The Forensic Biometric Analysis of Emotions from Facial Expressions and Physiological Processes from the Heart and Skin

Azeza Al Masri 1* and Shashi K. Jasra 1*

ABSTRACT:

Decision-making, perception, memory and social interactions are greatly driven by emotion. Emotions can be measured from facial expressions through the facial muscles. A group of four students were exposed to emotionally loaded stimuli (videos and images) in its full complexity to assess the valence of the emotional expression, the associated arousal, skin respiration and the heart rate. The i-Motions software has the capability to detect voluntary as well as involuntary physiological responses of the different individuals. The responses of the participants when shown different stimuli were personalized. The software has great potential in the forensic sciences for analyzing the responses.

Keywords: Biometrics, physiological processes, emotions, forensic science, skin, GSR, heart, brain

1 Forensic Sciences, University of Windsor, Windsor, Ontario, Canada N9B 3P4

*Communicating Authors contacts: almasria@uwindsor.ca ; sjasra@uwindsor.ca
Introduction

Emotions are one of the factors that make humans different from other species and they aid greatly in criminal investigations. There are three critical components of an emotion; the first component is how a person experiences the emotion, the second component is how this person’s body reacts to the emotion, and the third component is what behavior is in response to the emotion. Some respondents in the research may be able to control some of their facial expressions and emotions, but they may not be able to control their skin sweating nor their heartbeat. Facial expressions are grouped into two categories; voluntary and involuntary facial expressions. The brainstem controls involuntary and unconscious expressions that occur on the face. On the other hand, the motor cortex controls the intentional and conscious facial expressions. This is why a fake smile does not appear genuine. A fake smile does not trigger neurological, emotional and physiological responses from the body as a genuine smile. In the brain, the amygdala controls the threatening, fearful, high sexual appeal or body pleasure and autonomic functions associated with arousal. Therefore, the motor cortex controls some of the voluntary facial expressions, while the amygdala controls voluntary functions including facial expressions, pupil dilation, respiration, skin conductance and heart rate.

Humans are able to produce varying sets of facial expressions, but the universal facial expressions that everyone can make are joy, anger, surprise, fear, contempt, sadness and disgust. Galvanic skin response (GSR) originates from the activation of the excretion of sweat from sweat glands. The sweating in the arms and soles of the feet is triggered by emotional arousal. Therefore, the galvanic skin response can detect patterns associated with emotions that can be quantified statistically. The density of sweat glands varies in the body, but the densest areas with sweat glands are the forehead, cheeks, palms, finger and the soles of the feet.

When sweat glands become activated, they secrete moisture through the pores to the surface of the skin. The changing positive and negative ions in the sweat causes a current to flow and changes in skin conductance. As skin conductance increases, skin resistance decreases. GSR is measured in Micro-Siemens or Micro-Mho. GSR sensors have a 1-cm² measurement site made of silver/silver-chloride and are placed in Velcro straps. In a research paper with the title “Forensic psychology: Violence viewed by psychopathic murderers”, they did an Implicit Association Test, which is a measure of the hidden attitudes and beliefs that a person may not be willing or unable to report. They used this research to prove that psychopathic murderers have abnormal cognitive traits to boost their violent actions. In their research, they stated that violent murderers lack remorse, they are emotionless, lack sympathy, excellent lying abilities and can control their emotion. Not every facial expression is voluntary and this research there is the ability to find out which of the respondents are able to control their facial expressions and feeling, but at the same time, the respondents cannot control their heart rate nor their skin (the amount of sweat). Another device used in this research is the PPG (photoplethysmography) which are light sensors that sense the rate of blood flow by the heart’s pumping action.
In another research paper, they used the concept when people view certain documents; they have emotions associated with this document. They had 763 volunteers and they studied the results aggregated or collectively. They tagged basic emotions such as anger, disgust, fear, happiness, and sadness and analyzed their intensities. They retrieved the images from Flickr.com and each image caused an emotion and analyzed their data using SPSS. Hence, it seems possible to apply collective image emotion tagging to present a new search option for basic emotions. Their analysis was based on emotional surveys based on PHP and HTML.

Using i-Motions software, the facial expressions are detected depending on the head orientation. It has six facial landmarks (eye and nose position). There are seven basic universal emotions, valence; and gives the ability to analyze complex states such as frustration, confusion, in addition to twenty Action Units, regardless of the respondent’s sex and whether or not respondent wears glasses. It can give live analysis of the emotions as well.

This research in biometrics are aids investigating offences, individualizing a perpetrator, and describe the forensic evaluation of the activity of an individual. This research can introduce a useful tool to the forensic world as it could be used to avoid wrongful convictions, in airport security to indicate potential terrorism threat. It can greatly aid in lie detection and help police officers in investigation interviews. It could also be used to analyze the true emotions and intentions of witnesses and suspects in court or in a lineup.

Materials

i-Motions software. A quiet office at the University of Windsor to avoid distractions with comfortable seating and great lighting. A shimmer kit that includes; a galvanic skin response and heart rate. Logitech HD camera and a fast laptop for mobility and simplicity of use with Bluetooth connection.

Methods

1. In the office the temperature has to remain between 20 to 24 degrees Celsius to avoid any changes in the results due to environmental stress
2. The temperature was 22 degrees Celsius
3. Open the window slightly to allow for air flow
4. Download and install the i-Motions software on a laptop
5. Connect the webcam to a USB and launch the software
6. Configure the device from the global tap, then preferences, then video and select the camera as Logitech HD, select the audio device and click preview. Check allow the webcam to collect data.
7. Connect the shimmer dock to the laptop using the USB port; make sure the shimmer device is fully charged and ready to be used.
8. Configure the device from the global tap, then preferences, then sensor. Add the shimmer sensor and select the USB port of the shimmer dock. Click on configure. Let it load and select the GSR, In A13 (optical heart rate). Enable Heart rate conversion, set it at 2 and select Internal ADC channel A13 from the drop down menu. Enable sampling rate at 102.4Hz and set GSR at auto range. Click apply.

9. Confirm that the shimmer sensor connection is high and it is at 102.4Hz. Make sure there is a green square around the face in the camera allowing for facial detection.

10. Start a new study in iMotions software

11. Add the stimuli (pictures and videos)

12. Each picture and video is associated with one of the seven basic emotions. Choose to show the pictures and videos in a random order. The pictures are shown to the respondent for 8 seconds.

13. Add a respondent

14. Type the date, name, age, gender and any comments

15. Record and calibrate the neutral emotion of the respondent (this step is called recording a baseline). It is 6 seconds long. The purpose of this step is to remove any bias during the analysis.

16. The stimuli will appear right after the baseline

17. Shown or given specific stimuli, such as a videos and pictures.

18. Each of the following stimuli is associated with an emotion.

19. Have the respondent sit on the comfortable seat

20. Make sure there is proper illumination of the face with a dark background

21. The respondents must relax and not talk

22. Informed the respondent about the consent ethics form and explained the procedure

23. If long hair, make sure face is not occluded.
   - No hats
   - No sun glasses
   - No talking on mobile phones
   - No chewing gum
   - No beverages

24. Head position in relation to the camera is frontal and straight for all respondents, but + or -20 degree angle is acceptable.

25. Inform the respondent not to move their limbs to avoid any discrepancies in the results

26. The GSR Velcro strap is wrapped around the respondent’s index and middle finger

27. The PPG Velcro strap is wrapped around the respondent’s ring finger

28. For both the GSR and PPG, the device has to be to the inside of the palm on the finger

29. The participants see the stimuli for the very first time and then they react to it.

30. Click record when ready.

31. Their reaction is recorded using the iMotions software
32. The data is analyzed from the colored graphs for each of the emotions. The data of the skin and heart are also analyzed.

33. The raw data is exported to be further analyzed and downloaded in an excel file.

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Stimulus Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – Picture</td>
<td>A grasshopper in the mouth of a human</td>
</tr>
<tr>
<td>2 - Picture</td>
<td>Factories polluting the environment</td>
</tr>
<tr>
<td>3 – Video – length 1:04 sec</td>
<td>Sharks eating and attacking humans</td>
</tr>
<tr>
<td>4 – Video – length 1:48 sec</td>
<td>News report about two friends stabbing and violently trying to kill their third friend</td>
</tr>
<tr>
<td>5 – Picture</td>
<td>Homeless child sitting in the street with a toy</td>
</tr>
<tr>
<td>6 – Picture</td>
<td>Poor child looking for food in the trash</td>
</tr>
<tr>
<td>7 – Picture</td>
<td>Laughing infant with eyelashes as his eyebrows</td>
</tr>
</tbody>
</table>

### Results

Even though some of the participants tried to control some of their facial expressions when exposed to some stimuli, their galvanic skin response as well as their heart rate and optical heart rate gave a clear idea of whether they were happy or joyful, threatening or fearful. To avoid any biases of reactions, in case any of the participants sees the labelling of the pictures and videos, they were labelled by numbers. The respondents were exposed to the stimuli for the first time. The respondents reacted to the stimuli based on their knowledge and experiences. There were similar reactions between the respondents, but some reaction to the stimuli were more intense than others.

<table>
<thead>
<tr>
<th>Stimulus Label</th>
<th>The Associated Emotion With the Stimulus</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Emotion – baseline</td>
</tr>
<tr>
<td>1</td>
<td>Disgust</td>
</tr>
<tr>
<td>2</td>
<td>Contempt</td>
</tr>
<tr>
<td>3</td>
<td>Fear</td>
</tr>
<tr>
<td>4</td>
<td>Surprise</td>
</tr>
<tr>
<td>5</td>
<td>Sadness</td>
</tr>
<tr>
<td>6</td>
<td>Anger</td>
</tr>
<tr>
<td>7</td>
<td>Joy</td>
</tr>
</tbody>
</table>

To analyze the emotions first, the participants had personalized emotions. A facial expression does not have to be a representative of a single emotion; it could be a representative of two emotions or more. For all stimuli, when there is an increase in Galvanic skin response
there is a peak in PPG. The facial expressions of Male 2 remained neutral for around 50% of the time, but there were great changes in the heart rate PPG and GSR. There was an increase in the heart rate, peaks in PPG and an increase in GSR. Even though there was a decrease of GSR at the end of the stimuli, the heart rate and PPG still increased. There was a reaction when exposed to stimulus 2, which is disgust, there was an increase in heart rate, the peaks of PPG became more prominent and there was an increase in GSR. For Female 1, there was a decrease in heart rate, a decrease in GSR, but the peaks for PPG became more prominent, this may be an indicator of stress when watching stimulus 3. All respondents have similar responses to the stimuli, but each response varies in intensity.

The results of the different stimuli with emotional reactions such as joy, surprise, anger, fear, contempt, disgust and sadness by individual respondents are depicted in the Figures 1-7. Comparison of the neutral, positive and negative time percentage to all the stimuli by the respondents are shown in Figure 8-10.

The analysis of the GSR for stimulus 1, 2 and 3 for all the respondents are shown in Figures 11-13.

Figure 1: Female 2 spent 2 percent of the time in joy and male 1 spent 10 percent of the time in joy when shown stimulus 1. Change in emotion was visible in stimulus 3, 4, 6 and 7.
Figure 2: Female 2 had a surprise emotion for 6% of the time when shown stimulus 6 and 5% when shown the baseline.

Figure 3: Male 1 showed anger in stimulus 4.
Figure 4: None of the participants showed a facial expression of fear to any of the stimulus.

Figure 5: Many of the participants had the emotion of contempt. Mainly in stimuli 1, 3, 4, 5, 6, and 7.
Figure 6: Zero disgust time percent for all respondents

Figure 7: Female 1 was sad at 2 percent of the time
Figure 8: Male 2 had around 50 neutral time percent for all stimuli, Male 1, female 1, female 2 had varying emotions depending on the stimulus.

Figure 9: Male 1 and Female 2 showed positive time spent with stimuli 1, 4, 5 and 1, 2 and 5 respectively.
Figure 10: Male and Female 2 showed negative time spent mainly with stimuli 1,2,4 and 1,3,4,5 respectively.

Figure 11: Increased GSR for Male 1 and decreased GSR for Male 2
Figure 12: Increased GSR for Male 1

Figure 13: There is an increase in GSR for Male 1
Discussion

The heart rate is not directly proportional to the GSR. At some points of the analysis, there was an increase in the heart rate, but there was a decrease in GSR. This is because the respondent has no idea what may happen in the next stimulus. In other cases, there was an increase in heart rate, GSR and PPG, indicating a highly stressful condition for the respondent. There is no cardiovascular or cardio respiratory change because of this change in heart rate; it is simply the effect on the heart of chemicals and nerves responding to an external experience. The sympathetic components increase heart rate by releasing the neural hormone catecholamines - epinephrine and norepinephrine. The cardiovascular control center for the body is located in the ventro-lateral medulla. Here heart rate slows if activated by the cardio inhibitory center in the medulla or speeds up if activated by the cardio accelerator.23

Some of the respondents focused on keeping their neutral facial expression and forgot about keeping the neutral heart rate and galvanic skin response.

The results would vary if the respondents saw the stimuli for the first time versus respondents who already saw the stimuli then their reactions were recorded.

The Implicit Association Test is used to measure beliefs that people are not willing to report. They may feel fear to report something they believe in due to the consequences that it may lead. The i-Motions software can analyze the true emotions live and record them based on physiological, neurological and emotional processes.24

It is important to know the limitations of the research. Part of this research is the study of emotions; there are factors that affect emotions such as lack of sleep, taking medications and the experiences of each person. The intensities of the emotions may be exaggerated or decreased when the person is exhausted. Certain medications may cause certain emotions such as depression. Therefore, all the emotions will be negative. To eliminate this issue, the respondent has to be relaxed, had enough sleep. The research has to be very focused on the variables tested and exclude any unnecessary variables. The respondents for the present study are four volunteers from the same age group. The volunteers are two males and two females. For future studies it would be better to have respondents from different age groups and recording the different emotions based on their experience.

Conclusion

The emotions of the participants varied, from someone who had a completely neutral face, someone who had some facial expressions, and someone who responded to the stimuli
moderately, to someone who reacted to all of the stimuli to some degree. The responses of the participants could vary if they knew the objective of this research or not. The i-Motions software is able to give detailed analysis on each frame of the facial expressions, GSR and heartbeat.

Acknowledgements

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References


