Received: 7 July 2023 | Revised: 10 April 2024 | Accepted: 23 April 2024

DOI: 10.1111/psyp.14605

ORIGINAL ARTICLE

PSYCHOPHYSIOLOGY SPR WILEY

Individuals lack the ability to accurately detect emotional piloerection

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Abstract

Piloerection (e.g., goosebumps) is an essential thermoregulatory and social signaling mechanism in non-human animals. Although humans also experience piloerection—often being perceived as an indicator of profound emotional experiences—its comparatively less effective role in thermoregulation and communication might influence our capacity to monitor its occurrence. We present three studies (total $N=617$) demonstrating participants' general inability to detect their own piloerection events and their lack of awareness that piloerection occurs with a similar frequency on multiple anatomical locations. Self-reported goosebumps were more frequent than observed piloerection. However, only 31.8% of self-reports coincided with observable piloerection, a bias unrelated to piloerection intensity, anatomical location, heart-rate variability, or interoceptive awareness. We also discovered a self-report bias for the forearm, contradicting the observation that piloerection occurs with equal frequency on multiple anatomical locations. Finally, there was low correspondence between self-reports of being "emotionally moved" and observed piloerection. These counterintuitive findings not only highlight a disconnect between an obvious physiological response and our capacity for self-monitoring, but they underscore a fascinating divergence between human and non-human species. Although piloerection is vital in non-human organisms, the connection between piloerection and psychological experience in humans may be less significant than previously assumed, possibly due to its diminished evolutionary relevance.

KEYWORDS

Piloerection, goosebumps, emotion, awareness, chills

1 | INTRODUCTION

Piloerection—the erection of hair resulting from the contraction of the *arrector pili* muscle—is a highly conspicuous phenomenon observed across multiple animal species, including humans. In non-human species, piloerection serves as an important thermoregulatory and social-communicative mechanism (McPhetres & Zickfeld, 2022). Avian species contract feather muscles for intricate mating displays (Dakin & Montgomerie, 2009), and mammalian species erect their body hair in response to perceived environmental threats (Wright, 1978). Although humans lack sufficient body hair, rendering piloerection ineffective for the purposes of social communication (Tansey & Johnson, 2015), humans do experience piloerection quite frequently.

Given the overt nature of piloerection and its utility in non-human organisms, one might expect humans to accurately monitor and report its occurrence. After all, piloerection is commonly perceived as an indicator of emotional experiences. Likewise, contemporary psychology predominantly presumes individuals possess accurate insight into their emotional experiences, often relying on self-reported data as the sole methodology (McPhetres et al., 2021). In contrast, because piloerection is assumed to be vestigial in humans, it may be that we lack the capacity to accurately monitor and report piloerection because it is void of any useful psychological or social information. Instead, humans have language to communicate internal states and we have clothes to assist with thermoregulation. Therefore, it is also reasonable to expect that humans would not monitor these physiological cues.

Nonetheless, the extent to which humans can accurately detect piloerection remains unexamined and, apparently, unquestioned. One reason for this is because much of the research on piloerection has relied on self-reports, rather than objective observation (McPhetres & Zickfeld, 2022). In the studies reported here, we combine self-reporting with objective observation of piloerection on multiple anatomical sites, offering novel insight into individuals' awareness and the nature of this physiological phenomenon. Understanding these dynamics is critical for refining our approach to interpreting data about human emotional and physiological experiences.

2 | METHOD

2.1 | Study 1

Study 1 was designed with the goal of inducing as many instances of piloerection as possible to explore the physiological and emotional correlates of piloerection. Here, we test whether participants can accurately detect and report piloerection by examining if a goosebump was self-reported within a time window around observed piloerection events.

2.1.1 | Participants

In a laboratory experiment, 90 subjects were recruited from the university participant pool and the surrounding community. There were 72 females and 18 males ranging in age from 18 to 50 ($M = 21.08$, $SD = 5.33$). All subjects reported being healthy, not smoking or drinking alcohol daily, not taking any medications, and were awake for at least 2 h prior to the session. Participants were compensated with either course credit or cash payment. Due to time constraints, four participants were not exposed to all seven videos, and five participants experienced computer errors where the study was ended early.

2.1.2 | Procedure

Participants arrived in a laboratory where they were connected to physiological recording equipment (BioPac MP160) and seated in a private cubicle at a computer running e-Prime (v2.0; Psychology Software Tools). Participants wore a t-shirt and shorts to facilitate placement of cameras and electrodes. Though not relevant to the results reported here, we also collected electrodermal activity, skin temperature, cardiac impedance, and blood pressure, and two saliva samples. Following a baseline period, they viewed seven piloerection-inducing videos in randomized order. Briefly, the videos are short commercials, films, or movie trailers, which are available online. For example, the trailer for the film Avengers: Endgame, a video of a young girl singing on America's Got Talent, and a commercial about mothers of Olympic champions are among the stimuli. The goal of this study was simply to induce as many piloerection events as possible via a variety of content. The reasons why piloerection occurred and the other qualities of the stimuli are not relevant to the present investigation, but further details of the videos are available in the Supplementary Materials (see Table S1).

Camera recording

Participants were attached to a series of cameras to objectively verify the presence of piloerection. Cameras were synced to Acknowledge (v 5.0). Following a design similar to the "goosecam," a small opaque box with a camera continuously recorded a ~5 × 5 cm area of participant skin, illuminated by a white LED light at approximately a 10° angle to highlight skin texture.

The first 50 participants were connected to only a single camera placed on their dominant anterolateral thigh. This location was chosen to avoid movement artifacts from the forearm and because hair follicles on the thigh are larger and more spaced out, making them easier to see on video recordings. Furthermore, a previous study (Wassiliwizky et al., 2015) claimed that participants identified "the legs" as the most common site of piloerection, though this claim was not subject to any formal analysis.

However, after anecdotally realizing that participants seemed to be self-reporting goosebumps without evidence on the cameras, we began placing three additional cameras to rule out the possibility that we were "missing" instances of goosebumps. The remaining 40 participants were connected to four cameras: one on the upper dorsolateral arm, one on the dominant dorsal calf, and one on the non-dominant anterolateral thigh. This was first tested with 10 participants without the rest of the physiological equipment. Then, we resumed the full protocol with the remaining participants.

Self-reported goosebumps

Participants were given a hand-button and asked to press the button whenever they felt they were experiencing goosebumps for any reason.

2.1.3 | Data pre-processing

Data analysis proceeded in several stages for a variety of observed and calculated variables.

Piloerection

Piloerection was recorded two ways: (1) via a self-reported "button-press" in real time, and (2) via manual coding of video recordings. The combination of these two types of observations allowed us to determine *accuracy* by examining whether a self-report occurred within a window around observed piloerection.

Manual coding. The video recordings were analyzed manually using BORIS (Friard & Gamba, 2016). We chose BORIS because of difficulty with the Gooselab software—specifically with a lack of sensitivity, difficult with movement artifacts, and the inability to derive the actual beginning of a goosebumps episode (because Gooselab provides only continuous scores).

Two coders manually coded each video and discussed any disagreements until 100% agreement was reached. The first author then reviewed a random subset of the coding for quality checks. Piloerection events were coded as either "large bumps" or "small bumps," and the timing marker was placed at the beginning of the event. *Large bumps* were defined as clearly visible bumps symmetrically encompassing the hair follicles. *Small bumps* were defined as twitches which occurred in-between the base of hairs (e.g., aligning with arrector pili locations), but which were not fully formed bumps, and which did not include raised hair follicles. For a detailed description of the morphological characteristics of piloerection, see McPhetres et al. (2024).

Accuracy. Accuracy was defined as a self-reported goosebumps occurring within a 16-s window around observed piloerection events. Using the EDA "event" routine in MindWare (v. 3.2.9; MindWare Technologies LTD, Gahanna, OH), we analyzed a symmetrical 16-s window around observed goosebumps. If participants pressed the button at any point within that window, the report was coded as accurate on part of the participant.

A 16-s window was chosen to be extremely liberal in our analyses. Goosebumps can linger for more than 10 s at a time, and participants may not necessarily press the button exactly at the start of an episode. Similarly, BORIS makes it difficult to code with specificity of less than one second. Thus, with this approach, we would overestimate (rather than underestimate) accuracy by allowing for participants to press the button at *the beginning or the end* of a given goosebumps episode.

Heart-rate variability

Heart rate was monitored via Lead II electrocardiogram. To emulate the approach taken by Lischke et al. (2021), we used the HRV (v. 3.2.9) routine in MindWare to compute RMSSD and pNN50. Each measure was computed for a 60-s window around each goosebump event. A 60-s window is sufficient to determine an accurate average variability score. Pre-processing included visually inspecting each segment and correcting or estimating R peaks from the ECG wave.

Interoceptive awareness

We began collecting data for interoceptive awareness shortly after halfway through data collection. At this point, we attempted to recontact previous participants and provided an online survey for them to complete the measure. We were able to recontact 15 participants, bringing the total count for this measure to 36. A power analysis indicates that this sample size is sufficient to detect an $r = .45$ with a power of 80% in a cross-sectional design, although linear-mixed model designs are much more powerful this analysis with multiple observations within-person should provide ample power for any effect of reasonable size.

Using the Multidimensional Assessment of Interoceptive Awareness (MAIA, 8), we calculated the subscales for noticing ($\alpha = .69$), attention regulation ($\alpha = .84$), emotional awareness ($\alpha = .76$), and body listening ($\alpha = .85$). All questions were answered on a scale from 0 (never) to 5 (always).

Goosebump awareness

At the end of the MAIA, we added a single item "If I get goosebumps, I am aware of it." Like the MAIA, the question was answered on a scale from 0 (never) to 5 (always).

2.2 | Study 2

Through the process of conducting Study 1, we anecdotally noticed that participants seemed to believe that piloerection was most commonly shown on the forearm. Thus, we conducted Study 2 in an attempt to understand the locations at which participants are monitoring without the possibility of interfering with their natural bodily awareness. Even though we are unable to verify whether participants objectively showed piloerection (because Study 2 is online), we will see the locations at which they report experiencing piloerection.

2.2.1 | Participants

Five hundred participants were recruited through Prolific in exchange for monetary compensation. There were 205 males and 291 females (4 identified as non-binary or preferred not to say) with a mean age of 40.4 ($SD=13$).

2.2.2 | Procedure

Participants accessed an online survey on Qualtrics where they were randomly assigned to watch one of three videos from Study 1. Videos were selected to be short to reduce participant time investment (see Supplementary Materials). In order to help reduce reports of "the chills" or other sensations, participants were told that we are interested in goosebumps, were given a description and images of goosebumps, and were asked to pay attention to their bodily experience while watching the videos.

After the video, participants were asked if they experienced goosebumps. Those who answered "Yes" were shown an image of a body and asked to click on the one area where they experienced the most intense goosebumps, followed by a second image for which they were asked to click on up to 10 other spots where they experienced goosebumps. Finally, they gave their age and sex and the survey was completed in about 5 min.

2.3 | Study 3

Study 3 was carried out to examine how emotional responses change after being repeatedly exposed to the same emotional stimuli. The result of that investigation will be reported elsewhere (McPhetres et al., 2023). However, we used this opportunity to have participants self-report the feeling of being "emotionally touched or moved," which represents a strong emotional feeling that is sometimes associated with "the chills." The chills is often thought of as similar to piloerection, but does not necessarily involve actual piloerection.

2.3.1 | Participants

In Study 3, 30 participants were recruited from the psychology participant pool as well as from the surrounding community. There were 24 females and 5 males ranging in age from 18 to 50 ($M=19.93$, $SD=0.88$); demographics data for one participant were not recorded. All participants were healthy, and they did not smoke or drink alcohol daily, were not taking any medications, and were awake for at least 2 h prior to the session. Participants were compensated with either course credit or cash payment.

Video recording data for three participants was lost due to a computer error, precluding the quantification of piloerection events for those participants. Thus, these three participants are not included in the analysis presented here, reducing our total sample size to 27.

2.3.2 | Method

Similar to Study 1, participants arrived in a laboratory where they were connected to physiological equipment and seated at a computer running e-Prime (v 3.0) in a private cubicle. All setup, equipment, and analysis procedures were the same as in Study 1. However, the experiment procedure differed slightly (see details in the supplement). Following the baseline period, participants were randomly assigned to watch one of two videos used in Study 1: "Mom" ($n=16$) and "Singer" ($n=14$) videos. During these videos, participants were instructed to press a button whenever they felt "emotionally touched or moved."

3 | RESULTS AND DISCUSSION

In Study 1, 57% ($n=52$) showed objective piloerection and 51% ($n=46$) self-reported *goosebumps*. This represents the most effective set of piloerection-inducing stimuli reported in the physiological literature to date (McPhetres & Zickfeld, 2022). However, only 31.8% of objective piloerection events mapped onto self-reported goosebumps. Specifically, subjects self-reported more

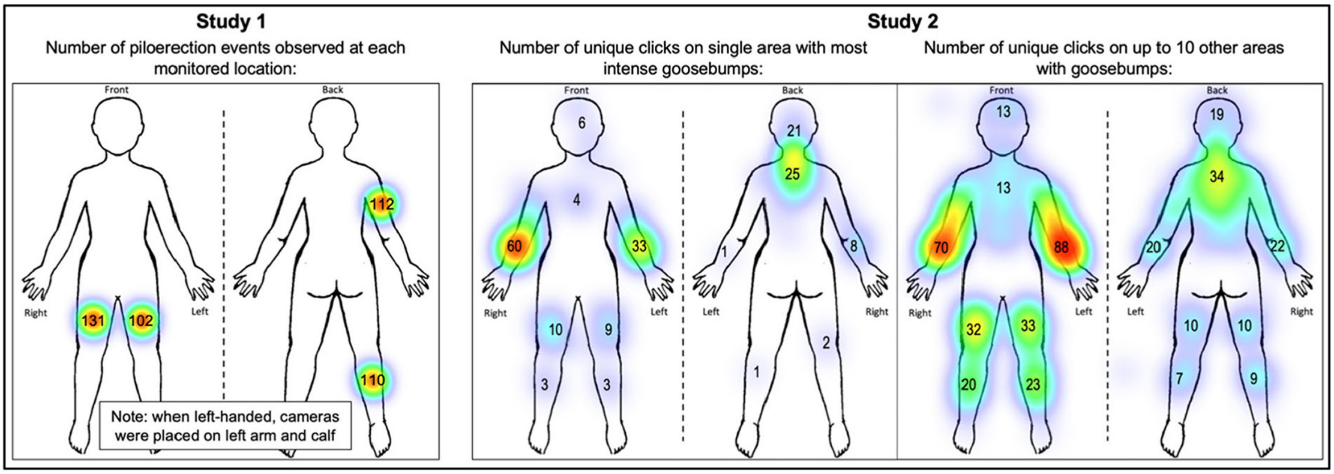

FIGURE 1 Whereas piloerection was observed with similar frequency on multiple anatomical locations in the laboratory, the forearm was the most common location of self-reported goosebumps in an online survey. For Study 1, only counts for multi-camera participants are shown, and only counts from the three videos also used in Study 2; for Study 2, $N = 187$ self-reported experiencing goosebumps at an average of 2.69 (mode = 1) locations; $k = 2$ erroneous clicks were excluded.

goosebumps than there were observed instances of piloerection, and very few of those self-reports aligned with observed piloerection.

Accuracy was largely homogeneous: Only 15 participants (16%) were accurate at a level greater than chance. A Welch's *t* test reveals that, compared to those with lower accuracy levels, those participants did not show more piloerection events ($p = .800$, $d = .10$ [95% CI: −.50, .70]), nor did they press the button more times ($p = .600$, $d = .23$ [95% CI: −.39, .85]).

We first explored the discrepancy between self-reported and observed piloerection events. In total, there were 1447 self-reported goosebumps and 1012 objective piloerection events—an average of 31.4 ($SD = 51.6$) self-reports and 19.4 ($SD = 28.6$) objective piloerection events per person. This contradicts the hypothesis that participants were not engaged or were not following instructions. To test the possibility that piloerection episodes were undetected due to limited camera placement, we increased the number of monitored camera locations from one ($n = 50$) to four ($n = 40$). However, the difference in accuracy between single-camera (26.6%) and multi-camera (33.7%) settings was negligible, accounting for only 2% of variance in accuracy (pseudo-$R^2 = .02$, $p = .230$). This suggests, in line with other research (McPhetres, 2023; McPhetres et al., 2023), that piloerection is likely to occur on multiple locations simultaneously.

In Study 2 ($N = 500$), we examined whether participants' biased attention toward specific body regions influenced self-reporting. After watching one of three piloerection-inducing videos in an online survey, participants clicked on an image of a human body to indicate where they experienced goosebumps.[1] Although we are unable to verify that participants truly showed piloerection, these self-reports serve as a proxy for the locations that participants monitor. As seen in Figure 1, results revealed a strong bias for the forearm, which accounted for 41% of unique reports ($k = 251$). Put differently: the majority of people indicated the forearm as the single most intense location and, when given the opportunity to select any number of other locations, they simply selected the other forearm. However, laboratory data from Study 1 (considering only the three videos used in Study 2) indicated that piloerection occurs with relatively equal frequencies across all anatomical sites ($\chi^2 = 0.60$, $p = .900$), further contradicting the common belief that piloerection is more common on the forearm. Accuracy rate was similar across all anatomical locations (pseudo-$R^2 < .01$): 39.8% on the dominant upper dorsolateral arm, 38.18% on the dominant dorsal calf, 33.3% on the left anterolateral thigh, and 39.69% on the right anterolateral thigh.

For comparison, when considering all seven videos, the conclusions are the same. Piloerection occurs with relatively equal frequencies across all anatomical sites ($\chi^2 = 0.40$, $p = .900$; see Figure 1; also see Table S2 for additional analyses), and accuracy rate was similar across all anatomical locations (pseudo-$R^2 < .01$): 30.6% on the dominant upper dorsolateral arm, 35.76% on the dominant dorsal calf, 32.9% on the left anterolateral thigh, and 30.65% on the right anterolateral thigh.

[1]The human body outline depicted in Figure 1 was created by Thuy-vy Nguyen, who holds the copyright to the image. It is reproduced here with permission.

We then revisited data from Study 1, focusing instead on identifying those times when people were accurate. First, we tested the hypothesis that more intense episodes of piloerection—conceptualized as "large" versus "small" piloerection—would be more noticeable. However, accuracy for the most intense episodes of piloerection remained below chance levels (40.1% on average; semipartial-$r^2 = .011$, $p < .001$). Furthermore, past research suggests that heart-rate variability moderates awareness of bodily sensations due to the correspondence between changes in the cardiopulmonary system and emotionally significant events (Lischke et al., 2021). Emulating the approach taken in Lischke et al. (2021), we used two common measures of heart-rate variability—the proportion of successive heartbeat intervals exceeding 50 ms (pNN50), and the root mean square of successive differences between normal heartbeats (RMSSD). We also analyzed each variability in two ways using separate mixed-effects regression models. First, we predicted accuracy levels with individual differences in baseline (i.e., resting) heart-rate variability. Second, we predicted variability measures (in 60-s epochs) around each piloerection episode with accuracy and baseline variability (e.g., a residual change model using mixed-effects regression). However, no correlations were found between accuracy and two heart-rate variability measures (all semipartial-$r^2 < .031$, all $p > .06$).

Next, we tested the hypothesis that awareness of piloerection is an individual difference. We computed multiple subscales from the Multidimensional Assessment for Interoceptive Awareness (Mehling et al., 2018) to approximate awareness of physiological sensations. Additionally, we added a single item "If I get goosebumps, I am aware of it." However, a series of mixed-effects regression analyses indicate that no subscales, nor the single goosebumps item, were predictors of accuracy (all semipartial-$r^2 < .04$, all $p > .150$). Additionally, those participants with accuracy levels greater than chance were no higher on any individual subscale (all ps $> .200$). In fact, 27 participants indicated that they would "Always" be aware of goosebumps (a score of 4 or 5 out of 5), although they were no more likely to be accurate than any other participant ($\text{Odds}_{\log} = .92$, $p = .330$).

Finally, in Study 3 ($N = 27$), we considered the hypothesis that participants were conflating piloerection with "the chills" or other similar emotional experiences. Being "emotionally moved" is one of the experiences associated with the "chills" but which does not necessarily involve piloerection (Zickfeld et al., 2019). In this study, participants used the button to self-report when they felt "emotionally moved or touched" while watching one of two piloerection-inducing videos. In total, 63% ($N = 17$) showed piloerection—an average of 24 piloerection events per person—and 81% ($N = 22$) reported being emotionally moved or touched. However, only 24.6% of self-reports corresponded to piloerection. This again suggests a general difficulty in monitoring and reporting physiological experiences rather than conflation with similar physiological or emotional experiences.

4 | CONCLUSIONS

Overall, findings from these studies demonstrate a general inability to detect piloerection, as well as a lack of awareness regarding its occurrence across multiple body locations. Specifically, while participants frequently self-reported goosebumps, very few of those self-reports occurred within the time window around observed piloerection events. These findings may be counterintuitive, as piloerection is frequently viewed as a hallmark of profound emotional experiences. However, the vestigial nature of piloerection in humans suggests that it should hold limited significance in the context of individual or social experiences. This may be one reason why it is not accurately monitored or reported.

This dissociation is important for understanding human emotional responses. First, other past research has recognized a low correlation between chills and goosebumps (Laeng et al., 2021), as well as between self-reported and objective goosebumps (Benedek & Kaernbach, 2011), although the present study is the first to investigate this in depth. Second, a recent review (McPhetres & Zickfeld, 2022) also discussed the lack of clear correlations between piloerection and self-reported emotions (see also Benedek & Kaernbach, 2011). Therefore, either piloerection is not as closely tied to emotions as previously believed, or humans may not be as adept at identifying their emotional responses as assumed. Similarly, the apparent bias toward reporting piloerection on the forearm may shed light on human's bodily awareness. The upper body is used for communicative purposes (Clough & Duff, 2020), whereas the legs are not usually a focal point in social situations. The arms are usually more visible and exposed, so people may be more aware of piloerection here than other locations. It may be a better use of cognitive resources to direct attention toward the arms, thereby leading to a bias where piloerection is ignored on other parts of the body.

A final point to address pertains to the subjective experience reported by participants—that is, the self-reported goosebumps. There were a significant number of self-reports, suggesting that participants were experiencing some form of physiological or psychological event. It is conceivable that participants lack the perceptual acuity to distinguish between various physiological sensations, though a more plausible hypothesis is that this indicates the presence of a selection bias (e.g., survivorship bias). Given the emotional nature of the stimuli, participants likely experienced an emotional response. At times, emotions may seem to coincide with sensations that lack a physiological manifestation—for example, "the chills" or "tingles down the spine." Operating under the common assumption that specific emotions correlate with piloerection, participants may infer that piloerection has taken place and report it. On occasion, this might coincide with an actual piloerection event, serving to reinforce the presumption that piloerection indicates specific emotions but ignoring the unnoticed piloerection events. That is, the only observations that "survive" are those that are reinforced by an emotional experience, thus introducing a bias toward correlating piloerection with the emotional state. Interestingly, scientists are familiar with, but not immune to, such biases. This is illustrated by nearly two decades of literature referring to piloerection as an indicator of awe despite the absence of any empirical evidence (McPhetres & Shtulman, 2021).

In conclusion, these findings highlight one important divergence between humans and non-human animals. There are many examples of physiological and psychological attributes shared between humans and non-human animals, including the fundamental structure of the nervous system, which allows us to respond to changes in the external environment. It is easy to focus only on similarities between our species. In this case, however, piloerection serves as an example of how evolutionary pressures have contributed to the unique development of humans, leading us down a divergent evolutionary trajectory and distinguishing us from our non-human relatives.

AUTHOR CONTRIBUTIONS

Jonathon McPhetres: Conceptualization; data curation; formal analysis; investigation; methodology; project administration; resources; software; supervision; validation; visualization; writing – original draft; writing – review and editing. **Ailin Han:** Data curation; investigation. **Halo H. Gao:** Investigation; project administration. **Nicole Kemp:** Investigation; project administration. **Bhakti Khati:** Data curation; investigation; project administration. **Cathy X. Pu:** Data curation; investigation; project administration. **Abbie Smith:** Investigation; project administration; supervision. **Xinyu Shui:** Data curation; investigation; project administration.

FUNDING INFORMATION

None.

CONFLICT OF INTEREST STATEMENT

None.

DATA AVAILABILITY STATEMENT

Data are available on the open science framework at the following link: https://osf.io/ps2fq/?view_only=0c2ab9cd5beb410c9f48419351a1b8a1.

ETHICS STATEMENT

Ethical approval was obtained from the Psychology Department Ethics Board at Durham University: PSYCH-2021-12-06T16_03_28-mqbg73.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Table S1. Description of the piloerection-inducing video stimuli used in Study 1.

TABLE S2. Correlations between the number of piloerection episodes at each anatomical location.

How to cite this article: McPhetres, J., Han, A., Gao, H. H., Kemp, N., Khati, B., Pu, C. X., Smith, A., & Shui, X. (2024). Individuals lack the ability to accurately detect emotional piloerection. *Psychophysiology*, *61*, e14605. https://doi.org/10.1111/psyp.14605