

MEASURING EMOTION: REACTIONS TO MEDIA

SHIMMER, DUBLIN, IRELAND

INTRODUCTION

At Shimmer, we have the privilege of counting some of the world's largest market research companies among our clients and partner organisations, providing us with a unique opportunity to learn, together with those organisations, about how we can interpret biophysical data to gain insights into the emotions of their target audiences. Shimmer platform users and collaborators also include world-class academic researchers, investigating novel ways of analysing physiological data to develop new metrics and techniques that will impact on health and wellness. The goal for many of these groups is the same - to quantify emotion.

There are two primary categories of emotion - conscious and unconscious. Conscious emotions involve some cognitive processes in eliciting the emotional response, whilst unconscious emotions are dominated by the autonomic processes of the nervous system [1], [2]. Traditional tools, like surveys and questionnaires, can give useful insights into an individual's state of mind and their emotional response to certain stimuli with which they are presented, but the data obtained from these tools are subject to memory bias, societal influences, and various other factors [2]. Furthermore, an individual may only recall their conscious emotional response and relate it to stimuli to which they are aware they have been exposed. Reactions to subtle stimuli, such as a gradual build-up of stress in a challenging situation, may be impossible to quantify using traditional methods alone.

In recent years, the measurement of emotions has been transformed by the availability of wearable devices that can measure physiological signals and provide insights far beyond the noisy information obtained from surveys, questionnaires and other sources of subjective data. It is well known that emotions regulate the autonomic nervous system, which, in turn, causes variations in the secretion of sweat on the skin's surface, as well as changes in the heart rate and respiration rate [3]–[5]. These changes, often imperceptible to the individual experiencing them, can be unobtrusively measured by miniature wireless sensing devices, providing a continuum of data, which can be interpreted to provide invaluable insights into the individual's level of engagement and arousal, in response to all stimuli, both the perceived and the unnoticed.

There are two primary areas in which such technology is being applied: the first is healthcare and health research, with uses in the fields of autism [6]–[8], epilepsy [9], dementia [10], sleep [11], and anxiety disorders [12], [13], to name but a few; the other is the emerging and rapidly growing field of neuroscience in media and marketing, including film and media production [14], user interface and experience (UI/UX) design [15], advertising [2], product development [16], packaging design [16], [17], and many others besides. Shimmer's biophysical sensing technology is being used across a wide range of these application areas, for example [13], [18], [19].

This article focuses on emotional responses to media and aims to provide a brief introduction into two of the most important metrics for measuring emotion - skin conductance and heart rate - and how these metrics can be measured using Shimmer technology. A case study is included, outlining an experiment carried out by Shimmer, during which data was collected from a large group of adults while watching a series of short films. Preliminary analysis of the data is described, highlighting some of the similarities and differences between individuals' emotional responses and the metrics used to measure them. A more detailed analysis of the data is the subject of ongoing work.

EMOTIONAL METRICS

GALVANIC SKIN RESPONSE

Galvanic skin response (GSR), also known as skin conductance or electrodermal activity (EDA), is a measure of the conductance of a very small electrical current applied to the skin, which indicates the level of sweating at the skin's surface. Emotional arousal induces a sweat reaction, which is particularly prevalent at the palmar surface of the hands and fingers and the soles of the feet, due to the large concentration of eccrine sweat glands at those body locations [20].

The GSR signal is composed of two main components: a slowly varying tonic or baseline level, known as skin conductance level (SCL) and a phasic component, known as skin conductance responses (SCRs), which include reactions to specific eliciting stimuli and non-specific skin conductance responses (NS-SCRs). NS-SCRs are SCRs that are not related to any eliciting stimulus and occur spontaneously in the body at a typical rate of 1-3 per minute [20]. SCRs are of interest in emotional quantification, as they provide a measure of the level of arousal and engagement of an individual, in response to stimuli in their environment. Individual SCRs are often characterised by metrics such as their latency, amplitude, rise time and recovery time, and the

interpretation of these metrics to provide insights into emotional state is a very active area of research. A good review of literature regarding how various metrics, including GSR metrics, are related to emotions can be found in [5].

Differences in the general GSR traits of individuals have also been studied in the past, and two groups defined: "electrodermal labiles" - those who exhibit high incidence of NS-SCR and/or slow skin conductance response (SCR) slope in response to stimuli - and "electrodermal stabiles" - those who exhibit a low rate of NS-SCR and/or fast SCR slope [20]. Separating NS-SCRs from elicited SCR is a challenge, in practice, especially when measuring data in unsupervised settings, such as continuous monitoring throughout daily life, where details of what types of stimuli were encountered by the subject and when those stimuli occurred are not available.

GSR signals are best measured from the palmar surface of the fingers or hands, although other body locations are sometimes used [21]. Typical SCL values vary from $2\mu\text{S}$ to $20\mu\text{S}$ ($50\text{k}\Omega$ to $500\text{k}\Omega$ resistance) [20]. GSR can be measured using the Shimmer3 GSR+ module, which is designed to resolve SCLs from $0.2\mu\text{S}$ to $100\mu\text{S}$ ($10\text{k}\Omega$ to $4.7\text{M}\Omega$), with an auto-ranging feature that selects the most appropriate signal path in hardware, to match the range and resolution of the device with the skin conductance value in real time.

HEART RATE

The rate and strength at which the heart pumps blood around our bodies is controlled by various mechanisms, among them, autonomic and hormonal influences [22]. The mechanism of interest for measurement of emotion is the control of the cardiovascular system by the autonomic nervous system (ANS). The heart rate (HR) and heart rate variability (HRV) are influenced by both the sympathetic and parasympathetic parts of the ANS; an increase in activity of the sympathetic nervous system leads to an increase in HR, whilst an increase in parasympathetic activity causes a decrease in HR [4]. The influence of the parasympathetic branch is greater than that of the sympathetic branch on HR [22]. The parasympathetic branch tends to cause HR activity across the entire frequency spectrum, whilst sympathetic nervous system regulation tends to be detected in the low frequency spectrum, below 0.15 Hz [4].

Even though the autonomic nervous system and, hence, emotional state, has a significant impact on HR and HRV, the cardiovascular system is also influenced by other factors, such as metabolism and activity level, and, as such, it is more difficult to detect emotional state from HR and HRV metrics than from skin conductance. However, there are published works which indicate the HR and HRV may be useful for measuring the valence of emotion; i.e. whether it is a positive emotion, like joy, or a negative emotion like sadness or fear [23]–[25]. Negative emotions have been reported to have a stronger influence on HR and HRV than positive or neutral emotions [26]. A useful review of some of the recent work in the field can be found in [5].

There are a number of ways to measure HR and HRV, most commonly electrocardiography (ECG) and photoplethysmography (PPG). Both signals can be measured with Shimmer3 sensors. ECG measures the electrical activity of the heart, which allows distinctive features of individual heart beats to be detected using common signal processing techniques. PPG involves the measurement of blood volume in the blood vessels just below the skin's surface using light transmitters and receptors. Again, common signal processing techniques can be used to detect individual heart beats. The ECG signal produces a more accurate measure of heart period, HR and HRV, due to the high resolution of the signal, compared to the PPG signal, which consists of lower frequency and, hence, lower resolution features. This makes the ECG more appropriate for clinical applications in which high accuracy is of critical importance. However, because the measurement of ECG requires the placement of electrodes on the subject's body (e.g. on the chest), the PPG signal, measured from the earlobe via the Shimmer Optical Pulse Ear Clip, was used to capture HR in this study as it is much less intrusive and more comfortable for the experimental participants and a clinical level of accuracy was not required.

GROUP QUANTIFICATION

In March, 2015, Shimmer teamed up with the Science Gallery at Trinity College Dublin to gather emotional response data from a group of one hundred adults during the screening of a series of short films. The films were chosen by the team at the Science Gallery to contain a variety of themes, in order to elicit different types of reactions from the audience. More details about the chosen films and ethics approval for the experiment can be found in the Appendix at the end of this document.

DATA COLLECTION SETUP

Each participant was given a Shimmer3 GSR+ device on arrival, which was worn around the wrist of their choice. GSR electrodes were attached to the palmar surface of the index and middle fingers of the chosen hand and a Shimmer Optical Pulse Ear Clip

was attached to the ear-lobe on the same side. GSR and PPG data was logged to the SD card on-board the Shimmer and logging was started for each subject upon entering the theatre.

All Shimmer devices were synchronised with the real time clock from a Windows PC via Consensys software [27]. This allowed the logged data to be easily annotated with the start and end times of each film, which were recorded by a mediator during the event. The screening of the first film started approximately 25 minutes after the first subjects entered the theatre and the total duration of the screenings was approximately 53 minutes. The duration of the films varied between 71 seconds and 19 minutes. There was a brief intermission of varying duration between each pair of consecutive films, during which pre-recorded introductions by some of the films' directors were screened.

It is important to note that no additional information was gathered from subjects, via questionnaires or other methods, to measure their self-reported responses to the media. As such, the focus of this work is on the sensed data only; i.e. the skin conductance and heart rate, and how those data compare and contrast among subjects and for different films. No effort has been made to look for connections between the sensed data and self-reported emotional state (arousal and valence).

DATA PROCESSING

Because the absolute value of skin conductance is affected by many subject-dependent and environmental factors, such as skin dryness and temperature, among others, the skin conductance was normalised for each participant, using the max and min values measured throughout the 53 minutes of the event, resulting in a normalised range of 0 to 1 throughout the recording for display purposes. Prior to normalisation, the skin conductance was filtered by a low pass filter with a corner frequency of 5Hz to eliminate high frequency noise, such as mains interference and motion artefact.

The recorded PPG signal was converted to HR estimate, using an algorithm developed at Shimmer, which is based on a combination of peak detection and probabilistic decision rules to eliminate the effects of false peaks or missed beats. Instantaneous heart rate estimates are reported for each detected heart beat, with no averaging. Heart rate was found to vary between approximately 50 and 120 bpm for most subjects. The variability of heart rate is considered more interesting in this study than the absolute value of the resting heart rate.

OUTCOMES

Data recorded from various participants will be displayed in this section, with some observations about the differences and similarities among individuals, as well as the differences and similarities between the HR and GSR for an individual.

SKIN CONDUCTANCE

The GSR data for a number of subjects is illustrated in Figure 1, which shows the measured skin conductance and estimated heart rate for four of the participants throughout the entire duration of the film screening. Start and end times are indicated for each film.

Some of the subjects were observed to have a slowly varying GSR, in general, and large amplitude peaks occurring at various instants, indicating responses to stimuli, whilst other subjects had a rapidly changing skin conductance with significant phasic activity throughout the entire data collection. The former subjects appear to belong to the category of electrodermal stabiles, whilst the latter subjects appear to display electrodermal lability. Because this experiment did not include the collection of GSR data from subjects in rest conditions (i.e. in the absence of any stimuli), a formal quantification of NS-SCRs is not possible from the dataset. However, visually inspecting the data in Figure 1, it is easy to differentiate the two groups, with two of the subjects whose data is displayed (Subjects #002 and #040) show a low rate of NS-SCR, whilst the other two subjects (Subjects #012 and #037) showing a high rate of NS-SCRs. Elicited SCRs at specific instants during the recording are very easy to visually identify in those with low NS-SCR rate but more difficult in those with a high NS-SCR rate.

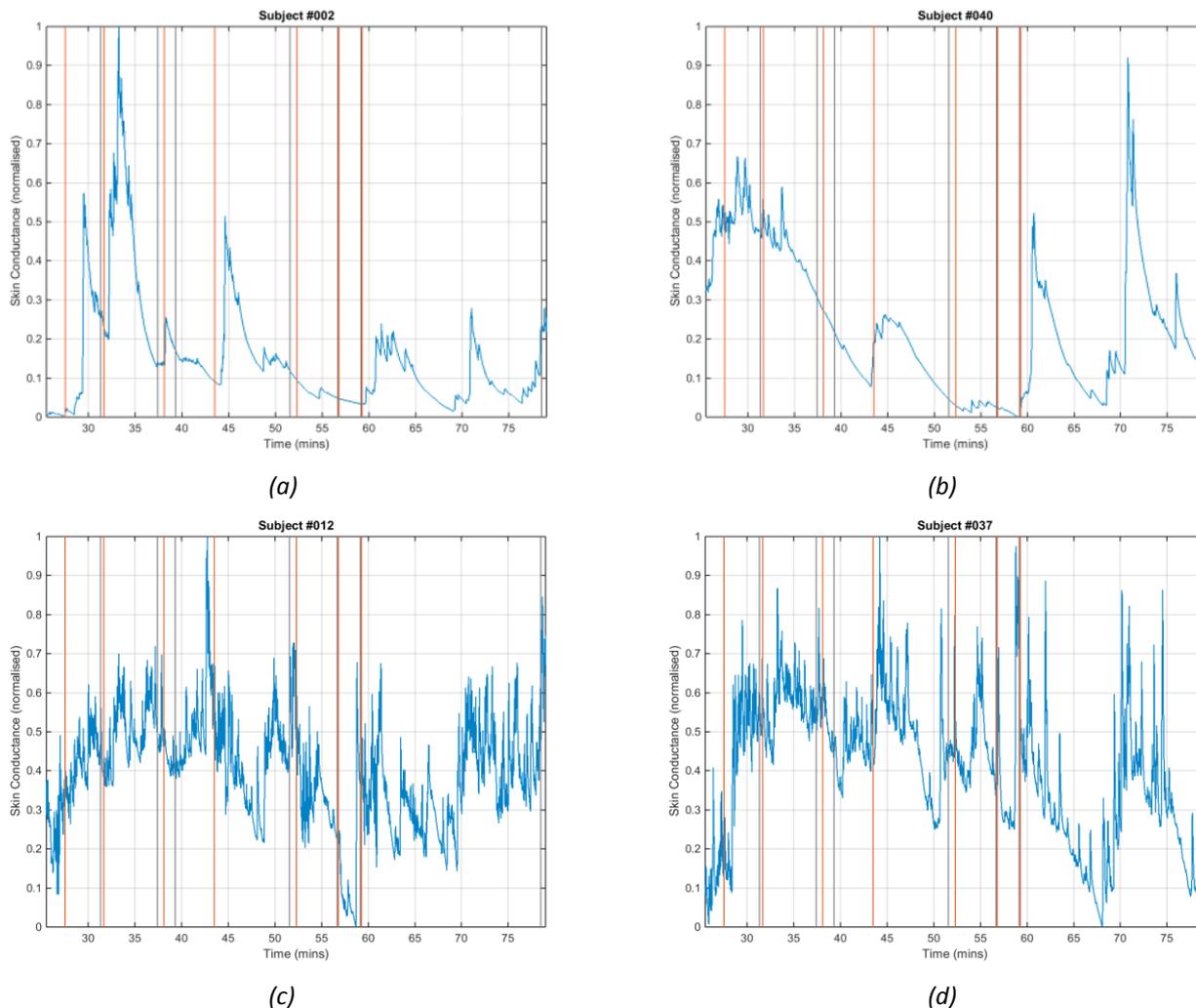


Figure 1 Skin Conductance from a subset of subjects. Vertical lines indicate start (orange) and end (grey) times of films. Electrodermal stables: Subjects #002 (a) and #040 (b) had a low rate of NS-SCRs, in general, with significant peaks in response to stimuli. Electrodermal labiles: Subjects #012 (c) and #037 (d) had a rapidly varying skin conductance signal, in general, with frequent NS-SCRs.

Figure 2 shows a histogram of the mean number of SCRs per minute for all subjects during all films. The range is (0.51, 8.97) SCRs per min, which is significantly higher than the typical rate of NS-SCRs (1-3 per min) reported in [20]. This suggests that specific SCRs measured have been elicited in response to the content of the films.

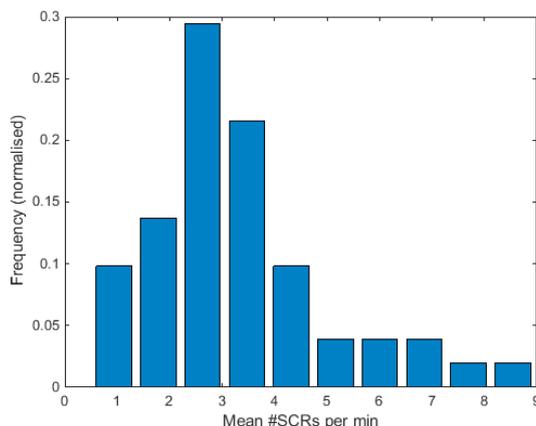


Figure 2 Histogram of mean number of SCRs per minute for all subjects during all films.

Certain instants at which a skin conductance reaction was provoked simultaneously in all (or most) subjects can easily be visually identified; for example, at approximately 32 minutes; 59 minutes and 71 minutes, referring to the timescale (x-axis) in Figure 1. It is likely that these instants relate to events in the films that induced a common reaction in most audience members. The

amplitude of the response varies among individual subjects, indicating both physiological differences and variation in how much each individual was emotionally aroused and engaged by the content. The number of SCRs evoked during each film will be explored in more detail in the *Comparison of Responses to Different Films* section, below.

HEART RATE

Figure 3 shows heart rate estimates for four of the subjects in the experiment. The heart rate for these subjects is plotted with a scale of 40 to 120 BPM for ease of visual comparison. In general, heart rate is always subject to some variability, due to regulation by both the sympathetic and parasympathetic nervous systems, as well as other mechanisms. For this reason (because heart rate is modulated by more than just emotions), the effect of emotional response on heart rate is less apparent than the effect on skin conductance, when visually examining the heart rate data over the entire duration of the event.

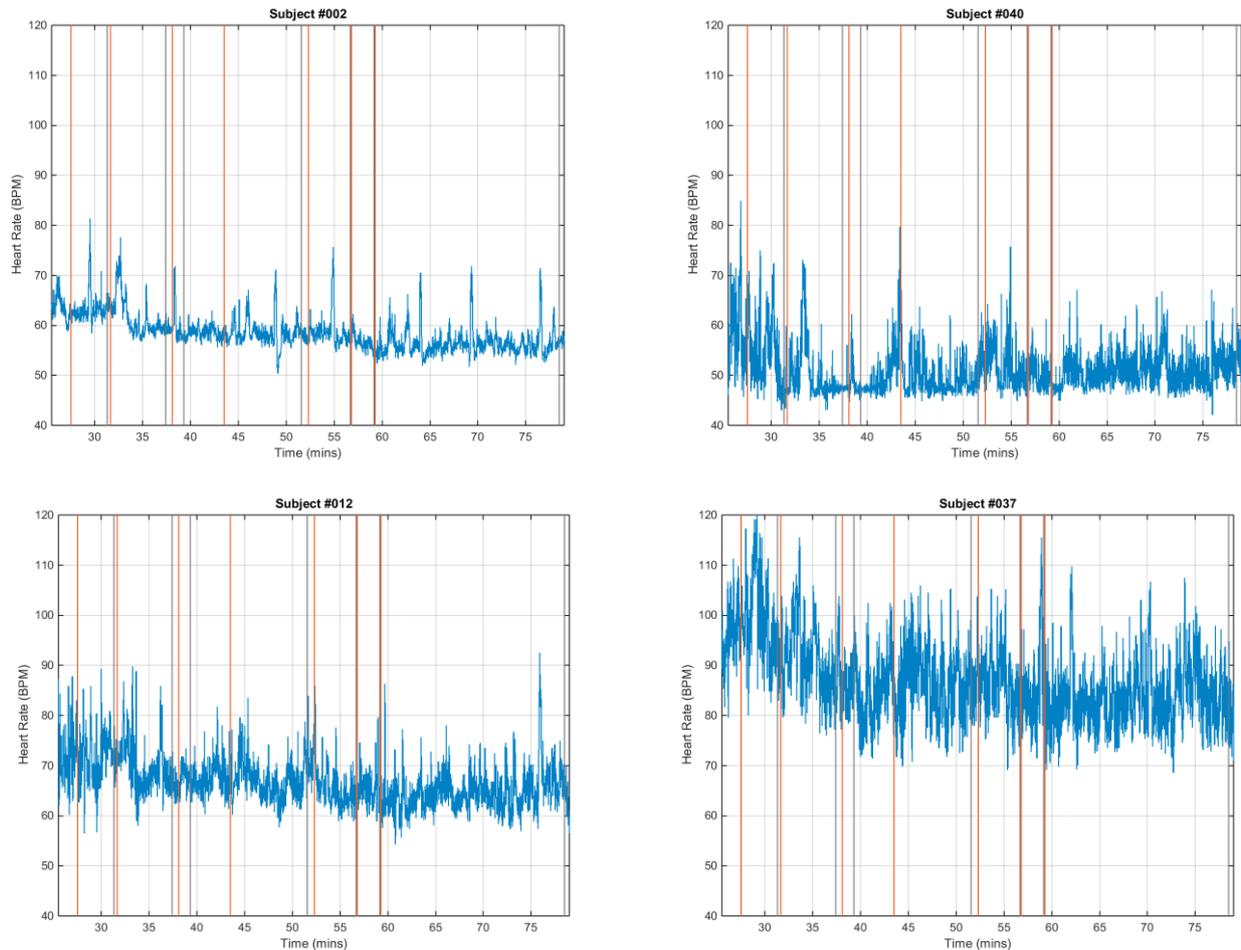


Figure 3 Heart rate from a subset of subjects. Vertical lines indicate start (orange) and end (grey) times of films. The subjects whose heart rate data are displayed are the same subjects whose skin conductance data were displayed previously.

In order to gain a deeper insight into heart rate activity during the experiment, the heart rate signal for each subject was heavily filtered to retain only very low frequency components. Following filtering, the signal was processed with an algorithm to detect peaks in the heart rate, i.e. instances where the low frequency component of the heart rate increased and subsequently decreased. Only peaks which exceeded a specified threshold were considered. The number of peaks was found to be highly variable among subjects in this experiment and no significant insight into the emotional activity was found, in general. Other metrics of heart rate variability were also investigated but found not to provide insight in this study.

JOINT ANALYSIS OF SKIN CONDUCTANCE AND HEART RATE

Figure 4 shows the skin conductance and heart rate for two subjects, Subject #002 and Subject #037. For Subject #002, there are visible instances of a sudden increase in heart rate, followed by a quick decrease, returning the heart rate to its baseline value. Because the variability of the heart rate for this subject is, in general, relatively low, these short instances of increased heart rate are clearly visible. Examining the signal at a higher resolution, as shown by zooming in on a short section of the plot, it can be seen that these instances of a sudden and short-lived increase in heart rate coincide with significant responses in the GSR signal,

suggesting that the variation in heart rate is caused by the same stimulus as the GSR reaction. Examples of this effect are evident at approximately 27 mins, 30 mins and 31 mins in Figure 4 (c).

For Subject #0037, the heart rate estimate displays more variability than that for Subject #002, in general, and, examining the entire duration of the recording at a low resolution, it is not easy to visibly identify instances of a sudden increase or decrease in heart rate. However, examining the signal at a higher resolution, as in the previous case, shows that there is, once again, a coincidence of sudden, short-lived increase in heart rate and GSR response at certain instants, for example, at approximately 59.6 minutes in Figure 4 (d).

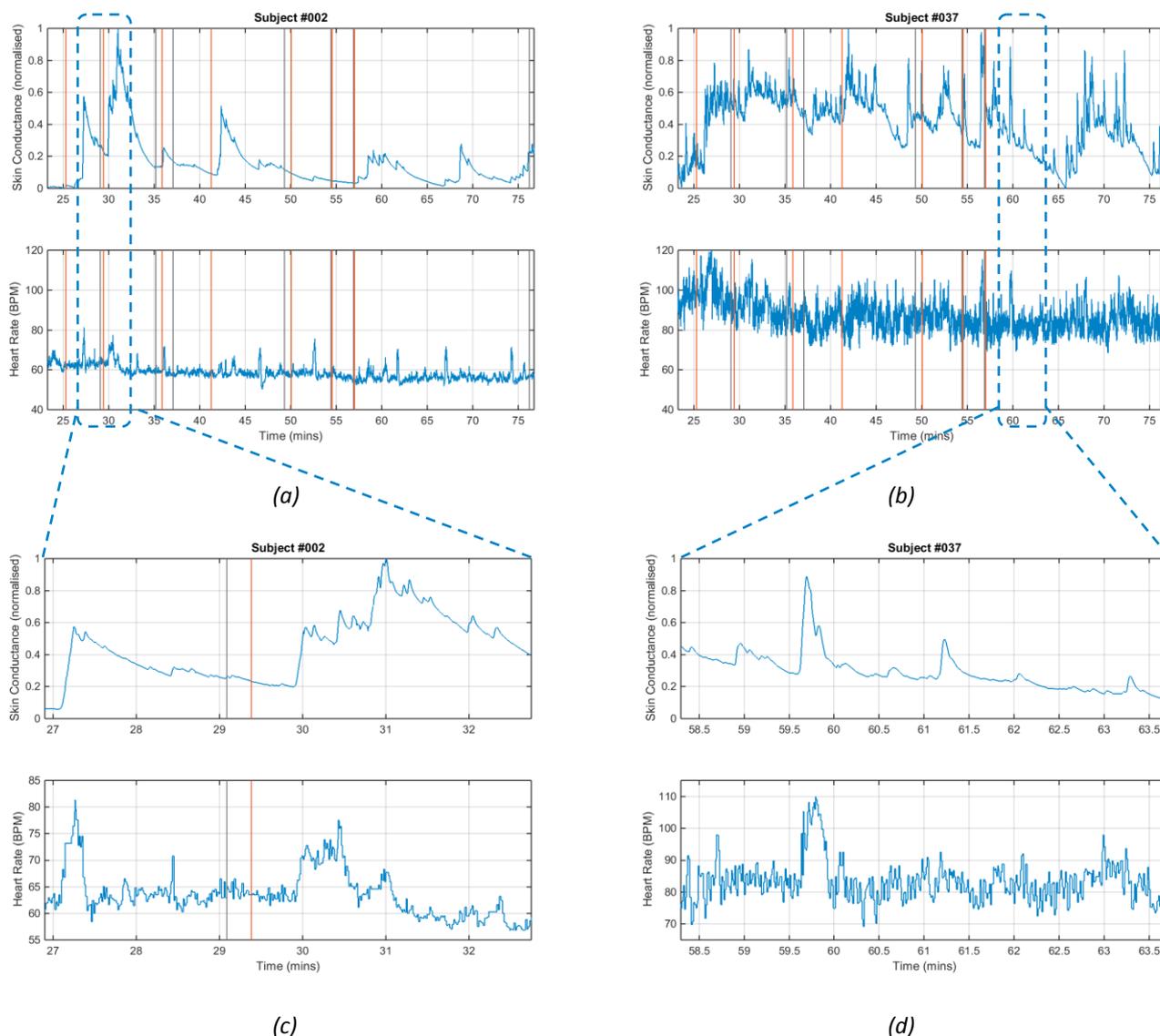


Figure 4 Skin Conductance (upper plot) and Heart Rate (lower plot) from Subject #002 (a), (c) and Subject #0037 (b), (d). Vertical lines indicate start (orange) and end (grey) times of films. Data are displayed for the entire duration of the recording (a), (b) and zoomed in around a short period during which there are visible responses (c), (d).

A more controlled experiment, in which the valence of emotions and/or of the stimuli is recorded, is required to further investigate the relationship between GSR and HR and, specifically, to determine if the combination of HR and HRV with GSR data can assist with the detection of valence of emotion.

COMPARISON OF RESPONSES TO DIFFERENT FILMS

GSR and HR data, recorded from Subject #002 throughout the entire event, is illustrated in Figure 5. The total number of SCRs detected during each film, along with the number of SCRs per minute for each film are listed in Table 1. From the skin conductance and SCR data, it appears that Film #2 elicited the highest rate of SCRs in this subject. Conversely, Film #6 appears to have elicited no emotional response from the subject, whilst during Film #5 there appears to be only a single response (at about the half way point). This visual analysis suggests that Films #5 and #6 were not very engaging for Subject #002, whilst the

content of the other films, in particular, Film #2, were more engaging and evoked emotional activity in the participant. Correlation was not found, in general, between the number of heart rate peaks and SCRs.

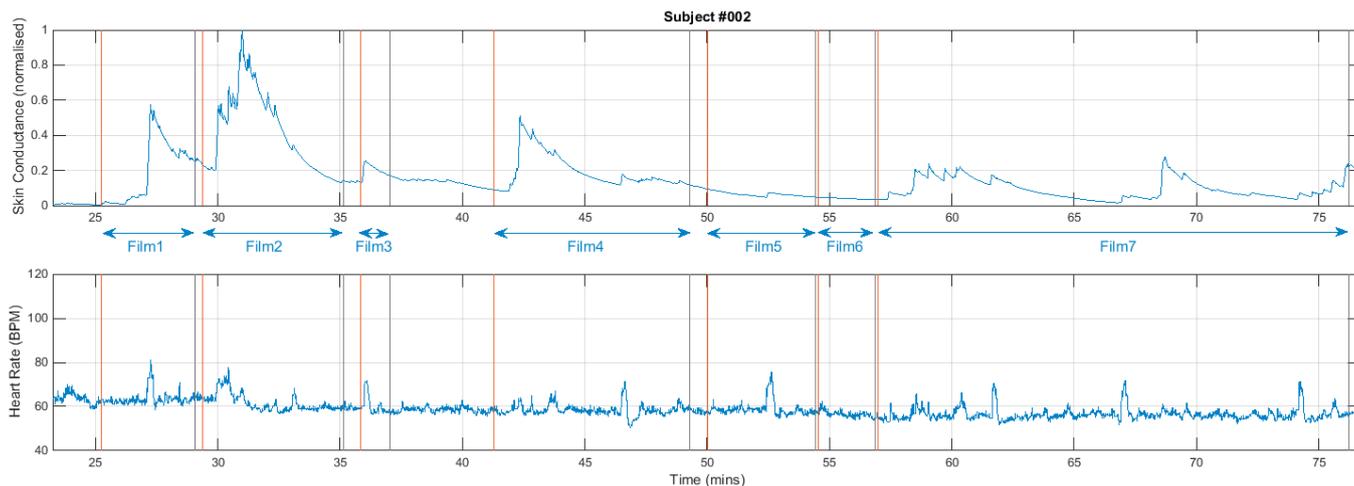


Figure 5 GSR and HR data for Subject#002, with film times annotated.

| Film # | #SCRs | #SCRs per min | # HR peaks | #HR peaks per min |
|--------|-------|---------------|------------|-------------------|
| 1 | 5 | 1.3 | 1 | 0.26 |
| 2 | 18 | 3.1 | 2 | 0.35 |
| 3 | 1 | 0.8 | 1 | 0.85 |
| 4 | 11 | 1.4 | 3 | 0.37 |
| 5 | 1 | 0.2 | 1 | 0.23 |
| 6 | 0 | 0 | 0 | 0.00 |
| 7 | 18 | 0.9 | 8 | 0.42 |

Table 1 Numerical summary of data for Subject #002.

The box-plots in Figure 6 illustrate the number of SCRs per minute for each film across all subjects. Figure 6(a) shows the total number of SCRs per minute, whilst the data in Figure 6(b) was normalised, by dividing by the total number of SCRs for the subject, to remove the effects of electrodermal lability. The most engaging film, in terms of SCRs per minute evoked across all subjects, appears to be Film #1, whilst the least engaging films are Film #3 and Film #6. The films which evoked the most similar response across all subjects, in terms of the narrowest distribution of normalised number of SCRs per minute, are Film #7 and Film #4.

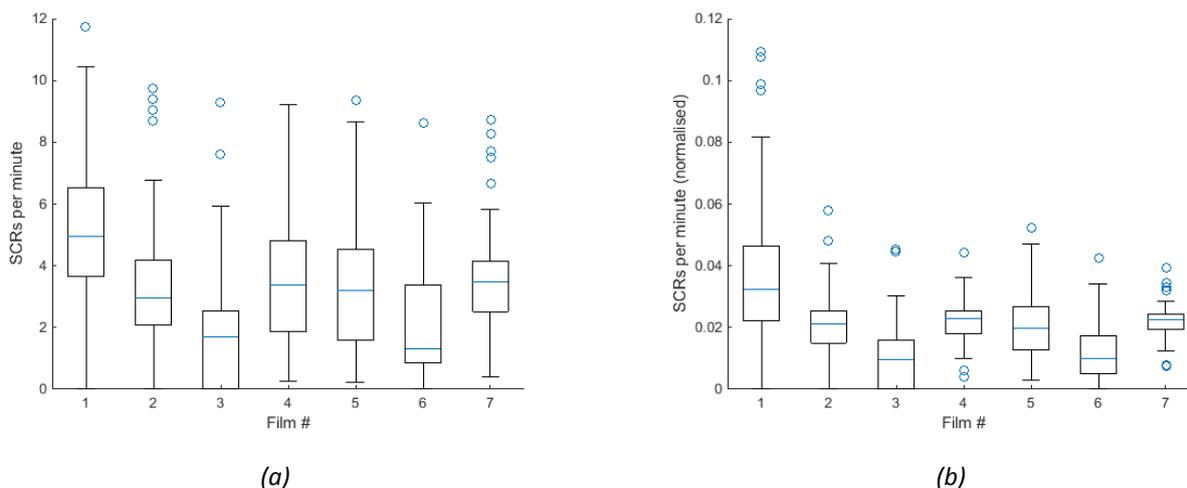


Figure 6 Box-plots showing number of SCRs per minute for each film (all subjects); (a) total number of SCRs per min and (b) normalised number of SCRs per min.

DISCUSSION

At Shimmer, we are always looking for new insights into the data that can be collected from our sensors and new ways that those data can be interpreted to provide valuable information about the individual and about groups. The experiment described in this article was a fun way for us to explore the field of Group Quantification, providing insights into emotional engagement at both an individual level and for a large group. The kind of metrics that are being investigated by Shimmer and many of our clients and partners will provide invaluable information to researchers in fields as diverse as optimisation of media content for maximum engagement and clinical applications like autism, epilepsy and anxiety.

Whilst the connection between heart rate and emotions is more difficult to measure than that between skin conductance and emotional engagement, there has been evidence in the unsupervised data that we collected to suggest the coincidence of heart rate activity with skin conductance events, as expected from the published literature on the subject. Similarly, a strong connection between skin conductance responses and the content of the screened films was found across all subjects, as was expected, whilst various levels of electrodermal lability were evident among the participants.

This article provides a summary of the preliminary findings of our data analysis - more detailed research is underway, aimed at improving our understanding of GSR and PPG signals and the most significant characteristics and features that can be extracted from those signals. This ongoing research will have an important impact on some exciting new product developments that will be coming soon from Shimmer - stay tuned!

REFERENCES

- [1] L. F. Barrett, "Solving the emotion paradox: categorization and the experience of emotion.," *Pers. Soc. Psychol. Rev.*, vol. 10, no. 1, pp. 20–46, 2006.
- [2] K. Poels and S. Dewitte, "How to capture the heart? Reviewing 20 years of emotion measurement in advertising," *J. Advert. Res.*, vol. 46, no. 1, pp. 18–37, 2006.
- [3] J. Cacioppo, L. G. Tassinary, and G. G. Berntson, Eds., *The Handbook of Psychophysiology*, 3rd ed. New York: Cambridge University Press, 2007.
- [4] D. K. Laundav, C. B. F. Jensen, P. Baekgaard, M. K. Petersen, and J. E. Larsen, "Your heart might give away your emotions," in *Proceedings of the 2014 IEEE International Conference on Multimedia and Expo Workshops (ICMEW)*, 2014, pp. 1–6.
- [5] S. D. Kreibig, "Autonomic nervous system activity in emotion: A review," *Biol. Psychol.*, vol. 84, no. 3, pp. 394–421, 2010.
- [6] D. Mathersul, S. McDonald, and J. A. Rushby, "Autonomic arousal explains social cognitive abilities in high-functioning adults with autism spectrum disorder," *Int. J. Psychophysiol.*, vol. 89, no. 3, pp. 475–482, 2013.
- [7] D. Mathersul, S. McDonald, and J. A. Rushby, "Automatic facial responses to briefly presented emotional stimuli in autism spectrum disorder," *Biol. Psychol.*, vol. 94, no. 2, pp. 397–407, 2013.
- [8] S. W. White, C. A. Mazefsky, G. S. Dichter, P. H. Chiu, J. A. Richey, and T. H. Ollendick, "Social-cognitive, physiological, and neural mechanisms underlying emotion regulation impairments: understanding anxiety in autism spectrum disorder," *Int. J. Dev. Neurosci.*, vol. 39, pp. 22–36, 2014.
- [9] J.-A. Micoulaud-Franchi, I. Kotwas, L. Lanteaume, C. Berthet, M. Bastien, J. Vion-Dury, A. Mcgonigal, and F. Bartolomei, "Skin conductance biofeedback training in adults with drug-resistant temporal lobe epilepsy and stress-triggered seizures: A proof-of-concept study," *Epilepsy Behav.*, vol. 41, pp. 244–250, 2014.
- [10] V. E. Sturm, J. S. Yokoyama, J. A. Eckart, J. Zakrzewski, H. J. Rosen, B. L. Miller, W. W. Seeley, and R. W. Levenson, "Damage to left frontal regulatory circuits produces greater positive emotional reactivity in frontotemporal dementia," *Cortex*, vol. 64, pp. 55–67, 2015.
- [11] A. Sano, R. W. Picard, and R. Stickgold, "Quantitative Analysis of Electrodermal Activity during Sleep," *Int. J. Psychophysiol.*, vol. 94, no. 3, pp. 382–389, 2014.
- [12] A. Myllyneva, K. Ranta, and J. K. Hietanen, "Psychophysiological responses to eye contact in adolescents with social anxiety disorder," *Biol. Psychol.*, vol. 109, pp. 151–158, 2015.
- [13] G. Crifaci, G. Tartarisco, L. Billeci, G. Pioggia, and a. Gaggioli, "Innovative technologies and methodologies based on integration of virtual reality and wearable systems for psychological stress treatment," *Int. J. Psychophysiol.*, vol. 85, no. 3, p. 402, 2012.
- [14] F. R. Balteş, J. Avram, M. Miclea, and A. C. Miu, "Emotions induced by operatic music: Psychophysiological effects of music, plot, and acting. A scientist's tribute to Maria Callas," *Brain Cogn.*, vol. 76, no. 1, pp. 146–157, 2011.

- [15] P. A. Nogueira, V. Torres, R. Rodrigues, and E. Oliveira, "An annotation tool for automatically triangulating individuals' psychophysiological emotional reactions to digital media stimuli," *Entertain. Comput.*, vol. 9–10, pp. 19–27, 2015.
- [16] L. Danner, S. Haindl, M. Joechl, and K. Duerrschmid, "Facial expressions and autonomous nervous system responses elicited by tasting different juices," *Food Res. Int.*, vol. 64, pp. 81–90, 2014.
- [17] L. Liao, A. M. Corsi, P. Chrysochou, and L. Lockshin, "Emotional responses towards food packaging: a joint application of self-report and physiological measures of emotion," *Food Qual. Prefer.*, vol. 42, pp. 48–55, 2015.
- [18] W.-L. Hu, J. J. Meyer, Z. Wang, T. Reid, D. E. Adams, S. Prabhakar, and A. R. Chaturvedi, "Dynamic Data Driven Approach for Modeling Human Error," *Procedia Comput. Sci.*, vol. 51, pp. 1643–1654, 2015.
- [19] E. Morgan, H. Gunes, and N. Bryan-Kinns, "Using affective and behavioural sensors to explore aspects of collaborative music making," *Int. J. Hum. Comput. Stud.*, vol. 82, pp. 31–47, 2015.
- [20] M. E. Dawson, A. M. Schell, and D. L. Fillion, "The Electrodermal System," in *The Handbook of Psychophysiology*, 3rd ed., J. Cacioppo, L. G. Tassinary, and G. G. Berntson, Eds. Cambridge University Press, 2007, pp. 159 – 181.
- [21] M. van Dooren, J. J. G. J. de Vries, and J. H. Janssen, "Emotional sweating across the body: Comparing 16 different skin conductance measurement locations," *Physiol. Behav.*, vol. 106, no. 2, pp. 298–304, 2012.
- [22] G. G. Berntson, K. S. Quigley, and D. Lozano, "Cardiovascular Psychophysiology," in *The Handbook of Psychophysiology*, 3rd ed., J. Cacioppo, L. G. Tassinary, and G. G. Berntson, Eds. Cambridge University Press, 2007, pp. 182 – 210.
- [23] H. Hamdi, P. Richard, A. Suteau, and P. Allain, "Emotion assessment for affective computing based on physiological responses," in *Proceedings of the IEEE International Conference on Fuzzy Systems*, 2012, pp. 10–15.
- [24] Y. Gu, K.-J. Wong, and S.-L. Tan, "Analysis of physiological responses from multiple subjects for emotion recognition," in *Proceedings of the 2012 IEEE 14th International Conference on e-Health Networking, Applications and Services (Healthcom)*, 2012, pp. 178–183.
- [25] J. Fleureau, P. Guillotel, and H. T. Quan, "Physiological-based affect event detector for entertainment video applications," *IEEE Trans. Affect. Comput.*, vol. 3, no. 3, pp. 379–385, 2012.
- [26] M. Bensafi, C. Rouby, V. Farget, B. Bertrand, M. Vigouroux, and a. Holley, "Influence of affective and cognitive judgments on autonomic parameters during inhalation of pleasant and unpleasant odors in humans," *Neurosci. Lett.*, vol. 319, no. 3, pp. 162–166, 2002.
- [27] Shimmer, "Consensys Software," 2015. [Online]. Available: <http://www.shimmersensing.com/shop/consensys>.

APPENDICES

APPENDIX A: SCREENED FILMS

Table 2 below contains details of the Short Films screened during the event. The films are not listed the order in which they were screened.

| Title | Director | More information |
|--------------------------------|----------------|---------------------------|
| Abiogenesis | Richard Mans | More Info |
| A Tale of Momentum and Inertia | Kameron Gates | More Info |
| The Brain Hack | Joseph White | More Info |
| Polis | Steven Ilous | More Info |
| PostHuman | Cole Drumb | More Info |
| Wanderers | Erik Wernquist | More Info |
| We Go Forward | Filipe Costa | More Info |

Table 2 Details of short films included in the screening (not listed in order of screening)

ETHICS

All participants were over 18 years of age. Ethics approval was obtained from Trinity College Dublin in advance of the event and participants were informed at the time of booking that data would be collected from them during the screening. No demographic information or data that could identify the participants was recorded by Shimmer at any time.