Emotional Prosthesis for Animating Awe through Performative Biofeedback

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ABSTRACT

Awe is a heightened emotional state of fear and wonder that creates a physiological response resulting in a cascade of hairs standing on end, also known as piloerection or goosebumps. This latent sense once served an animalian purpose of survival, but now lies dormant and is often not experienced consciously. In fact, 55 percent of the population reports to not feel this sensation that is noted to be healthy. The AWE Goosebumps artifact is an emotion prosthesis that animates the latent sensation of awe for embodiment and externalizes cues for communication. As the sensation is not experienced consciously, the techno fashion invites an opportunity to be a second skin for frisson biofeedback, behavior training, and expression to others as a tool to transform the doldrums of modern day to performative states of wonder.

CCS CONCEPTS

• **Human-centered computing** → **Interaction design process and methods**; *Interaction design theory, concepts and paradigms*; • **Applied computing** → Arts and humanities.

KEYWORDS

wearable technology, e-textile, goosebumps, awe, frisson, GSR, biofeedback, inflatable, textile, extimacy

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1 INTRODUCTION

Awe is a heightened emotional state of fear and wonder that creates a physiological response resulting in a cascade of hairs standing on end. This visceral phenomenon is deemed frisson as the skin shivers from a rush of feelings with a result of piloerection or goosebumps. This latent sense once served a purpose, but now lies dormant, and is often not experienced consciously. In fact, 55 percent of population reports to not feel this sensation and in turn it is noted to be found in the healthiest population, paired with wellbeing.

Goosebumps are often associated with frisson, a physical manifestation of emotional experiences, intuition, feelings, or memories revealed on the surface of our body. The AWE Goosebumps (Fig. 1) is a speculative design that imitates and intensifies this physical sensation and expresses it to others. A series of biosensors (galvanic skin response (GSR), breathing, and heart rate variability (HRV) sensors) responds to the biometric data of excitement and awe by illuminating and inflating the silicone kiragami cut-outs on the back of the garment. The biometric data is then also translated into color changes and haptic feedback, with blue to teal colors representing inhale and exhale, and expanding inflatables with pink illumination representing excitement.

This paper presents the garment AWE Goosebumps that aims to externalize and animate the feeling of goosebumps and awe. We address the design process and discuss how the materials and shapes of AWE Goosebumps were selected to create a biofeedback loop for the wearer. We then discuss how the concept of 'second skin' in the form of techno fashion has inspired the design.

Figure 1: AWE Goosebumps design. Elena Kulikova Photography. ©Sensoree

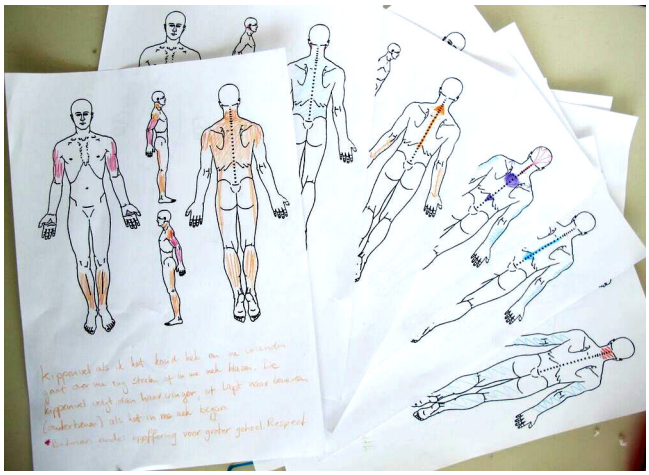

Figure 2: Body diagrams from the interviews: Where do you feel goosebumps? (reproduced from [11]) ©Sensoree

2 DESIGN RESEARCH

For the initial design research, we interviewed twelve people to find which kinds of goosebumps they can identify and what colors they associate with these different types of goosebump sensations [11]. Most people experienced piloerection when cold. The second most popular sensation among the respondents was the aesthetics-based emotional goosebumps. Some respondents admitted never having felt these sensations and further research led us to find that up to 55 percent of people in fact do not experience this thrill at all [3, 4], which offers a design opportunity for teaching new behavior. Those who did describe a frisson of emotions indicated that they felt goosebumps on their mid to upper back and neck and on the outside of their lower arms, see Fig. 2. These explorative user tests informed the material choices, colors, and form factor for the eventual AWE Goosebumps design.

First, we tested haptic options to find which technology corresponded with the authentic sensation. Muscle wire, vibration motors, and pneumatics were tried and we decided to develop a silicone textile that would act like a goosebump prosthetic. Eco Flex 30 silicone was found to be very similar to the texture of human skin and, as this material is also used in prosthetics for comfort, we felt this was an ideal material base to create a sensory amplifier that could be worn on the skin, see Fig. 3 and 4. When testing the silicone inflatables, it was discovered that many test users wanted to feel more pressure on the skin. To achieve this, a more rigid yet flexible material was needed that would hold the pneumatics in place while simultaneously allowing for expansion. Inspired by and experimenting with netting, we first came up with a kiragami technique - a paper-cutting technique that could be employed with rigid fabric to make it elastic yet retain tension, see Fig. 5. The first test pieces were laser-cut, but in the end the gesture of hand-cut kiragami turned out to define the most organic embodiment of awe, see Fig. 6. Vinyl fabric was chosen as it has a sturdy woven base to contain the inflatables and a slightly stretchable top layer to allow for outward expression as well.

The 3D-printed encasement design for the hardware of pumps and biosensors was inspired by the body's anatomy. The adrenal glands functions located in the kidneys and near sacrum inspired shapes and locations, see Fig. 7. As with the combination of biosensors, we were aiming to map the sympathetic nervous system that is controlled by the adrenal glands in the kidneys. The design itself became like a tangible external nervous system to showcase the inside.

Figure 3: Silicone inflatable goosebumps. First version required external encasement which lead to kiragami. ©Sensoree

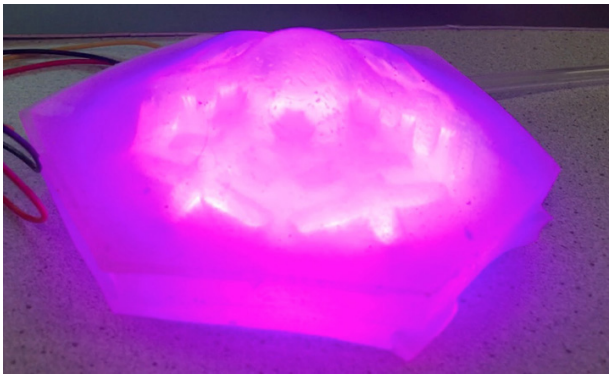

Figure 4: Silicone inflatables with LED lights to showcase biosignals. Pink is awe. ©Sensoree

For the body diagrams, the user group was given colors to express the types of piloerection. For frisson, most test users chose the color pink. From this information, we decided to use light illumination to act as a code to display internal biosignals that would peek through the kirigami cut outs for a dramatic effect. First, we showcased the baseline of breathing with blue to signify the oxygen level - dark blue for exhaling and light blue and green for inhaling. Second, we punctuated the excited state of awe with pink light and inflation to open the spaces of the kiragami.

3 THE BIOFEEDBACK LOOP

AWE Goosebumps is a biofeedback loop for the wearer. This loop consists of a combination of three components: a detection system (sensing), controlling system (think), and feedback system (actuation) [5]. It starts with the integrated biosensors that detect the skin conductance, breathing, and heart rate of the wearer, with the help of a small embedded microcontroller.

In practice it is a difficult task to detect the exact state of goosebumps ('piloerection'). Attempts have been made with sensors detecting the physical deformation of the skin [7] - however, a reliable way of detecting the moment of 'awe' indirectly by biosignals has not been established yet. The work by Seery et al. shows some results by aligning the sensation of 'awe' using biopsychosocial model of challenge and threat, incorporating cardiovascular measurements [8, 12].

The current hardware setup consists of a central controller (embedded microcontroller board, Arduino Nano) which connects the biosensing device input to an amplifier stage which controls pumps, valves and lights.

For sensing, first we created a Galvanic Skin Response (GSR) sensor, and later added a Bitalino biosensing microcontroller and electrocardiogram (EKG) components on a chest strap with a breathing stretch sensor were used to monitor biosignals from the wearer. With this combination of biosensors primarily a level of arousal can be detected - a divergence from a baseline level - the ultimate goal is eventually to map the internal physiological sensations of frisson before it occurred on the surface of the skin [11].

For actuation, three small pumps are used which are usually used to operate the inflating cuffs of blood pressure sensors. Miniature valves are added to control the airflow into the pockets, making it possible to control the pressure (level of inflation) and the rate of inflation. The deflation rate is fixed (by tube diameter and maximum valve throughput).

In the current design 3 groups of pockets can be inflated simultaneously and can be controlled separately.

RGB LED lights have been added to each individual pocket and added further into the design, see figure 4. A number of pockets has been added without inflation capabilities, however they still act as diffusor for these RGB LEDs, adding to the overall 'flow' of the animations projected on the device. These LEDs are individually addressable (using a commonly used 'neopixel' protocol), so the color can be changed simultaneously with the inflation or deflation of an individual pocket. A color scheme has been designed (which will be explained later) to suit the emotional intention of the design.

A number of pre-defined sequences has been programmed into the embedded controller for testing and user evaluation purposes. Besides these fixed sequences, real-time control of the device is possible through a USB data link.

The hexagonal pockets have been produced with casted silicone (ecoflex) using a mold which is manufactured on a 3D printer (Ultimaker 2+ using standard PLA). The parametric design of the mold has been made in OpenSCAD, which allows generating a virtual endless number of designs by simply changing parameters such as size, wall thickness, etc. By doing a number of iterations changing the size and thicknesses, see for example an early version in figure 3, the

parameters leading to the best suited design were found. The shape, especially the inner 'snowflake' part, were found to be the most determining factors for an esthetically pleasing, but also useful haptic force generating pocket.

Based on a number of experiments with casual wearers we eventually came up with a simple process for determining the moment of actuation. During the startup of the garment a baseline is established by measuring a number of consequetive samples and taking an average value. This entails that during the startup phase the wearer has to be calm and relaxed - to get a 'neutral' reading. As soon as this baseline or threshold value is transgressed for a measure of time (typically in the range of seconds) a predefined animation of inflating (and deflating) pockets and corresponding lights will be played.

As we find that the garment does effectively initiate a biofeedback process once it starts to pump air into the inflatables and transforms the color of the LED strips in accordance with the biometric data - this biofeedback process can raise awe awareness in an outside in, prosthetic function. The wearers who tested the final design, responded with expressions joy and wonder on their faces, reporting the sensation of silicone inflatation on skin itself created awe and a tingly sensation.

In addition to the biofeedback loop, AWE Goosebumps has a performative character. Through colour changes and inflation, the design externalizes and visualizes internal physiological signals, giving direct feedback to wearers and their direct surroundings. Finally, a new feedback loop begins when the wearer physically responds to the behavior of the garment or to the reactions on this behavior within the environment. By creating a natural, calm, subtle and non-intrusive biofeedback loop that is linked to activities, posture or level of arousal, AWE Goosebumps can invite behavioral change. In this way, the system thus takes on the role of a second skin, a friendly flexible exoskeleton that has the potential to guide, coach and enhance excitement of the wearer.

4 EXTIMACY AND THE SECOND SKIN

Extimacy is a term that defines the phenomenon of externalized intimacy that occurs when intimate internal feelings are shown to the outside world [11]. By employing biosensors to read body systems, AWE Goosebumps translates physiological states into visible and tangible transformations in the garment. In a way, these tangible and real-time transformations give a voice to the internal body, offering biofeedback for the wearer as well as a tool for communication with others. This non-verbal communication tactic also offers emotion contagion [1, 9] as it is expressed to others. The goal for others in the vicinity of the wearer is to be inspired to feel and participate in the wonderment too.

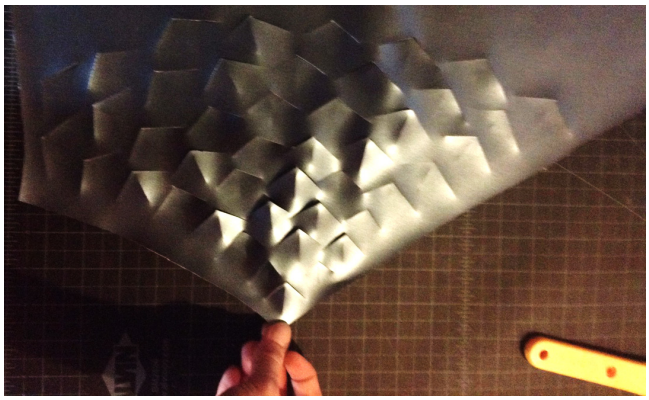

Figure 5: Hand cut kiragami on the grain of excitement. ©Sensoree

Figure 6: Silicone inflatables with kiragami encasement. ©Sensoree

AWE Goosebumps is inspired by the manner in which skin reacts to its environment. We used both human and animal skin as a source of inspiration for modeling the laser-cut material of the design, thus taking the notion of the second skin quite literally by mimicking and animating its material texture, look, and behavior.

The skin is the largest and heaviest organ that covers one seventh of the body and weight. Our skin not only acts as protection while filtering environment from germs, sun, but also as expression tool to show health and convey emotion with the elaborate full body nerve network. From a new materialist perspective, the duality between human and non-human is blurred, questioning where the garment begins, and the body ends [14].

After skin, clothes are the most intimate surface between our bodies and the world around us [15]. Wearing clothes comes so natural to us that they are generally experienced as an integral part of our embodied existence, hence the prevalent metaphor of clothing as a 'second skin' [2, 6, 13]. The animated goosebumps equip the wearer with a second and

'technological skin', through which she can sense and locate things beyond and in addition to the perceptual capacities of her 'first and fleshy' skin [6].

When the wearer of AWE Goosebumps experiences excitement, stress or anger, her heart rate, skin moisture, and temperature will increase, causing the dress to turn bright pink. Through interpreting the color pink as a sign of excitement, the wearer is consequently alerted to her own emotional state. This awareness may affect the wearer in multiple potential ways. It might cause her to calm down and her temperature and heart rate to drop to a normal level or, on the contrary, it might invite a practice towards a learned behavior as she tries to embody the feeling to allow the experience of awe more frequently. Another, more negative possible outcome could be for the wearer to feel ashamed of herself in front of others and hence even more stressed and anxious. The feedback loop we designed, however, was aimed to specifically train for positive effects of wonder.

Exposing the inner state of the wearer to the outside world, as well as visualizing how the wearer's body reacts to her environment, the garments "experiments relentlessly with ways of defining and redefining the boundaries between self and other, subject and object, inside and outside" [16]. The incorporation of technology affects the material ontology of garments, animating the very matter of fashion [14]. In allowing some of the material qualities of the human skin to flow into those of the garment, and vice versa, AWE Goosebumps presents an interesting analogy and permeability between the human and flesh and the external world. The notion of extimacy helps to understand how this design provides a biofeedback loop that increases bodily awareness among wearers while simultaneously allowing them to communicate intimate inner feelings to the external world.

5 EMBODIMENT WITH TECHNOLOGY

The AWE Goosebumps design expands beyond bio-mimicry and enters a new realm of bio-expose. In a circular fashion, the design inspiration came from the natural world, and with current technologies, exposes the vulnerability of humans to develop a closer relationship with themselves and others.

In the current trend, media is seen as a dissociative. A way to escape true states of being. The screen based culture is passive and acts like a setative to dull the sensory nervous system. Could these same tools that provide sensory deprivation be used conversely enhance, enliven, and embody ourselves?

"The medium is the message," stated by McLuhan [10], refers to the potency of the artifact independant of context. We often look at the contexts to define purpose, but the chosen material itself gives a statement. In the MainStream media of the time, McLuhan notes media as extentions of senses, but with consequences as it often dulls senses and while also with intentions to connect people it also isolates us, resulting in the Age of Anxiety. The interconnections of techonologis in turn rapidly propel us toward an analog Global Village. Where we become more intimate.

Figure 7: Inka Siefker is the circus performer who inspired the design. Elena Kulikova Photography ©Sensoree

In the current context of society's rapid elevation into state of information, The AWE Goosebumps artifact offers a new invention animating the latent sense of surprise and wonder and seeking to animate the intuitive self. Now, in this modern world, we ask how might we find our way back to our inate nature? Could these very same technologies that once were sensory deprivation tools, become tools to enhance our primal senses? Furthermore, might the subtle awakenings of the wonders of the world open a doorway to peaceful interactions with the self and others?

AWE Goosebumps was created in part from examining the past to speculate future scenerios for healthcare and wellbeing. Historically, an overarching inspiration was the technological metaphor of Godzilla impact on the collective psyche. One might ask, what is the connection between a subtle and intimate design like AWE and such a political and historical example of the destructive potential of technology? The media is the message of a larger global movement. On screen, Godzilla is recognized as a gigantic tormenting and destroying reptile that came from the sea. As a metaphor, Godzilla is known as the embodiment of the atomic bomb that was deployed in Japan in 1945. The Japanese called the beast Gojira, who was awoken and fed by nuclear bombs in World War 2. The sea might refer to the underlying subconscious thought of the 1950s who sought a story and a tangible entity to attach the horror of nuclear war between countries on a collective earth. Externalizing traumatic events and giving emotions a voice, albeit one that sometimes breaths fire, is a powerful tool in mental wellbeing.

Moving forward into the future, we question how we might embody ourselves with emotional armor comprised of tools from the current technological world. Placing the screen on our bodies, as a second skin, the AWE Goosebumps seeks to empower the unique human with an emotional armor. During current global socioeconomic and environmental affairs that might otherwise induce apathy and stagnation, we offer a wearable tool to maintain childlike amazement and wonder. Our animated emotive textile for frisson feedback and expression invites the wearer to feel more, become awe aware, and share the thrill. The wearer's vulnerability exposed in the second skin becomes a powerful asset to non-verbally communicate levels of excitement to connect.

6 CONCLUSIONS

Awe Goosebumps (Fig. 1, 7), a garment that aims to externalize and amplify feelings of goosebumps and awe. Inspired by human and animal skin, modern technologies are woven to be wearable. The bioresponsive fashion illuminates and inflates silicone contained by kiragami cut-outs to mimic physiology functions. This sensory extention is extimacy - animated intimacy - creates a thrill biofeedback loop for the wearer that is shared with the environment, bringing succinct emotions into the wild.

For future research, we suggest to investigate the more philosophical and social implications of wearing such 'technological skins' that aim to not only increase self-awareness, but that also invoke 'extimacy': inner states are exposed to the outside world, such that others are also more aware and excited by the positive emotion contagion.

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