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

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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:

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
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., Bahr 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.
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 one’s 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.

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.

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.

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.
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 Prolific1. 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 (9%) of them knew American Sign Language, c.f., https://www.handspeak.com, accessed 14.03.2018 and North America (64, 50%) took part in the study. Number of participants per country of residence (COR) and country of origin (COO).

Around half the participants had a University or college degree (66, 52%), and a few (3, 2%) had doctorate/postdoctoral level qualification as highest level of education (ISCED3 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%) indicated levels 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.

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).

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.

1Prolific, https://prolific.ac, accessed 14.03.2018
2American Sign Language, c.f., https://www.handspeak.com, accessed 18/04/06
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 Representativity**

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 amongst 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 than 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’ 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, \(p<0.05, r=0.1\)).

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=1.3, \(p=0.07, r=0.1\)) 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 persuasive 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 wireless communicating artifacts, e.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 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.

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