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The voluntary control of piloerection

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Autonomic systems in the human body are named for their operation outside of conscious control. One rare exception is voluntarily generated piloerection (VGP) – the conscious ability to cause goosebumps – whose physiological study in scientific history is confined to three single-individual case studies. Almost nothing is known about the physiological nature and emotional correlates of this ability. The current manuscript investigates the physiological, personality, and emotional phenomenology of a sample of thirty two individuals capable of VGP. Physiological descriptions were consistent with previous reports, describing a consistent stereotypical pattern of sensation and action. Most participants reported VGP was accompanied by psychological states that typically accompany involuntary piloerection (e.g. absorption), and using VGP during activities that elicit involuntary piloerection (e.g. music). Compared to previously collected samples, participants reported significantly higher openness to experience, and absorption in response to aesthetic situations. These preliminary findings suggest that this rare and unusual physiological ability has strong emotional and personality correlates.

The Voluntary Control of Piloerection

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ABSTRACT

Autonomic systems in the human body are named for their operation outside of conscious control. One rare exception is voluntarily generated piloerection (VGP) – the conscious ability to cause goosebumps – whose physiological study in scientific history is confined to three single-individual case studies. Almost nothing is known about the physiological nature and emotional correlates of this ability. The current manuscript investigates the physiological, personality, and emotional phenomenology of a sample of thirty two individuals capable of VGP. Physiological descriptions were consistent with previous reports, describing a consistent stereotypical pattern of sensation and action. Most participants reported VGP was accompanied by psychological states that typically accompany involuntary piloerection (e.g. absorption), and using VGP during activities that elicit involuntary piloerection (e.g. music). Compared to previously collected samples, participants reported significantly higher openness to experience and absorption in response to aesthetic situations. These preliminary findings suggest that this rare and unusual physiological ability has strong emotional and personality correlates.

INTRODUCTION

"Certainly that heart is steel-framed which, in spite of one's chanting the holy name of the Lord with concentration, does not change when ecstasy takes place, tears fill the eyes and the hairs stand on end."

Bhāgavata Purāṇa, 2.3.24, 800-1000AD

The study of exceptional individuals is central to the history of human neuroscience. Famous case studies include patients with specific neurological insults, such as naturally occurring lesions (e.g., Louis Leborgne; Broca, 1861), victims of crimes or accidents (e.g., Phineas Gage; Harlow and Martin, 1868), or patients receiving neurosurgery (e.g., Henry Melaison; Corkin, 1984). Detailed observations of these individuals were critical to initial developments within language processing, behavioural inhibition, and amnesia/memory consolidation respectively. Non-invasive imaging techniques allow contemporary research to pursue similar case study or small-sample approaches without autopsy, and relevant patients continue to make important contributions to the neuroscience of behaviour (e.g., Patients B.G. and A.M.; Khalsa et al., 2016). In this tradition, the present paper seeks to identify unusual individuals to illuminate the psychophysiology of emotion – in particular, small populations of people with atypical autonomic physiology who are otherwise healthy, in order to identify any corresponding patterns in their physical, cognitive, or emotional experiences.

An example here is illustrative: suppose two people, one healthy and neurotypical, the other identical but with a specific injury to the thoracic sympathetic ganglia. If the first walks face-first into a spider's web in the dark, we might expect subsequent reflex reactions (e.g., eye-blink, self-defensive posture) followed by the autonomic nervous system (ANS) increasing heart rate (HR) in preparation for whole-body mobilisation. The second would most likely have normal reflexes, normal rapid appraisal of the situation (i.e., a realisation of what has happened, that a spider is most likely somewhere nearby), and then subsequently a normal fear reaction (i.e., spiders are phylogenetically appraised by humans as dangerous and/or disgusting), but *reduced physical symptoms of fear or panic*, as their heart remains steady, palms dry, and so on. That is, this 'sympathetically-impaired' person would experience a dissociation between strong emotions and their typical embodied experience. If we consider emotion an interface between cognitive interpretations and the physical experience of the body (e.g., Schachter & Singer, 1962), how should we understand the perception of the relevant physiology being altered? What then would the experience be?

As an additional layer of complication, consider the above scenario in an individual with strong conscious control over their heart rate. How does someone experience an embodied mental state when they can consciously control its autonomic precedents or antecedents? Somewhat paradoxically, the relevant control in this case would be over the ANS, the portion of the peripheral nervous system traditionally defined as operating outside volitional or conscious control, from the Greek *autos* (self) and *nomos* (laws), i.e., self-governing. However, delineation between autonomic and somatic (i.e., voluntary) functions is not clear-cut. Respiration is the classic example of an autonomic mechanism directly amenable to conscious control. Absent of any form of conditioning, there is also evidence of volitional control of HR (Bell & Schwartz, 1975; White, Holmes, & Bennett, 1977) and blood pressure (Lowdon, Murray, & Langley, 2011). As autonomic systems co-modify, the above effects may be combined. For instance, conscious control of respiration might also be considered a deliberate modification of blood pressure (Joseph et al., 2005). Some curious case studies from meditative traditions concerning HR control (Young & Taylor, 1998) and temperature (Benson et al., 1982) have also been reported. Related research has also taken place under the rubric of biofeedback, where conscious access to a previously non-conscious ability is provided by physiological instrumentation in order that it may be consciously strengthened (e.g., somatic control of skin temperature; Taub & School, 1978). Finally, a separate case again is the conscious control of pupillary contraction and dilation, which is both capable of being conditioned (Cason, 1922) and responds directionally to imagined changes in luminance (Laeng & Sulutvedt, 2014).

In addition to the above, there is an autonomic mechanism that to our knowledge has never been systematically investigated – *piloerection*, often referred to as 'goosebumps.' Piloerection is commonly observed during cold, fearsome, or intensely evocative emotional stimuli, and is subserved by the pilomotor projections of the sympathetic nervous system (SNS). Evidence in the scientific literature to suggest that piloerection can be consciously controlled has been observed in only three published case studies over a period of more than a century (Benedek, Wilfling, Lukas-Wolfbauer, Katzur, & Kaernbach, 2010; Lindsley & Sassaman, 1938; Maxwell, 1902). Voluntarily generated piloerection (VGP) is described below in brief (Table 1).

[Table 1 around here]

While we may therefore conclude that in some individuals it is possible to voluntarily control piloerection, almost nothing else is known. The incidence of this ability, its significance, its method of action, and its potential psychological correlates have never been examined.

VGP is unusual for several reasons, even in light of other examples of conscious physiological control. First, the *arrector pili* which control the erection of individual hairs are smooth muscles, and have no somatic control in the manner of skeletal muscles. A reductionist physiological account would conclude conscious piloerection was not possible. Second, VGP was described in

all three case studies as being 'discovered' by the person experiencing it; they all outline various experiences where VGP was uncovered as a latent ability without the involvement of conditioning, biofeedback, expectation, or training. Thus, no pathway to acquire this ability is known. Third, VGP offers control over a physiological phenomenon which is intimately involved in emotional experience. Bodily sensations and emotions frequently have overlapping language where autonomically-mediated experiences are inherent within strong emotions ('her palms were damp,' 'he had butterflies in his stomach,' and 'their hearts were pounding'), and likewise here 'my hair was standing on end'. Modern accounts of the nature of emotion consider the role of integrating the perception and feedback of somatic symptoms such as goosebumps (e.g., Schachter & Singer, 1962). Other self-perceived physical symptoms, such as the ability to feel the heart beating in the chest ('cardiac interoception'), have been associated with emotional (Pollatos, Kirsch, & Schandry, 2005) and physical (Herbert, Ulbrich, & Schandry, 2007) self-regulation. In this tradition, the presence of piloerection during intense experiences has been shown to correlate strongly with reported emotional intensity, and seems to be particularly associated with states of being 'moved' or 'touched' (Benedek & Kaernbach, 2011; Wassiliwizky, Wagner, Jacobsen, & Menninghaus, 2015), or in 'awe' (Schurtz et al., 2012). Whether VGP is in any way related to the subjective experiences associated with involuntary piloerection remains an open question. Likewise, the relationship between VGP and the tendency to experience *involuntary* piloerection is unknown.

Almost nothing is known about psychological correlates of VGP. Is it accompanied by emotions and sensations usually associated with involuntary piloerection? Do people capable of VGP use this ability to enhance or moderate their psychological experiences? Only one of the three case studies cited above mentions any psychological aspect; the subject in question reported that voluntary piloerection was experienced as "rather pleasurable than otherwise" (Maxwell, 1902, p. 373). This individual further reported unusual features – he could use VGP for headache relief, observed no special sensitivity during fear, sympathy, or music, and experienced piloerection most of the time while watching football. The other case studies primarily focused on the automated detection or physiology of VGP (Benedek et al., 2010; Lindsley & Sassaman, 1938).

Another question of interest is whether people capable of VGP have a unique personality profile. Maxwell (1902) initially speculated that the ability might be associated with a neurotic personality disposition, however, he observed the individual under study as an intelligent student who was particularly curious about any information that could be gained about his special ability. Individual differences in the propensity to experience piloerection and related psychological states are most consistently associated with the personality domain of openness to experience—a domain that reflects individual differences in cognitive exploration (DeYoung, 2015). A questionnaire item reporting on experiences of aesthetic chills in response to music and poetry is the highest, or one of the highest loading items, on the openness to experience questionnaire,

suggesting that experiences of aesthetic chills are a universal marker for openness to experience (McCrae, 2007). Furthermore, openness is associated with observed and self-reported chills in response to music (Colver & El-Alayli, 2016; Nusbaum & Silvia, 2011; Silvia, Fayn, Nusbaum, & Beaty, 2015), and the arts more generally (Silvia & Nusbaum, 2011). Open people are more prone to being absorbed in their experiences generally (Wild, Kuiken, & Schopflocher, 1995), and in aesthetic contexts specifically (Silvia & Nusbaum, 2011). They are also more likely to report experiences of awe (Shiota, Keltner, & John, 2006), and recall awe-based crying experiences with music (Cotter, Silvia, & Fayn, 2017). Much of this work addresses the relationship between openness and experience of 'chills.' While chills may not be identical to piloerection in the sense that they may not necessary involve either body hair moving visibly or the skin dimpling due to activity of the *arrector pili,* we may assume they are strongly related; drug studies using alpha-1 agonists (i.e., sympathomimetics, many of which induce strong goosebumps) also produce congruent sensations in skin areas without visible hair (Stephens, 1986), which users more commonly describe as a 'skin crawling' sensation. No hypotheses were formulated for other personality domains, but a short measure of the Big Five was administered for exploratory comparisons with normative data.

The links between piloerection, the experience of chills, and existing personality correlates tentatively imply that individuals with voluntary control over these symptoms tend to experience states of being moved, touched, and/or awed more frequently, and score higher on openness to experience measures. However, hypothesised differences in openness are contingent on whether the experience of VGP is accompanied by psychological experiences that are associated with involuntary piloerection. In summary, VGP provides potential insight into both the nature of autonomic regulation and a correlate of emotion and personality.

The present study is the first we are aware of to characterise this ability in a sample of any size.

METHOD:

This study was approved by the Human Research Ethics Committee at the University of Sydney (Project number: 2015/598).

Participants

Participants for the study were concurrently recruited from two distinct pools. Prior to starting the study, all participants had to provide consent via a digital consent form.

Pool 1: Online

Given the suspected rarity of VGP, the first pool was recruited online via advertisements placed on psychology-relevant Facebook groups, and requests placed on any website which mentioned a congruent phenomenon. All links given referred to our own Facebook group created for recruitment[1], which gave a full general description of the study before linking participants to the questionnaire, in order to reduce confirmation bias in recruitment.

Thirty-five participants completed some of the survey, but only thirty-two (n=32; 22 males) answered all the physiology-related questions on which the exclusion criterial was based, two people did not complete the personality questions, and two others did not complete the aesthetic experiences scale. Missing data was not imputed; relevant indices were calculated with cell sizes of existing values. Participants with missing data were excluded only from analyses that involved variables with missing data.

Pool 2: Mass undergraduate screening

The second pool consisted of first year psychology students recruited via a mass screening questionnaire (n=682). For the screening, the following question was asked:

> "Goosebumps are raised hair follicles that appear on your arms and other body parts when you are cold, afraid, or experience heightened emotions. However, some people can give themselves goosebumps just by thinking it. Is this something you can do?"

Endorsement of the screening question provided an indication of the prevalence of VGP in a large student sample. Those who endorsed the question (n=120) were invited to participate in the study, twenty-two completed the survey. To ensure that the final sample consisted of participants who genuinely have the ability for VGP, this data remained un-analyzed until we had set criteria, as described below, based on previous case studies and results of the general web survey.

Procedure

Participants from both recruitment pools completed the study online via a series of questionnaires programed in Qualtrix. Participants first read a general description of the study and were subsequently asked for consent, after which all questionnaire measures were delivered. The study was approved by the ethics committee at Sydney University (Project #2015/598).

Measures

The questionnaires administered consisted of questions regarding personal demographics (age/gender), physiological aspects of VGP, some standardized personality questionnaires with a

[1] https://www.facebook.com/voluntarygoosebumps/

particular focus on openness to experience scales, tendency to experience powerful aesthetic emotions, and experiential/psychological questions.

Physiological questionnaire

This questionnaire was modeled off the original case studies, and assessed the age of discovery of VGP, important bodily sites (where the sensation initiated, where it occurred, and where it was strongest), response latency and decay, any control over body parts or sidedness, relationship with the respiratory cycle, and any potential practice schedules. Participants were also asked to describe in detail their skill, and the precise series of events used to precipitate VGP.

Personality

Big Five Personality

Personality was assessed via the Ten Item Personality Inventory (TIPI; Gosling, Rentfrow, & Swann, 2003). The TIPI is a brief assessment of five personality domains that has been administered extremely widely (i.e., to more than 300,000 people), and thus has well-established norms (Gosling, Rentfrow, & Potter, 2014). The 5 domains are assessed with 2 items each, thus 10 items in total. Such short measures tend to suffer from low reliability – this is an acknowledged factor of personality domains measured with few items, and with this scale in particular (Credé, Harms, Niehorster, & Gaye-Valentine, 2012; Gosling et al., 2003). In the current sample, particularly low reliability was observed for openness (Cronbach's α=0.26) and emotional stability domains (α=0.37), with slightly higher consistency for agreeableness (α=0.55), conscientiousness (α=0.62), and extraversion (α=0.65) domains. Given the low reliability of these scales, we compared our VGP sample to population norms on both two-item domains and individual items.

Openness/Intellect domain

We also administered a subscale of the Big Five Aspect Scale (BFAS) to assess the openness/intellect domain more thoroughly. The BFAS divides each personality domain into two aspects (DeYoung, Quilty, & Peterson, 2007). In the case of openness, aspects reflecting sensory exploration (openness) are differentiated from abstract/semantic exploration (intellect) (DeYoung, 2015). In the current sample, internal consistencies for the overall domain (α=0.84), as well as openness (α=.68) and intellect (α=.88) aspects were acceptable. No other subscales from the BFAS were administered.

Aesthetic experience scale

To test whether VGP individuals in our sample were more likely to experience strong aesthetic states, we administered the aesthetic experience scale (Silvia & Nusbaum, 2011). This scale was

developed to assess individual differences in the frequency of powerful aesthetic experiences associated with involuntary piloerection. The scale breaks up into three factors that assess chills (three items), feeling touched (two items), and absorption (five items). In the current sample, the internal consistency was good for all three scales (α=0.72-0.89).

Other psychological experience questions

To assess whether VGP was associated with psychological sensations, we asked participants whether VGP was accompanied by experiences associated with involuntary piloerection. We used items from the aesthetic experience scale (excluding the chills items), where participants could choose any number of the experiences (feelings of awe and wonder, feeling touched, feeling like crying, feeling absorbed or immersed, losing track of time, feeling like you are somewhere else, and feeling detached from your surroundings) that accompanied VGP.

We also asked participants whether they used their VGP ability to produce goosebumps during different activities such as listening to music, watching film or TV series, viewing art, reading literature or poetry, engaging in creative activities, watching dance, theater, playing computer games, and an 'other' option where participants could fill in a free response indicating the activity during which they use their ability. Finally, we also included a yes/no item asking participants whether they used their ability to prolong involuntary piloerection.

RESULTS:

Pool 1: Online

When asked to describe the process of VGP, thirty-two out of thirty-five participants in the online sample gave a detailed description. These open-field responses overwhelmingly described a process which was physical and reflex-like, rather an exercise of the imagination or re-experiencing:

> *P3: "Decide I want to give myself goosebumps, and with my next exhale, they come..."*
>
> *P4: "I think about goosebumps, they start to appear, I shudder/shiver, and there they are."*
>
> *P10: "I tighten a muscle behind my ears … and the goosebumps appear on my back and then travel to my arms."*

P11: "I just concentrate on the back of my neck and I get them."

P12 "I tense my ears and scalp, (which also feels like i'm tensing the inside of my head) which sets off a shiver that runs down the back of my neck and around to my arms and chest."

P18 "When I intend to cause them - outside of meditation (i.e; willfully)[sic]*, I focus conscious attention above and towards the back of the neck/base of skull and allow it."*

P20 "When you hear of news that's life-changing, you may gasp, open your eyes wide, and suddenly feel very cold. When I mimic these physical reactions… I can reproduce the effect coming from the back of my neck."

P21 "I have to be fairly relaxed and not distracted, but I basically just think about the feeling itself and that is usually enough."

P24 "I simple [sic] *think of doing it. I don't need to have a* [sic] *emotion involved, in fact I can do it now without feeling any emotion whatsoever."*

P25 "I just think about the act of having goosebumps and focus a little on the nape of my neck."

P28 "I think of this energy (I have no name for it) and then it comes."

P32 "I flex a "muscle" … in my brain. Sometimes i have to concentrate a little if i've been doing it for a while."

The online sample participants that met the above criteria were typically adult (mean age=32.44 yrs.; SD=10.55), and discovered their VGP ability as teenagers or young adults (mean age of discovery =16.91 yrs.; SD=6.17). Most had substantial experience with the ability (15.53 yrs.; SD=10.75). Only two participants reported discovering VGP as a latent ability when they encountered the study recruitment material. Location was broadly international, but largely from Anglophone countries (n=14, USA; n=3, UK, Australia; n=2, New Zealand, Canada, Argentina; n=1, Germany, Norway, Wales, Austria).

Participants reported the sensation as beginning on the back of the head/neck (71.88%) far more than any other site (e.g., arms, 21.86%; top or sides of head, 15.63%). Every participant reported the physical sensation of goosebumps on multiple bodily sites (mean=5.75), overwhelmingly on the arms (90.63%), but also commonly on the back of the head/neck (75%), upper back (71.88%), shoulders (65.63%), legs (62.5%), top/sides of the head (53.13%), or lower back (46.88%). The

sites where the sensation was reported strongest were the back of the head/neck (65.63%) or arms (53.13%).

Participants overwhelmingly reported the response as quick to initiate; 81.3% said the response began instantaneously (i.e., 0 to 1sec) or quickly (2 to 4sec), while time taken to initiate and then withdraw the response was highly variable, ranging from almost instantaneous to more than 15 seconds. In general, participants reported having no control over the location of the goosebumps they provoked (75%), having them occur equally on both sides of the body (68.75%), and having no control over their 'sidedness' (71.88%).

Participants were, in general, extremely or somewhat surprised that the general population does not share their ability (71.88%). They primarily described their experience of VGP as very easy or effortless (65.63%), or requiring 'some concentration or focus' (28.13%). Only two participants (6.25%) described the phenomenon as 'effortful.' Very few participants described the experience of VGP as solely requiring imagination or emotion, such as recalling a moving, sad, or dangerous scenario (15.63%); the rest reported that VGP was possible as a purely physical phenomenon.

The respiratory cycle appeared to have no influence over the phenomenon, as participants reported being able to produce VGP during inspiration (81.25%), expiration (81.25%), with full lungs (78.13%), or with empty lungs (59.38%). Participants reported that they practised their ability using a variety of schedules: at least weekly (37.5%), at least monthly (15.63%), rarely (9.38%), or never (37.5%).

Most participants (71.88%) reported at least one psychological state previously found to relate to involuntary piloerection accompanying their VGP experience. The most common reported were absorption/immersion (53.13%), awe/wonder (46.88%), and detachment (37.5%). The least commonly reported were feeling: 'touched,' 'being somewhere else,' 'like crying,' or 'losing track of time.' This suggests VGP is associated with feelings congruent to experiences of involuntary piloerection. Participants also reported the following normal cutaneous sensation of goosebumps during commonly piloerective stimuli: when cold, during music, during films or television, when afraid, when touched lightly, during the experience of aesthetic or natural beauty, etc. (note: these are in decreasing rank order).

Participants generally reported to have no personal explanation for their ability (37.5%) or offered a scientific mechanism (37.5%; descending noxious inhibitory control, various neurotransmitters, the autonomic nervous system, circulating epinephrine, biofeedback, etc.) Only a single participant mentioned anything akin to a spiritual or non-mechanistic process.

Next, we tested whether participants used their VGP abilities during activities that tend to elicit involuntary piloerection. Of the sample, 71.88% reported using their ability in response to at least one of the activities. The most frequently reported activities where participants used their ability

were music (53.13%), film/television (28.13%), literature (25%), creative activities (25%), art (21.88%), dance (18.75%), theatre (15.63%), and gaming (12.5%). The 'other' category was also frequently endorsed (46.88%), and included meditation, engagement with nature, exercise, sex, work or study for added energy and concentration, and to warm up. Only one participant mentioned using the ability to alleviate pain, as was the case in Maxwell (1902. Thus, most of the sample reported using their ability in contexts where involuntary piloerection is frequently reported. Around half (53.13%) reported deliberately using their ability to prolong experiences of involuntary piloerection.

To test whether VPG-capable individuals experience emotions and experiences associated with involuntary piloerection more frequently, we compared their scores on the aesthetic experiences scale to the largest available sample previously collected from university students (n=188; Silvia & Nusbaum, 2011). VGP-capable participants reported a higher frequency of feeling absorbed ($t = 2.20$, $p = .036$, Cohen's $d = .42$, 95% CI: 0.043 – 1.207), and no difference in the frequency of chills ($t = 1.89$, $p = .068$, Cohen's $d = .35$, 95% CI: -1.200 – 0.047) or being moved ($t = 0.281$, $p = .781$, Cohen's $d = .05$, 95% CI: -0.663 – 0.503).

Since we had no prior information regarding the sample characteristics of the VGP-capable participants, we compared personality data to normative data from the largest published samples for the relevant scales (Table 2). The VGP sample was significantly higher on BFAS Openness/Intellect, in both the domain and aspect level, and the differences produced large effect sizes. This was not replicated with the TIPI measure of openness, but the difference was significant for one of the openness items. No other differences were observed at the domain level of the TIPI, but there were some differences at the item level. The VGP sample scored significantly lower on an agreeableness item, and significantly higher on an emotional stability item; both differences were medium in effect size.

[Table 2 around here]

As a post-hoc follow-up, Figure 1 compares the BFAS Openness/Intellect omnibus score against large samples where relevant data was available (8 samples drawn from six papers; Antinori, Carter, & Smillie, 2017; DeYoung et al., 2007; Fayn, K., Silvia, P. J., MacCann, C., & Tilioipoulos, 2017; Fayn, MacCann, Tiliopoulos, & Silvia, 2015; Sun, Kaufman, & Smillie, 2017; Weisberg, DeYoung, & Hirsh, 2011). Uncorrected p-values (t-test, two-tailed) range from 0.051 to 10^{-7}.

Pool 2: Mass undergraduate screening

From all of the above, we summarize representative VGP characteristics as follows:

(1) VGP occurs on a volitional basis; participants report producing goosebumps via *an intentional and non-reflective* activity, as in a volitional movement; no exercise of the imagination (such as re-experiencing previous excitement or imagining trauma) is involved**.**

(2) VGP involves a specific pattern of sensation; participants report a sensation *beginning at the back of the head/neck*, and *strongest or most noticeable on the back of the head/neck, or arms*.

(3) VGP involves low effort and short latency; participants report the sensation as beginning within a few seconds, and without strong effort.

[Figure 1 around here]

After the three criteria above were determined, the undergraduate data collected from a local sample was opened and analysed. Per the above criteria, none of the undergraduates surveyed reported a congruent VGP phenomenon, and thus a follow-up physiological investigation was not conducted.

DISCUSSION:

To our knowledge, this paper outlines the first sizable sample ever characterised who have a voluntary ability to produce goosebumps. While this sample was not observed directly in a laboratory setting, participants principally reported an experience consistent with those previously identified in laboratory case-studies over the previous century (Benedek et al., 2010; Lindsley & Sassaman, 1938; Maxwell, 1902) and to each other.

As VGP is almost entirely unknown, even within the scientific study of autonomic physiology, we doubt very much that study participants were subject to demand characteristics. It is unlikely any participant had prior cues or expectations regarding how their ability might be expected to work due to its rarity. Neither did any participant have access to each other's responses. In open-field descriptions, no participant reported any aberrant or unusual phenomena, such as goosebumps on glabrous skin areas, a fast or instantaneous piloerection response (i.e., one where the sensation is quicker than the possible latency of the SNS), or an irregular dermatomal pattern. Neither were any parethesias described – itchiness, tingling, burning, and so on. Instead, the cutaneous component of VGP, its latency, and the body parts involved appear to be congruent with normal involuntary piloerection (i.e., identical to those experienced during cold, emotional elicitation, fear, etc.). No participant mentioned any injury, neurological insult, or pre-existing condition, relevant or otherwise, in their description of how VGP was possible. Overall, the responses we received paint a consistent picture of VGP as a perfectly normal and straightforward phenomenon, one which is curious, sometimes pleasant, and essentially benign.

Having established that VGP exists as previously described, these results both confound our understanding of voluntary control over the autonomic nervous system and provide some insight into its phenomenon. Lindsley and Sassaman (1938) debated at length whether VGP was due to an innate skill or to some form of conditioning, where an original piloerective stimuli (cold, fear, etc.) acts as an earlier unconditioned stimulus. Conditioning seems unlikely to us for three primary reasons. First, two participants discovered they could perform VGP only upon receipt of the study materials. Second, many describe stumbling across VGP either purely out of idle self-experimentation, often at a young age, or sometimes in a deliberative attempt to re-create a previous experience. For an association to form, it would have to be entirely without conscious awareness. Third, if the conditioning hypothesis were true, it would result in a remarkably consistent phenomenon which centres around a deliberative point on the back of the head or neck. There is no physiological explanation for why or how localised focus or tension is the most common physical trigger for a conditioned response.

It is also difficult to integrate the above into classic observations of piloerection from animal models. Animals display piloerection as a functional social signal in both aggression and defence (as well as during cold exposure), it can be observed on localised and generalised bodily sites, and the response can be evoked by the direct stimulation of a variety of sites within the brain and periphery (Blanchard & Blanchard, 1977; Maickel, Matussek, Stern, & Brodie, 1967; Shaikh, Barrett, & Siegel, 1987). However, in humans, we assume the ability is vestigial and observe little interindividual variation in site (except in the case of specific medical conditions such as pilomotor seizures; Loddenkemper et al., 2004).

With respect to psychological features of VGP, most participants reported that it was associated with emotional states observed during involuntary piloerection, such as absorption, immersion, and wonder. This suggests that VGP-capable individuals may be able to voluntary elicit these emotional states. This finding is in line with research demonstrating greater emotional reactivity after artificial induction of piloerection (Fukushima & Kajimoto, 2012). Further, approximately 72% of the sample reported using their ability to produce piloerection during various aesthetic activities. Of particular interest is one of the unsolicited uses reported, namely for attention/concentration (work, study, testing situation, lecture). Absorption is by definition a powerful engagement emotion, and attention and emotion are theoretically and empirically linked in terms of selection, orientation, and engagement (see Yiend, 2010 for a review). Using VGP ability to control attention during situations that require it is intriguing, and a viable target for future confirmatory research.

While some differences were observed at the item level of the TIPI, none would survive a correction for multiple comparisons. Thus, we leave the possibility of broad personality

differences for future confirmatory research, and will focus on discussing the strongest and most consistent finding –participants were noticeably higher than population norms on openness to experience. One prominent perspective on personality is that traits manifest in the intensity and frequency of states associated with the trait (Fleeson & Jayawickreme, 2015)—for example, those scoring higher on an openness scale are more likely to report openness states when assessed several times a day (Fleeson & Gallagher, 2009). Thus, the greater openness reported by the VPG-capable sample is in line with the greater frequency of reported absorption experiences, and that around half of the sample reported using their ability to prolong such experiences, as well as in situations that require attention. Unpacking these findings at this stage is speculative, but one possibility is that open people invest more time and effort into self-exploration. Openness is the strongest personality predictor of self-reflection (Trapnell & Campbell, 1999), and indeed some participants reported the discovery of the ability through self-experimentation and deliberate attempts to re-recreate a previous experience. However, the direction of causality cannot be assumed. It is also possible that VGP-capable people are more open because, via their ability, they experience absorption more often and thus are more likely to seek out new experiences.

The higher openness reported by our sample does not appear to be particularly driven by one aspect of openness to experience, but rather, our sample was higher in both openness and intellect. This distinction is theorised to reflect individual differences in cognitive exploration of sensory (openness) versus abstract (intellect) stimuli and situations (DeYoung, 2015), but also emotional versus cognitive engagement with sensory and abstract information (Fayn, Silva, MacCann, & Tiliopoulos, 2017). More specifically, openness positively, while intellect negatively, predicts self-reported frequency of chills (Silvia & Nusbaum, 2011). Thus, differences in openness were expected. In fact, the openness scale includes items that assess tendencies for absorption (e.g., “Get deeply immersed in music,” “Enjoy the beauty of nature”) and thus one might expect a stronger relationship with openness compared to intellect; however, the VGP sample is higher on both. While circularity in measurement could be claimed for openness, there are no items within the intellect scale that have such overlap.

FUTURE DIRECTIONS

Having established that this phenomenon can be reliably identified in multiple individuals, the immediate extension of this work is to add to previous observations. For instance, what overlap can be observed between other sympathetically-mediated sites in the periphery – does VGP imply a parallel response in the microvasculature, HR, or skin resistance? Moreover, does it

augment or antagonise sympathetic reflex responses such as startle? Finally, if VGP is an analogue of an emotional response, does it alter the nature of emotional experience to stimuli (both naturalistic and experimental)?

These questions approach constructs of interest within broader theories of emotion; for instance, constructionist theories of emotion. As an example, the Conceptual Act Theory (CAT) understands emotion from a constructionist perspective, where they are synthesised from physically perceived representations combined with an understanding of emotional categories themselves (e.g., Barrett, 2014). Interestingly, CAT proposes that emotions are born from interoceptive information (perceived from inside the body; e.g. the sensation of the heart beating or stomach turning), exteroceptive information (taste, smell, sound, etc.), and their integration with language in a 'conceptual act.' In this context, VGP is unusual in the sense of being able to produce both an internal sensation (most subjects describe an internal process which has a distinct activity or pathway) *and* a cutaneous sensation (the physical experience on the skin itself). A comparison to the experience of false haptic feedback, a manipulation where the hairs on the skin are raised using electrostatic charge without any internal experience (Fukushima & Kajimoto, 2012) would be instructive.

LIMITATIONS

There are several obvious limitations to the present study. First, as we failed to identify any participants from a large sample of local undergraduates, the investigation presented is purely descriptive by necessity - we had no opportunity to directly study the physiology of the phenomenon. Second, it is impossible to establish how many times our initial recruitment materials or survey were viewed, and VGP is sufficiently rare that we could not identify one in a sample of several hundred participants drawn from a general population. Thus, we have no reasonable estimate of the base rate of VGP, past being unable to identify it within a local sample of n=682. Considering this, and the fact that it has never been previously outlined, we can conclude nothing more than that VGP is reasonably uncommon. Third, while the BFAS openness/intellect measure demonstrated acceptable reliability, the TIPI measure was mostly unreliable. This is not uncommon when trying to measure personality domains with two items per domain. While the TIPI has been shown to correlate strongly with broader measures of the Big Five, short measures have been shown to increase Type 1 and Type 2 error rates (Credé, Harms, Niehorster, & Gaye-Valentine, 2012). Further, past work has particularly questioned the validity of the openness items within the TIPI, suggesting that they fail to capture central elements of openness to experience (Hofmans, Kuppens, & Allik, 2008), which may explain the inconsistency between the two different measures of openness in our sample. Fourth, self-

selected participants accessed via Internet recruitment answering a survey presumably out of curiosity might be assumed to display more personal openness. To address this requires either a carefully matched sample to any remotely collected data, or identifying a VGP-capable population who are not self-selected. As outlined above, this is a significant undertaking when studying a rare phenomenon.

CONCLUSION

This study is the first to outline the ability to produce voluntary piloerection in a sample of more than a single individual. This phenomenon is consistent between individuals, reasonably effortless, visibly distinct, and we can tentatively conclude has correlates within the personality domain of openness. VGP-capable participants were generally aware of their ability, regard it as harmless or pleasant, and often use it to modify or prolong sensory experiences. Individuals who display VGP may play an important role within the future study of emotion and emotional regulation, as the role of the ANS integrated within the physiology and experience of visceral emotions (shock, awe, fear, panic, disgust, etc.) is potentially illuminated by individuals with rare or unusual physiology.

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Table 1(on next page)

Characteristics of individuals displaying voluntarily generated piloerection (VGP)

1 *Characteristics of individuals displaying voluntarily generated piloerection (VGP)*

Reference	Age	Age discovered	Sites	Resp. time to completion	Resp. time to decay
Maxwell, 1902	27	11-12	Hips, thighs, back, arms	2-10s	2-10s
Lindsley and Sassaman, 1938	"middle aged"	10	Forearm, thigh, lower leg	7s	15-20s
Benedek et.al., 2010	35	27	Neck, spine, arms	5.15s	10.8s

2

Table 2(on next page)

VGP sample vs. populations norms for Ten-Item Personality Inventory items and domains, Big Five Aspect Scale subscales and domain.

VGP sample vs. populations norms for Ten-Item Personality Inventory items and domains, Big Five Aspect Scale subscales and domain.

Personality measure	Sample		Norms		Difference		Confidence Interval	
TIPI Items	Mean	SD	Mean	SD	p	Cohen's d	LL	UL
Extraverted, enthusiastic.	4.73	1.80	4.42	1.73	0.354	0.17	-0.19	0.53
Critical, quarrelsome (R).	3.43	1.72	4.08	1.72	0.047*	-0.38	-0.75	-0.01
Dependable, self-disciplined.	5.50	1.36	5.00	1.54	0.055	0.37	-0.01	0.73
Anxious, easily upset (R).	4.20	1.81	4.06	1.81	0.671	0.08	-0.28	0.44
Open to new experiences, complex.	6.00	1.20	5.49	1.34	0.029*	0.42	0.04	0.79
Reserved, quiet (R).	4.10	1.58	3.54	1.88	0.063	0.35	-0.02	0.72
Sympathetic, warm.	5.43	1.14	5.29	1.44	0.502	0.12	-0.24	0.48
Disorganized, careless (R).	4.40	1.65	4.22	1.85	0.552	0.11	-0.25	0.47
Calm, emotionally stable.	5.20	1.54	4.62	1.64	0.049*	0.38	>0.00	0.74
Conventional, uncreative (R).	5.23	1.78	5.52	1.54	0.385	-0.16	-0.52	0.20
TIPI Domain								
Extraversion	4.42	1.46	3.98	1.59	0.114	0.30	-0.07	0.66
Agreeableness	4.43	1.21	4.69	1.23	0.257	-0.21	-0.57	0.15
Conscientiousness	4.95	1.29	4.61	1.42	0.161	0.26	-0.10	0.62
Emotional Stability	4.70	1.32	4.34	1.48	0.145	0.27	-0.09	0.64
Openness	5.62	1.15	5.51	1.14	0.604	0.10	-0.26	0.45
BFAS								
Openness/Intellect	4.05	0.48	3.60	0.51	0.00002*	0.93	0.50	1.36
Openness	4.03	0.50	3.68	0.61	0.0005*	0.72	0.31	1.11

Intellect	4.07	0.68	3.53	0.63	0.0001*	0.8	0.39	1.21

Note: Reversed items are marked (R) and presented recoded in line with domain label.

1

Figure 1

VGP-capable sample score on BFAS Openness Domain vs. other available means.

Results are shown as mean +/- SE. The estimate forming more than half of the available data points (n=2643; Weisberg et al. 2011) was taken as the population norm, and in the below is marked with an asterisk.

**Note: Auto Gamma Correction was used for the image. This only affects the reviewing manuscript. See original source image if needed for review.*