

A peer-reviewed version of this preprint was published in PeerJ on 30 July 2018.

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Heathers JAJ, Fayn K, Silvia PJ, Tiliopoulos N, Goodwin MS. 2018. The voluntary control of piloerection. PeerJ 6:e5292 <https://doi.org/10.7717/peerj.5292>

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.

1 The Voluntary Control of Piloerection

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17

18 ABSTRACT

19

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

33

34 INTRODUCTION

35

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

39 Bhāgavata Purāṇa, 2.3.24, 800-1000AD

40

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

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

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

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

96 [Table 1 around here]

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

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

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

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

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

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

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

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

165

166 METHOD:

167

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

170 Participants

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

173 *Pool 1: Online*

174 Given the suspected rarity of VGP, the first pool was recruited online via advertisements placed
175 on psychology-relevant Facebook groups, and requests placed on any website which mentioned
176 a congruent phenomenon. All links given referred to our own Facebook group created for
177 recruitment¹, which gave a full general description of the study before linking participants to the
178 questionnaire, in order to reduce confirmation bias in recruitment.

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

185 *Pool 2: Mass undergraduate screening*

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

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

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

197 *Procedure*

198 Participants from both recruitment pools completed the study online via a series of
199 questionnaires programed in Qualtrix. Participants first read a general description of the study
200 and were subsequently asked for consent, after which all questionnaire measures were
201 delivered. The study was approved by the ethics committee at Sydney University (Project
202 #2015/598).

203 *Measures*

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

¹ <https://www.facebook.com/voluntarygoosebumps/>

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

208 *Physiological questionnaire*

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

215 *Personality*

216 *Big Five Personality*

217 Personality was assessed via the Ten Item Personality Inventory (TIPI; Gosling, Rentfrow, &
218 Swann, 2003). The TIPI is a brief assessment of five personality domains that has been
219 administered extremely widely (i.e., to more than 300,000 people), and thus has well-established
220 norms (Gosling, Rentfrow, & Potter, 2014). The 5 domains are assessed with 2 items each, thus
221 10 items in total. Such short measures tend to suffer from low reliability – this is an acknowledged
222 factor of personality domains measured with few items, and with this scale in particular (Credé,
223 Harms, Niehorster, & Gaye-Valentine, 2012; Gosling et al., 2003). In the current sample,
224 particularly low reliability was observed for openness (Cronbach's $\alpha=0.26$) and emotional stability
225 domains ($\alpha=0.37$), with slightly higher consistency for agreeableness ($\alpha=0.55$), conscientiousness
226 ($\alpha=0.62$), and extraversion ($\alpha=0.65$) domains. Given the low reliability of these scales, we
227 compared our VGP sample to population norms on both two-item domains and individual items.

228 *Openness/Intellect domain*

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

236 *Aesthetic experience scale*

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

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

243 *Other psychological experience questions*

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

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

256

257 RESULTS:

258

259 *Pool 1: Online*

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

264

265 *P3: "Decide I want to give myself goosebumps, and with my next exhale, they*
266 *come..."*

267 *P4: "I think about goosebumps, they start to appear, I shudder/shiver, and there*
268 *they are."*

269 *P10: "I tighten a muscle behind my ears ... and the goosebumps appear on my back*
270 *and then travel to my arms."*

- 271 P11: *"I just concentrate on the back of my neck and I get them."*
- 272 P12 *"I tense my ears and scalp, (which also feels like i'm tensing the inside of my*
273 *head) which sets off a shiver that runs down the back of my neck and around to*
274 *my arms and chest."*
- 275 P18 *"When I intend to cause them - outside of meditation (i.e; willfully)[sic], I focus*
276 *conscious attention above and towards the back of the neck/base of skull and*
277 *allow it."*
- 278 P20 *"When you hear of news that's life-changing, you may gasp, open your eyes*
279 *wide, and suddenly feel very cold. When I mimic these physical reactions... I can*
280 *reproduce the effect coming from the back of my neck."*
- 281 P21 *"I have to be fairly relaxed and not distracted, but I basically just think about the*
282 *feeling itself and that is usually enough."*
- 283 P24 *"I simple [sic] think of doing it. I don't need to have a [sic] emotion involved, in*
284 *fact I can do it now without feeling any emotion whatsoever."*
- 285 P25 *"I just think about the act of having goosebumps and focus a little on the nape*
286 *of my neck."*
- 287 P28 *"I think of this energy (I have no name for it) and then it comes."*
- 288 P32 *"I flex a "muscle" ... in my brain. Sometimes i have to concentrate a little if i've*
289 *been doing it for a while."*

290

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

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

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

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

311 Participants were, in general, extremely or somewhat surprised that the general population does
312 not share their ability (71.88%). They primarily described their experience of VGP as very easy or
313 effortless (65.63%), or requiring 'some concentration or focus' (28.13%). Only two participants
314 (6.25%) described the phenomenon as 'effortful.' Very few participants described the experience
315 of VGP as solely requiring imagination or emotion, such as recalling a moving, sad, or dangerous
316 scenario (15.63%); the rest reported that VGP was possible as a purely physical phenomenon.

317 The respiratory cycle appeared to have no influence over the phenomenon, as participants
318 reported being able to produce VGP during inspiration (81.25%), expiration (81.25%), with full
319 lungs (78.13%), or with empty lungs (59.38%). Participants reported that they practised their
320 ability using a variety of schedules: at least weekly (37.5%), at least monthly (15.63%), rarely
321 (9.38%), or never (37.5%).

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

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

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

338 were music (53.13%), film/television (28.13%), literature (25%), creative activities (25%), art
339 (21.88%), dance (18.75%), theatre (15.63%), and gaming (12.5%). The 'other' category was also
340 frequently endorsed (46.88%), and included meditation, engagement with nature, exercise, sex,
341 work or study for added energy and concentration, and to warm up. Only one participant
342 mentioned using the ability to alleviate pain, as was the case in Maxwell (1902). Thus, most of the
343 sample reported using their ability in contexts where involuntary piloerection is frequently
344 reported. Around half (53.13%) reported deliberately using their ability to prolong experiences
345 of involuntary piloerection.

346 To test whether VPG-capable individuals experience emotions and experiences associated with
347 involuntary piloerection more frequently, we compared their scores on the aesthetic experiences
348 scale to the largest available sample previously collected from university students ($n=188$; Silvia
349 & Nusbaum, 2011). VGP-capable participants reported a higher frequency of feeling absorbed (t
350 $= 2.20$, $p = .036$, Cohen's $d = .42$, 95% CI: $0.043 - 1.207$), and no difference in the frequency of
351 chills ($t = 1.89$, $p = .068$, Cohen's $d = .35$, 95% CI: $-1.200 - 0.047$) or being moved ($t = 0.281$, $p =$
352 $.781$, Cohen's $d = .05$, 95% CI: $-0.663 - 0.503$).

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

362 [Table 2 around here]

363 As a post-hoc follow-up, Figure 1 compares the BFAS Openness/Intellect omnibus score against
364 large samples where relevant data was available (8 samples drawn from six papers; Antinori,
365 Carter, & Smillie, 2017; DeYoung et al., 2007; Fayn, K., Silvia, P. J., MacCann, C., & Tiliopoulou,
366 2017; Fayn, MacCann, Tiliopoulou, & Silvia, 2015; Sun, Kaufman, & Smillie, 2017; Weisberg,
367 DeYoung, & Hirsh, 2011). Uncorrected p-values (t-test, two-tailed) range from 0.051 to 10^{-7} .

368 *Pool 2: Mass undergraduate screening*

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

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

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

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

377 [Figure 1 around here]

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

382

383 **DISCUSSION:**

384

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

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

404

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

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

426 With respect to psychological features of VGP, most participants reported that it was associated
427 with emotional states observed during involuntary piloerection, such as absorption, immersion,
428 and wonder. This suggests that VGP-capable individuals may be able to voluntarily elicit these
429 emotional states. This finding is in line with research demonstrating greater emotional reactivity
430 after artificial induction of piloerection (Fukushima & Kajimoto, 2012). Further, approximately
431 72% of the sample reported using their ability to produce piloerection during various aesthetic
432 activities. Of particular interest is one of the unsolicited uses reported, namely for
433 attention/concentration (work, study, testing situation, lecture). Absorption is by definition a
434 powerful engagement emotion, and attention and emotion are theoretically and empirically
435 linked in terms of selection, orientation, and engagement (see Yiend, 2010 for a review). Using
436 VGP ability to control attention during situations that require it is intriguing, and a viable target
437 for future confirmatory research.

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

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

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

468

469

470 FUTURE DIRECTIONS

471

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

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

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

492

493 LIMITATIONS

494

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

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

517

518 CONCLUSION

519

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

529

530 ACKNOWLEDGEMENTS

531

532 The authors would like to thank the anonymous participants who volunteered to be
533 involved in this study. We are immensely grateful for the insights you have provided.

534

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690

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

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	
	Mean	SD	Mean	SD	p	Cohen's d	LL	UL
TIPI Items								
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
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Note: Reversed items are marked (R) and presented recoded in line with domain label.

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.*

VGP vs. Community Samples

