solutions for active communication of presence and actions of body-worn cameras have been suggested by Egelman et al. [7], and explored in our prior research [13].

## CONCLUSION

We explored Opt-in and Opt-out gestures for privacy mediation with body-worn cameras based on a guessability-style elicitation study. Then, we evaluated nineteen gestures in a larger scale online survey, where we investigated ambiguity, representatives understandability, as well as social acceptance and comfort. Our work supplements existing work [4, 11, 29] and contributes a set of evaluated gestures for Opt-in and Opt-out that can motivate gestural interaction in future prototypes of privacy mediating systems. Our results indicate that it is feasible to create a gesture vocabulary for Opting-in and Opting-out of camera recordings. Systems employing gesture-based Opt-in and Opt-out need to be designed in a way such that they (1) employ gestures that are not a priori beset with meaning, but can be easily learned and associated with "recording" or "picture taking"; (2) Offer complementary gestures for both, Opt-in, as well as Opt-out; And (3) employ gestures that are extendable (e.g., through sequential linkage) to account for the need for granular, non-binary privacy preferences.

Moreover, our research empirically supports the maxim of designing for privacy protection as default (i.e., Opt-in), as Opt-out gestures often have an inherent negative connotation and may cause acquiescence effects. Nevertheless, future work will have to discuss the practicality of providing and obtaining informed consent in the context of ubiquitous (body-worn) cameras. We envision that, instead of being an exclusive method for privacy mediation, gestural Opt-in, respectively Opt-out could extend and supplement a less interactive e.g., automatic, context-sensitive approach implementing privacy-by-default, and privacy-by-design.

## REFERENCES


1. Christopher Ackad, Andrew Clayphan, Martin Tomitsch, and Judy Kay. 2015. An In-the-wild Study of Learning Mid-air Gestures to Browse Hierarchical Information at a Large Interactive Public Display. In *Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing (UbiComp '15)*. ACM, New York, NY, USA, 1227–1238. DOI: http://dx.doi.org/10.1145/2750858.2807532
2. David Ahlström, Khalad Hasan, and Pourang Irani. 2014. Are You Comfortable Doing That?: Acceptance Studies of Around-device Gestures in and for Public Settings. In *Proceedings of the 16th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '14)*. ACM, New York, NY, USA, 193–202. DOI: http://dx.doi.org/10.1145/2628363.2628381
3. Kayne Barclay, Danny Wei, Christof Lutteroth, and Robert Sheehan. 2011. A Quantitative Quality Model for Gesture Based User Interfaces. In *Proceedings of the 23rd Australian Computer-Human Interaction Conference (OzCHI '11)*. ACM, New York, NY, USA, 31–39. DOI:http://dx.doi.org/10.1145/2071536.2071540
4. Mukhtaj S. Barhm, Nidal Qwasmi, Faisal Z. Qureshi, and Khalil el Khatib. 2011. Negotiating Privacy Preferences in Video Surveillance Systems. In *Modern Approaches in Applied Intelligence*, Kishan G. Mehrotra, Chilukuri K. Mohan, Jae C. Oh, Pramod K. Varshney, and Moonis Ali (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 511–521. DOI: http://dx.doi.org/10.1007/978-3-642-21827-9_52
5. Liwei Chan and Kouta Minamizawa. 2017. FrontFace: Facilitating Communication Between HMD Users and Outsiders Using Front-facing-screen HMDs. In *Proceedings of the 19th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '17)*. ACM, New York, NY, USA, Article 22, 5 pages. DOI: http://dx.doi.org/10.1145/3098279.3098548
6. Tamara Denning, Zakariya Dehlawi, and Tadayoshi Kohno. 2014. In Situ with Bystanders of Augmented Reality Glasses: Perspectives on Recording and Privacy-mediating Technologies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 2377–2386. DOI: http://dx.doi.org/10.1145/2556288.2557352
7. Serge Egelman, Raghudeep Kannavara, and Richard Chow. 2015. Is This Thing On?: Crowdsourcing Privacy Indicators for Ubiquitous Sensing Platforms. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1669–1678. DOI: http://dx.doi.org/10.1145/2702123.2702251
8. Adam Harvey. 2012. CV Dazzle: Camouflage from computer vision. *Technical report* (2012).
9. Niels Henze, Andreas Löcken, Susanne Boll, Tobias Hesselmann, and Martin Pielot. 2010. Free-hand Gestures for Music Playback: Deriving Gestures with a User-centred Process. In *Proceedings of the 9th International Conference on Mobile and Ubiquitous Multimedia (MUM '10)*. ACM, New York, NY, USA, Article 16, 10 pages. DOI: http://dx.doi.org/10.1145/1899475.1899491

10. Yi-Ta Hsieh, Antti Jylhä, Valeria Orso, Luciano Gamberini, and Giulio Jacucci. 2016. Designing a Willing-to-Use-in-Public Hand Gestural Interaction Technique for Smart Glasses. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. ACM, New York, NY, USA, 4203–4215. DOI: http://dx.doi.org/10.1145/2858036.2858436
11. Jaeyeon Jung and Matthai Philipose. 2014. Courteous Glass. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication (UbiComp '14 Adjunct)*. ACM, New York, NY, USA, 1307–1312. DOI: http://dx.doi.org/10.1145/2638728.2641711
12. Adam Kendon. 1986. Current issues in the study of gesture. *The biological foundations of gestures: Motor and semiotic aspects* 1 (1986), 23–47.
13. Marion Koelle, Katrin Wolf, and Susanne Boll. 2018. Beyond LED Status Lights - Design Requirements of Privacy Notices for Body-worn Cameras. In *Proceedings of the 12th International Conference on Tangible, Embedded, and Embodied Interaction (TEI '18)*. ACM, New York, NY, USA, 177–187. DOI: http://dx.doi.org/10.1145/3173225.3173234
14. Mohammed Korayem, Robert Templeman, Dennis Chen, David Crandall, and Apu Kapadia. 2014. Screenavoider: Protecting Computer Screens from Ubiquitous Cameras. *arXiv preprint arXiv:1412.0008* (2014).
15. Theodore Kunin. 1955. The construction of a new type of attitude measure. *Personnel psychology* 8, 1 (1955), 65–77.
16. Sören Lenman, Lars Bretzner, and Björn Thuresson. 2002. Using Marking Menus to Develop Command Sets for Computer Vision Based Hand Gesture Interfaces. In *Proceedings of the Second Nordic Conference on Human-Computer Interaction (NordiCHI '02)*. ACM, New York, NY, USA, 239–242. DOI: http://dx.doi.org/10.1145/572020.572055
17. Desmond Morris. 1979. *Gestures, their origins and distribution*. Stein & Day Pub.
18. Jakob Nielsen. 1994. Enhancing the Explanatory Power of Usability Heuristics. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '94)*. ACM, New York, NY, USA, 152–158. DOI: http://dx.doi.org/10.1145/191666.191729
19. Jennifer Pearson, Simon Robinson, and Matt Jones. 2015. It's About Time: Smartwatches As Public Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '15)*. ACM, New York, NY, USA, 1257–1266. DOI: http://dx.doi.org/10.1145/2702123.2702247
20. Martin Porcheron, Joel E. Fischer, Stuart Reeves, and Sarah Sharples. 2018. Voice Interfaces in Everyday Life. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '18)*. ACM, New York, NY, USA, Article 640, 12 pages. DOI: http://dx.doi.org/10.1145/3173574.3174214
21. Blaine A. Price, Avelie Stuart, Gul Calikli, Ciaran Mccormick, Vikram Mehta, Luke Hutton, Arosha K. Bandara, Mark Levine, and Bashar Nuseibeh. 2017. Logging You, Logging Me: A Replicable Study of Privacy and Sharing Behaviour in Groups of Visual Lifeloggers. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 1, 2, Article 22 (June 2017), 18 pages. DOI: http://dx.doi.org/10.1145/3090087
22. Kathrin Probst, David Lindlbauer, Michael Haller, Bernhard Schwartz, and Andreas Schrempf. 2014. A Chair As Ubiquitous Input Device: Exploring Semaphoric Chair Gestures for Focused and Peripheral Interaction. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 4097–4106. DOI: http://dx.doi.org/10.1145/2556288.2557051
23. General Data Protection Regulation. 2016. Regulation (EU) 2016/679 of the European Parliament and of the Council of 27 April 2016 on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46. *Official Journal of the European Union (OJ)* 59, 1-88 (2016), 294.
24. Tiago Reis, Marco de Sá, and Luís Carriço. 2008. Multimodal interaction: Real context studies on mobile digital artefacts. In *International Workshop on Haptic and Audio Interaction Design*. Springer, 60–69.
25. Julie Rico and Stephen Brewster. 2009. Gestures All Around Us: User Differences in Social Acceptability Perceptions of Gesture Based Interfaces. In *Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services (MobileHCI '09)*. ACM, New York, NY, USA, Article 64, 2 pages. DOI: http://dx.doi.org/10.1145/1613858.1613936
26. Julie Rico and Stephen Brewster. 2010. Usable Gestures for Mobile Interfaces: Evaluating Social Acceptability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. ACM, New York, NY, USA, 887–896. DOI: http://dx.doi.org/10.1145/1753326.1753458
27. Jeremy Schiff, Marci Meingast, Deirdre K. Mulligan, Shankar Sastry, and Ken Goldberg. 2009. *Respectful Cameras: Detecting Visual Markers in Real-Time to Address Privacy Concerns*. Springer London, London, 65–89. DOI: http://dx.doi.org/10.1007/978-1-84882-301-3_5
28. Marcos Serrano, Barrett M. Ens, and Pourang P. Irani. 2014. Exploring the Use of Hand-to-face Input for Interacting with Head-worn Displays. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14)*. ACM, New York, NY, USA, 3181–3190. DOI: http://dx.doi.org/10.1145/2556288.2556984

29. Jiayu Shu, Rui Zheng, and Pan Hui. 2017. Your Privacy Is in Your Hand: Interactive Visual Privacy Control with Tags and Gestures. In *Communication Systems and Networks*, Nishanth Sastry and Sandip Chakraborty (Eds.). Springer International Publishing, Cham, 24–43. DOI:http://dx.doi.org/10.1007/978-3-319-67235-9_3

30. Julian Steil, Marion Koelle, Wilko Heuten, Susanne Boll, and Andreas Bulling. 2018. PrivacEye: Privacy-Preserving First-Person Vision Using Image Features and Eye Movement Analysis. *arXiv preprint arXiv:1801.04457* (2018).

31. Robert Templeman, Mohammed Korayem, David J Crandall, and Apu Kapadia. 2014. PlaceAvoider: Steering First-Person Cameras away from Sensitive Spaces.. In *NDSS*. 23–26.

32. Khai N. Truong, Shwetak N. Patel, Jay W. Summet, and Gregory D. Abowd. 2005. Preventing Camera Recording by Designing a Capture-Resistant Environment. In *UbiComp 2005: Ubiquitous Computing*, Michael Beigl, Stephen Intille, Jun Rekimoto, and Hideyuki Tokuda (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 73–86. DOI:http://dx.doi.org/10.1007/11551201_5

33. Julie R Williamson. 2012. *User experience, performance, and social acceptability: usable multimodal mobile interaction*. Ph.D. Dissertation. University of Glasgow.

34. Jacob O. Wobbrock, Htet Htet Aung, Brandon Rothrock, and Brad A. Myers. 2005. Maximizing the Guessability of Symbolic Input. In *CHI '05 Extended Abstracts on Human Factors in Computing Systems (CHI EA '05)*. ACM, New York, NY, USA, 1869–1872. DOI: http://dx.doi.org/10.1145/1056808.1057043

35. Takayuki Yamada, Seiichi Gohshi, and Isao Echizen. 2013. Privacy Visor: Method for Preventing Face Image Detection by Using Differences in Human and Device Sensitivity. In *Communications and Multimedia Security*, Bart De Decker, Jana Dittmann, Christian Kraetzer, and Claus Vielhauer (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 152–161. DOI: http://dx.doi.org/10.1007/978-3-642-40779-6_13