The Galvactivator: A glove that senses and communicates skin conductivity

Rosalind W. Picard and Jocelyn Scheirer

MIT Media Laboratory
20 Ames Street, Cambridge, MA 02139-4307
{picard,rise}@media.mit.edu

ABSTRACT

The galvactivator is a glove-like wearable device that senses the wearer's skin conductivity and maps its values to a bright LED display, making the skin conductivity level visible. Increases in skin conductivity tend to be good indicators of physiological arousal --- causing the galvactivator display to glow brightly. The new form factor of this sensor frees the wearer from the traditional requirement of being tethered to a rack of equipment; thus, the device facilitates study of the skin conductivity response in everyday settings. We recently built and distributed over 1000 galvactivators to audience members at a daylong symposium. To explore the communication potential of this device, we collected and analyzed the aggregate brightness levels emitted by the devices using a video camera focused on the audience. We found that the brightness tended to be higher at the beginning of presentations and during interactive sessions, and lower during segments when a speaker spoke for long periods of time. We also collected anecdotes from participants about their interpersonal uses of the device. This paper describes the construction of the galvactivator, our experiments with the large audience, and several other potentially useful applications ranging from facilitation of conversation between two people, to new ways of aiding autistic children.

1 INTRODUCTION

The skin conductivity response, also known as the electrodermal response, is the phenomenon during which the skin momentarily becomes a better conductor of electricity when either external or internal stimuli occur that are physiologically arousing. Arousal is a broad term referring to overall activation, and is widely considered one of two main dimensions of an emotional response. Measuring arousal is therefore not the same as measuring emotion, but is an important component of it. Arousal is not only an indicator of emotional activation; it is also a strong predictor of two important aspects of cognition: attention and memory (Reeves and Nass, 1996). Highly arousing events tend to attract attention and be more memorable than low-arousing events. We are interested in devices that help people communicate emotional information as part of our work in affective computing (Picard, 1997).

Skin conductivity is not a new signal to study. The empirical study of electrical changes in human skin was described more than 100 years ago by Vigouroux (Vigouroux, 1879; Vigouroux, 1888) and by Fere (1988). Since that time, the skin conductivity response has been widely studied in psychophysiology research (e.g., Boucsein, 1992). Skin conductivity is one of many signals commonly included in lie detection tests. It is also often included in studies of cognitive workload and stress.

Skin conductivity is sensitive to many different stimuli; thus, it is often hard to determine what caused a particular skin conductivity response. Typically, events of a novel, significant, or intense nature trigger a sudden increase in skin conductivity. Arousal level tends to be low when a person is sleeping, and high in activated states such as rage or mental workload. When you engage in a mental workload task, such as solving a series of math problems (even if not particularly hard), the level will tend to climb rapidly and then gradually decline. In general, the commencement of a new engaging experience tends to cause the skin conductivity to respond with this characteristic behavior.

Because many different kinds of events can elevate skin conductivity (strong emotion, a startling event, pain, exercise, deep breathing, a demanding task, etc.) it is impossible for an outsider to tell what made your sensor glow unless several potentially confounding factors are controlled. For example, if you remain seated in a comfortable chair in an auditorium, where temperature and humidity are fairly constant, and where your physical activity level does not change, and wear the sensor in the way that it was designed to be worn, then changes in the illumination about your baseline are likely to be meaningful indicators of changes related to psychological arousal.

Much has been learned about emotional, cognitive and physical correlates of the skin conductivity response. However, most research has been conducted on subjects in an unfamiliar laboratory setting, wired to a rack of equipment, who are told to act natural. Our design of an inexpensive glove-like wearable sensor enables the sensing to take place with people who are going about their daily activities. The use of an LED to communicate the signal makes it easy for the wearer to see the signal – there is no need to use a keyboard or computer; the changing level can be easily interpreted by children or adults. The only limitations on the wearer's activity are that the glove is not designed to be used under water. The glove has successfully endured a trip through a washing machine, and worked fine once washed, but it is not designed to work while immersed. The galvactivator attempts, through its small size, inexpensive components, and wearability, to bring the sensing of skin conductivity out of the laboratory, and into a naturalistic setting that encourages people to play with the sensor and to learn more about their skin conductivity response.

Because the LED is very bright, and appears on the back of the hand, the device can also easily communicate the wearer's skin conductivity response to others. The wearer is free to hide this signal (by hiding the back of the hand, or by dialing the LED off) or to show it to others. We think it is important that the wearer maintain control over the communication of the signal, especially since the signal is one that is not usually communicated to others in an ongoing way. We describe below an experiment where a large audience was given the opportunity to communicate this signal to the performers on stage, as well as to other individuals through more personal interactions.

2 APPARATUS

The galvactivator hardware consists of a small printed circuit board with analog circuitry that amplifies the skin conductivity signal, and maps it to a super-bright LED (LRI, Inc.). The electrodes are standard nickel-plated clothing snaps. The circuit is powered by two 3V-lithium ion batteries. The board and electrodes are embedded in a neoprene glove that slips over the hand and is secured with a velcro strap. The board can be easily pulled out to replace the batteries if needed. The back of the glove allows access to a thumb-wheel potentiometer (for setting individual baselines), and houses a star-shaped PVC window which serves to help diffuse the directional beam of the LED. Adjacent to the thumb-wheel is a small jack where the actual signal can be read out and recorded by a computer if desired; however, we designed the glove primarily to be worn without attachment to any other devices.

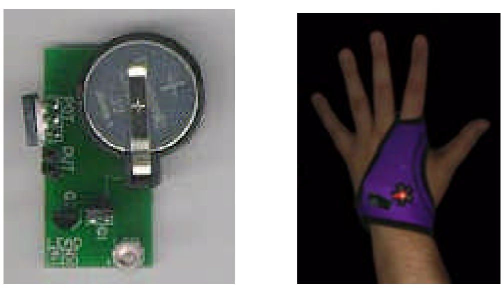

Figure 1: Galvactivator circuit board, Galvactivator on a hand.

The glove form-factor was designed to maximize comfort and minimize motion artifacts with a snug fit. To this end, the placement of electrodes differs slightly from traditional placement options (see Figure 2), but the signal from the galvactivator correlates with a traditional skin conductivity sensor at $p < .001$. Because of time and budget limitations, we designed the galvactivator as a one-size-fits-all device to be worn on the left hand. Consequently, some individuals required small modifications in order for it to fit correctly (i.e., small slits made in the finger hole for larger hands).

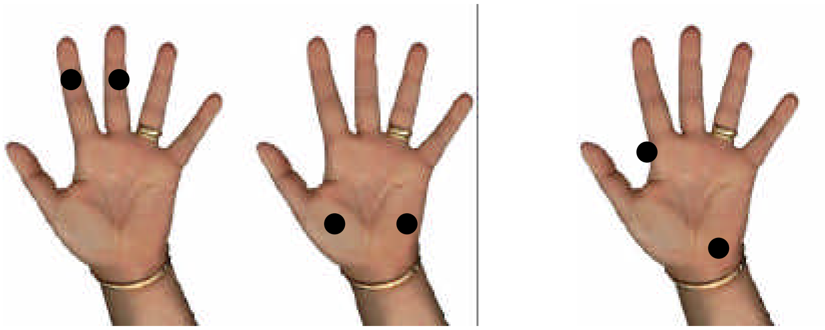

Figure 2: Traditional Placements (left, middle) and our placement (right).

Once the subject has set his proper baseline (established by resting for 5 minutes, then dialing the wheel until the light is dim), the signal is mapped linearly to the brightness of the LED. The display is sensitive enough to display both tonic (low frequency or long-term) and phasic (high frequency or short-term) components of the skin conductivity signal. However, reading the brightness of an LED is not as accurate as reading a numerical value output on a graph. The device was not designed for scientific recording and analysis of detailed changes in skin conductivity, but was designed to make it easy for the wearer and for those he communicates with, to easily see the patterns of change.

3 LARGE AUDIENCE USE OF THE GALVACTIVATOR

We conducted a large-scale test of the device, distributing 1200 galvactivators to attendees at the SENS*BLES symposium at MIT in October 1999. Audience members received their galvactivators mid-morning. They were given a short demonstration of how to properly put on the device. Then they were led through five minutes of a shared experience while wearing the device (described below) and were free to wear (or not wear) the device the rest of the day and take it home with them afterward, to keep.

Figure 3 illustrates the aggregate brightness output recorded from a section of a couple hundred people in the audience before, during, and after the shared experience. The graph shows the overall brightness of the video signal as measured by a camera positioned in the upper left of the auditorium. The auditorium was held to a constant darkness level so that the primary changes in brightness would be due to the collective galvactivator LED's. In Figure 3, we first see a calibration step where the audience was asked to hold their left hands so that the camera could see the LED, in order for us to obtain an estimate of the maximum brightness value that could be obtained (the devices were set to maximum brightness initially.) Then the audience was asked to turn their LED's away from the camera's view, to obtain an estimate of minimum brightness. Afterward, the audience was told about what would happen next (which elicited laughter as well as a heightened sense of expectation.) Then they were told to get out a balloon that had been given to them earlier, and they were led into a 30-second relaxation period, followed by instructions to dial the thumb-wheel so that their light was dim. (In theory, the wearer should rest at least five minutes before dialing the light dim; however, given time restrictions and the difficulty of anyone relaxing in the presence of 1200 people when they know they are part of a live experiment, we decided that 30 seconds was going to be acceptable.) Next, they were instructed to blow up their balloon to popping. The deep breathing combined with the hundreds of loud noise bursts and anticipation of their own balloon bursting, brought most people to their individual maximum value. (In Figure 3, this peak is somewhat less than the peak of everyone pointing the device, dialed to maximum brightness, directly at the camera, since not everyone's LED would be perfectly visible to the camera; however the peak is substantially higher than the preceding valley, where everyone set their baseline after the brief rest period. Episodes of clapping tended to raise the hands, pointing more LED's directly toward the camera, increasing the brightness the camera detected.

Continuous video of the audience was collected throughout the day, as well as video of the stage. Analysis of the videotapes shows significant areas of high and low brightness as correlated with stage events. The brightness levels of the video do not perfectly reflect the output of the galvactivators; for example, someone might hide his signal so that only he could see it, and in some cases there were camera flashes, despite that we prohibited photographers from using flashes while we were recording. Nonetheless, the brightness values that were measured appeared to be meaningful. In general, we found that with the arrival of a new speaker or performer on stage, that brightness increased (with audience anticipation as well as with their clapping.) Elicitation of laughter and of questions from the audience also tended to make the brightness increase. Live demonstrations also led to brighter values than did segments where a speaker just spoke with PowerPoint slides. These are all reasonable reactions, given what is known about skin conductivity and psychological arousal.

As well as acting as a device for mass communication, the galvactivator can be used to learn about one's own bodily responses in a myriad of situations–interacting with a computer, reading a book, engaging in conversation with others, and so forth. We collected many anecdotes from symposium participants, for example:

- *"It made me more aware of how I was feeling"*
- *"I noticed that the galvactivator lights up every time I laugh…"*
- *"We had a series of brainstorms the following day, and whenever an idea was sparked, before it was voiced, the device glowed."*
- *"It was a bit disheartening to see the audience go dim as I talked to them."*

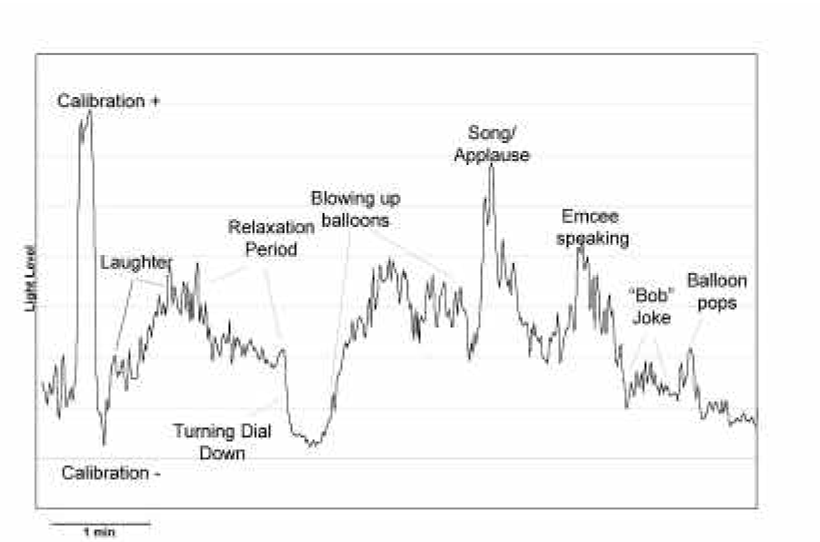

Figure 3: Brightness level of sensors from a segment of the audience.

Several people were observed having fun trying to make each other light up. Because feeling self-conscious or embarrassed can also raise skin conductivity, the device often led to conversations which included admissions of such feelings. Because the skin conductivity response is not usually visible to others, it raises many questions regarding the psychology of communicating this signal, and what impact this can have on inter-personal relationships. These issues are being explored in ongoing research with teens and their peers and parents.

4 POSSIBLE APPLICATIONS

A comfortable wearable skin-conductivity sensor has many potential applications. In addition to the mass-audience communication described above, one can imagine stadiums full of sports fans lighting up in the color of their team when the game gets exciting. One can also imagine its use among smaller audiences. One case we have explored is use in classrooms. Tenth and eleventh grade classes were given galvactivators to wear. After setting proper baselines, the students wore the gloves during ordinary classroom activity. The brightness was observed to be very low when they were instructed to engage in their regular reading task. It increased when the students were asked to write about something that interested them in their journals. A few students commented that wearing the device all day helped them gain insight into their personal learning style, including which types of activity engaged them best.

For communication purposes, the device affords new opportunities in nonverbal expression; there is anecdotal evidence that the galvactivator can change the course of person-to-person conversation. One student, who was wearing the device when she got in a fight with her parents, reported that after her mother saw the device glow, she asked the daughter about it, and they were then able to communicate more openly about the daughter's feelings.

We have also employed the skin conductivity signal as one of several signals used by a computer in trying to discern the affective state of the user. Skin conductivity tends to increase with anger and frustration; together with other signals from the user, it can be analyzed by the computer to try to infer how the interaction is proceeding (Scheirer et al.; Picard et al.).

Certain groups of people display characteristic skin conductivity patterns. For example, autistic children's skin conductivity tends to fluctuate between dramatic highs and lows, consistent with the difficulty these children experience in self-regulation, affecting their attentiveness and ability to interact with other people and things. A wearable skin conductivity sensor, coupled with a "squeeze vest" appears to be able to help the child, based on the principle that touching and squeezing a child from the sides tends to calm the child and bring their skin conductivity back into a normal range (work of Carlos Elguero of Univ. Mass, Amherst.)

Skin conductivity also tends to increase with pain and with stress, suggesting other potential therapeutic uses of the device where it might assist patients in helping manage these conditions. In particular, for patients who are nonverbal, changes in the LED brightness might help communicate to loved ones and to caregivers an aspect of what the wearer is feeling. Seeing a non-verbal friend "light up" when they recognize you can be very gratifying if they have no other means of acknowledging your presence.

5 CONCLUSIONS

The galvactivator is a new wearable device that senses the skin conductivity response – a correlate of physiological arousal – and makes the signal visible through a glowing LED. It takes a signal that has traditionally been studied in stringent laboratory settings and makes it available for study in naturalistic, real world environments. New modes of communication with the device have been demonstrated in both large audience settings and in smaller interpersonal communications. Collaborations using the device are currently being explored with educators, clinicians, and industry.

For more details about how the device is constructed, and for a list of frequently asked questions about skin conductivity, there is more information online at http://www.media.mit.edu/galvactivator.

ACKNOWLEDGMENTS

We would like to thank Nancy Tilbury and Jonny Farringdon of Philips Design & Research for their assistance with the design of the glove. Their aids in the UK included: Kelly Barrett, Philippa Wagner and Andrew Moore at Philips, Tirath Dillon and Nav Dillon at ACE Sportswear, Richard Extell and Kevin Niblett at GS and John McLeod at Micro Thermal Systems. Several colleagues at the MIT Media Lab gave valuable help during various stages of circuit design, prototype design and production of 1500 gloves: Dana Kirsch, Dan Overholt, Ted Selker, Joe Paradiso, Carson Reynolds, Matt Norwood, Henry Wu, Blake Brasher, Pamela Mukerji, Martin Howard, Joey Richards, Josh Strickon, and Eric Scheirer. We also thank George Northover and Scott Cohen at Accutek and David Allen at LRI.

REFERENCES

Boucsein, W. (1992). *Electrodermal Activity*, Plenum Press, New York.

Fere, C. (1988). Note on changes in electrical resistance under the effect of sensory stimulation and emotion. *Comptes Rendus des Seances de la Societe de Biologie* (Series 9), 5, 217-219.

Picard, R. W. (1997). *Affective Computing*, MIT Press, Cambridge, MA.

Picard, R. W., Vyzas, E. and Healey, J. (to appear) Toward Machine Emotional Intelligence: Analysis of Affective Physiological State. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

Reeves, B. & Nass, C. (1996). *The media equation : how people treat computers, television, and new media like real people and places*. Cambridge University Press, New York.

Scheirer, J., Fernandez, R., Klein, J., and Picard, R. W. (to appear). Frustrating the User on Purpose: A Step toward Building an Affective Computer. *Interacting with Computers*.

Vigouroux, R. (1879). Sur le role de la resistance electrique des tissues dans le'electrodiagnostic. *Comptes Rendus Societe de Biologie* (Series 6), 31, 336-339.

Vigouroux, R. (1888). The electrical resistance considered as a clinical sign. *Progres Medicale*, 3, 87-89.