Mood Journaling

An Exploration Of Real Time Mood Developments As A Function Of Heart Rate

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Abstract — **Mood journaling applications are a way to track and log feelings and moods. Through reminders they give you prompts to log and assess your mood. But these reminders do not occur when the mood actually changes; just randomly or at preset times. Research shows that the window to accurately detect these changes ranges from 5 to 15 seconds after a person experiences them. This paper explores the possibility of tracking mood developments in real time with heart rate as an indicator. Thirty-nine participants watched a set of negatively and positively rated pictures and were asked to fill in a mood assessment questionnaire when their heart rate went above a certain threshold.**

Index terms— psychophysiology, heart rate, mood, emotion, human-centered computing, wellness informatics, quantified self, fitness trackers, wearables

1. INTRODUCTION

Psychical Activity (PA) trackers such as heart rate (HR) monitors and pedometers have been around for decades but have recently seen rapid adoption (Shih, P. et al, 2015). With the rise of smartphone use, people can not only track their activities automatically but also set different goals. Automatic tracking gives them insights into their physical behaviors which can lead to setting personal goals and improving upon them (Klasnja et al., 2011). These data sets of physical behaviors and movement are ways to map someone's day and study physical behavior (Dunton et al 2014). They are collected automatically with little to no user intervention, which allows the data logging to continue without issue. In many ways, mobile devices and wearables have made it easier to monitor and gain insight into physical health and improving upon it. This results in more active people that have stronger feelings of excitement and enthusiasm compared to those who are less active (Conroy et al, 2011). However, what about mood? Some might argue that mood is equally important as psychical health. The fields of Psychical Activity (PA) research and consumer health informatics have but only touched upon this subject (Stuart, 2000), partly because of the lack of certainty about how someone can accurately monitor(track) their mental health and distinction between mood and emotion. PA tracking not only relies on the user collecting the data but also interpreting what the data means for them (Grinter et al, 2010).

There are mobile applications which ask users what their mood is at different intervals or let them assess their mood of the day. There are even ones that let users tag spikes in physiological charts such as heart rate. But assessing mood after several hours is not optimal. The window to detect mood can range between 5-15 seconds after experiencing it (Jerritta S, 2011). This research aims to explore the automation of mood journaling by tracking mood developments as a function of a physiological measure (heart rate). With this we propose a system that asks the user to asses their mood in a more comprehensive manner — current systems such as mood tracker applications and journals are confined to simple emoticons — through the aid of psychological mood assessment tests when mood developments occur in real time. This could improve the accuracy of the data collected by the user and system because it will asses mood well in the time frame of 5-15 seconds after a mood development and thus be more reflective of the mood that the person is experiencing.

1.1 Subject of this paper

Research presented in this paper will explore the question: *Can a wearable Heart Rate monitor be an indicator for real time mood developments?* The research topic is situated in the field of Psychophysiology which examines the measurement of physiological responses as they relate to behavior. The physiological measure of this paper - cardiac activity- is used as a means to monitor mood developments. In later chapters there are explorations of heart rate (HR) and its suitability as a measure for this research. This paper will also explore the value of HR data gathered from fitness trackers.

2. EXPLORATION AND BACKGROUND

This section will the explore heart rate in depth and asses other research done in this field.

In recent years - with the advent rise of PA trackers - manufacturers have started incorporating HR monitors into PA trackers through optical sensors that track blood racing through the veins (PPG; photoplethysmography). While not as accurate as ECG monitoring which directly monitors electronic signals produced by the heart, researchers have found equal results to ECG based heart rate trackers when energy expenditure is low(He, H, 2015). Other physiological measures include neuro imaging techniques such as PET and fMRI or galvanic skin response(electrodermal) which has shown similar results comparable to heart rate monitoring. The combination of the prevalence of HR sensors in current wearables and the general interest of the researcher has led to heart rate at the physiological measure chosen for this research. By restricting solely to the activity trackers and wearables, voluntary interaction of tracking physiological (gazing and frowning through electrooculography(EOG)) measurements were not considered.

2.1. Exploring the heart

HR is the number of total beats that occur within a minute. Heart Rate Variability (HRV) are changes in the intervals (R) (in milliseconds) between two heart beats (R-R). The two are often confused with one another. These are the two ways that studies concerning human performance use to measure HR. HR measured in BPM (beats per minute) measures the total number of R waves in cardiac cycle. HRV as mentioned before measures the change in milliseconds between de R-waves. Research pertaining to HR varies in the measurement of Hear Rate between BPM and HRV. Some argue (Zhao) emotion recognitions require beat-to-beat (R-R)measurements while others state that it is largely dependent on the period in which the researchers want to measure cardiac change (Andreassi, L, 2000). Also “The amount of cardiac change reported as a result of an experimental manipulation can differ considerably depending upon the metric chosen to represent change in cardiac function” (Bernston, 2007.). When a person is performing a task with low energy expenditure the HR can be between anything from 50 and 70 beats per minute (Letho, Buck, 2008). HR and energy expenditure attributed to physical load has a linear relationship with minimal variance (Sumida et al, 2013; Letho, Buck, 2008). HR is controlled by two branches of the autonomic (ANS) nervous system: the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS). The former accelerates the HR by releasing a hormone, while latter does the same but decreases the HR (Andreassi, L., 2000). The SNS increases cardiac output(amount of blood pumped out by the heart) when energy expenditure attributed to physical load is high(i.e. exercising) or in certain emotional situations (Andreassi, L., 2000). Technological improvements have made it so that HR monitors can be more readily accessible to the masses. No longer are people confined to specific spaces to monitor HR. This presents opportunities for researchers to explore HR and other factors outside of the confines of laboratories and research spaces (Dreifus, L 1993).

2.2 Mood and Emotion

There have been many models that have mapped different kind of emotions to different state of minds. William James' theory of emotions describes them "analogues to sensations like taste and smell". Russel et al (1986) have mapped similar emotions and facial expressions - using multidimensional scaling -to different cultures and age groups. Pleasure and arousal are major dimensions how adults interpret their own emotions and those of others (Ditman, 1972 via Russel 1986). But Barret (2006) argues that our view of emotions are not fixed and cannot be defined. Russel T describes these emotions as "inner experiences" that cannot be readily conveyed in words. Rolls (2008) argues that emotions consist of the cognitive processing of stimuli which assesses the valence which in turn can elicit a mood change if said stimuli has a strong negative of positive valance.

2.2.1 Assessing Mood

There are various ways to assess mood including lengthy questionnaires and evaluating indexes. Word based evaluations such as PANAS and POMS seem to be the most common practice either through self-reporting by subjects themselves or interviewers/ researchers. According to Robinson et al (2002) self-reports of current emotional states are much more accurate that ones that occur in a distant time relevant to the experience.

2.3 Heart Activity

How does the heart have has anything to do or say about mood developments? It is simply an organ that pumps out blood to tissues of the body. But early research has shown that changes in cardiac activity are related to psychological experiences and feelings. HR was also specifically chosen for this research because of is close correlation with a person's inner feelings (Kreibig, S.D 2010; Quintana D.S 2012 via Zhao n.d.)

2.3.1 Related Work and Scientific Context

The number of behavioral studies done using HR is very large. HR has shown in experiments to relate to various behaviors when performing certain motor tasks such as learning to drive a car (Ohkubo et al, 1972), where increased anxiety levels can also lead to increased HR. These HR increases were monitored for a longer period of time (5 days) and HR was measured in beats per minute. When a participant perceives they are performing a task well and get positive feedback from those actions, he/she can also have increased HR resulting from the increased involvement from the participant in the task (Andreassi 2000). Complex problem solving also results in increased HR as shown by researchers Lacey et al (1963). They measured the HR of participants while solving problems containing mental arithmetic. They found immediate acceleration during each problem performed. They concluded that cardiac acceleration is linked to mental activity and the processing information when problem solving.

Various images - and the resulting thoughts - can also increase HR as shown by research (Andreassi 2000). Participants were instructed to immediately think of a number sequence, followed by letters and emotions words. The research showed higher increase in HR when thinking about emotional words (eg. rape, death) than when thinking about letters. It can also take longer for HR recover to the baseline.

Several studies (Jennings (1992)) have shown a decrease in HR in anticipation of a certain stimuli. Mostly it happens a few seconds before the stimuli. Others (Elliot, 1974) have shown that HR is less suitable for differentiating between emotional reactions and that HR in general is inaccurate to pin point exact emotions. More recent research that has explored HR monitoring emotion is that of by Antonnen et al (2005). Their EMFi chair was designed for unobtrusive HR monitoring and they found that HR could respond to emotional stimulation and especially toward negative ones. They found that HR is a promising measurement for emotions because it captures them spontaneously and HR cannot be controlled as easily as other known researched signifiers as facial expressions. There is still some significant discussion between the exact difference between mood and emotion. For the sake of consistency this paper will focus on the mood definitions found throughout literature. One other recent study (Zhao, 2017) tried to unobtrusively monitor HR by extracting individual heart beats from RF-signals. Both studies by Antonnen et al and Zhao incorporated the the valence and arousal dimensions for mood measurement and asked participants to evaluate the stimuli after the fact. This research aims to ask participants shortly after the occurrence of a mood development.

3. METHOD

The purpose of this experiment is to detect when significant change cardiac activity occurs, brought on by stimuli with positive and negative valence. The detection will purely focus on the change in HR measured in ms (HRV). This change will be triggered by stimuli that is presented to the participant. Instead of evaluating the stimuli done by others, participants will evaluate their mood in that moment. In short: the visual stimuli could affect the mood of a participant depending on the valence of the pictures - and this will be detected by a change in cardiac activity. (Andreassi, L 2000, Rolls, 2008)

3.1 Participants

A total of 39 participants (N=39) took part in this research with an age range between 18 and 57.

3.2 Equipment

For this research there has been chosen to restrict the scope to HR monitors worn around the wrist (PPG). Studies (He, H et al 2015) have shown equal results between PPG and ECG when not engaging in high energy expenditure tasks. The participants in this study sat down. In this experiment participants will be connected to a Pulse Sensor - that mimics the same function as a wrist based HR monitor - which will be attached to the right index finger of the participant. The Pulse Sensor is connected to an Arduino which is connected to a Mac laptop running the Processing program. This will
monitor the HR activity for changes in ms.

3.3. Software parameters

The software monitors the HRV of the last 8 heart beats of the participant to calculate the mean HRV value. When new HRV value comes in, its is compared to the mean HRV of the last 8 heart beats. When the software detects at least a 10% change between the mean HRV and the new one, it prompts a questionnaire. 10% was the value estimated by the researcher in preliminary testing based on two subjects. Other researchers cited earlier in this paper monitored the HR in real time but did not incorporate any detection mechanisms but instead focused on post-test analyses - which is not suitable for this research. After filling in the questionnaire the participant is asked to relax so the heart beat recovers (potentially back to base heart rate). This is required to have enough variance between heart rate changes for the program to detect.

3.3 Stimuli and task

The participants were presented with pre-coded(valence, arousal) images from The Geneva affective picture database (GAPED)[1]. It is a set of emotional stimuli for experimental investigations of emotion and attention. Lowly arousing pictures with positive valence were positive stimuli. Highly arousing pictures with negative valence served as negative stimuli. The participants were asked to look at the images that displayed in a set of positive and negative pairs that were showed sequentially. This

[1] image codes A086 A095,A116,A123,A129, N015, N016, N017,N018, N019,H005, H041, H077, H081, H112, P046, P047 , P048, P049, P050, Sn068, Sn075, Sn095, Sn103, Sn104, N089 , N090 , N091, N092, N093, Sp091, Sp093, Sp094, Sp095, Sp096

pairing was done to have a clear dichotomy between positive and negative sets of images for optimal variance in heart rate.

3.4 Procedure

The participants get a short introduction into the procedure and tasks. Shortly thereafter the participant is fitted with the testing apparatus (Pulse Sensor). At the beginning of the test, the participant has to sit still so that their heart rate can stabilize. After the baseline HRV is established, participants are introduced to a series of low-arousing and high-arousing images. When HRV decreases by 10% or more (meaning HR increases) the participant will get signal to fill in a questionnaire. The questionnaire will be the Abbreviated POMS(see Fig. 1) which consists of a list of 40 adjectives. Participants indicate the degree to which they feel an adjective using a 5-point scale format. After a screen that asks to fill the questionnaire, a new mood assessment questionnaire is given with the task in to fill how the participant is feeling at that specific moment. Every subsequent decrease in HRV will trigger a signal. This signal based assessment closely shadows the The Descriptive Experience Sampling method (Hurlburt, 2006) where participants get beeps at random intervals to describe their environment, surroundings and inner thoughts. This method of randomness however would not be suited for this research since the signal intervals are tied to a physiological change.

The system would not wait for the participants HR to return to the baseline and would continue after 30 seconds after the participant filled in the questionnaire.

FIGURE I. EXCERPT QUESTIONNAIRE

Grouchy	0	1	2	3	4
Ashamed	0	1	2	3	4
Energetic	0	1	2	3	4
Hopeless	0	1	2	3	4
Uneasy	0	1	2	3	4
Restless	0	1	2	3	4
Unable to concentrate	0	1	2	3	4
Fatigued	0	1	2	3	4
Competent	0	1	2	3	4
Annoyed	0	1	2	3	4
Discouraged	0	1	2	3	4

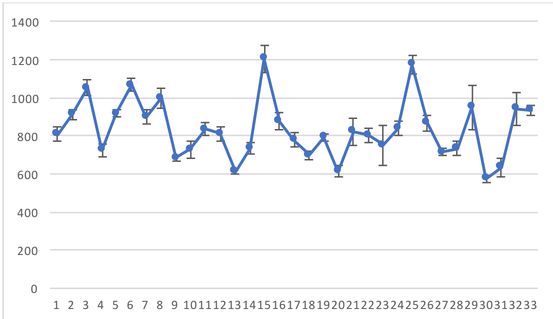
4. RESULTS

In this section we present the results coming from the experiments. Beginning with a look at the heart rate from the participants. Due to errors with the equipment and other interference, five participants were excluded from the analyses. Some participants were too nervous to continue the test so they were excluded from the analyses. Thus the analyses was conducted with 34 participants (N=34).

4.1 Heart rate

The standard deviations of the heart rate of all participants are shown in graph I. X-axis being the images and the y-axis HR in ms.

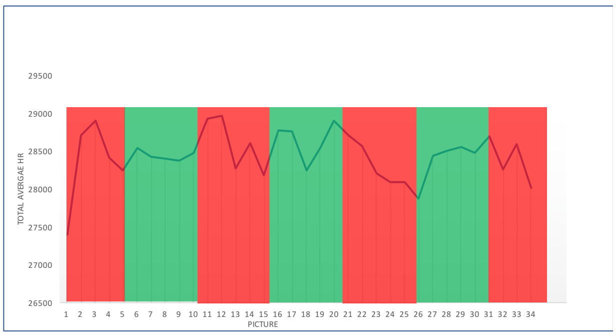
GRAPH I. STANDARD DEVIATION



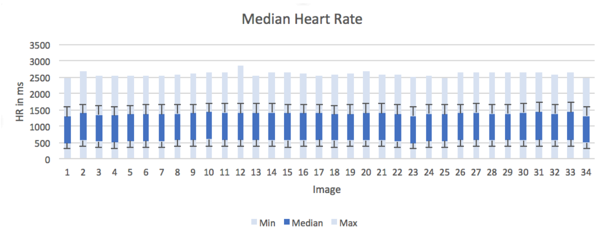
4.3 Heart during test

To see if the heart rate progression during the test corresponds with expectations, the mean heart rate form all participants was taken form the slide show section of the test. This is the part when a participant sees an image — excluding the prompt to fill in a questionnaire and the calm down state. All the mean heart rate values were summed up and presented in graph III. The red and green overlays represent the negative and positive rated images respectively.

GRAPH II. TOTAL MEAN HEART RATE



GRAPH III. MEAN HEART RATE



Furthermore the mean HR of participants is shown in graph III

4.3 Average HR vs rated images

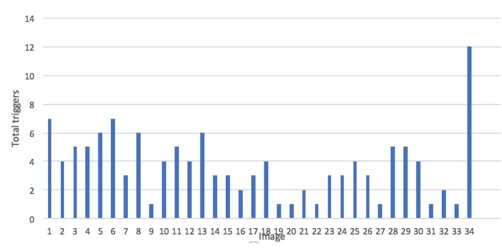
A series of Pearson's Correlation tests were performed to see whether there was correlation between the total average heart rate of all participants and the arousal and valence scores of the pictures. Results showed weak negative correlation ($N=34$, $r=-0.035$, $p=0.843$) with the valence values and weak positive correlation with arousal values ($N=34$, $r=0.131$, $p=0.460$).

4.4 Mood assessment scores vs valence arousal

A series of Pearson's Correlation tests were performed to see whether there was correlation between the total mood disturbance (TMD) score of the participants and the arousal and valence scores of the pictures. Results showed weak negative correlation ($N=34$, $r=-0.283$, $p=0.105$) with the valence values and weak positive correlation with arousal values ($N=34$, $r=0.287$, $p=0.099$).

4.5 Triggers

GRAPH IV. TOTAL TRIGGERS PER IMAGE



Graph IV shows the total trigger per image from all participants (N=34).

4.6 Participants comments

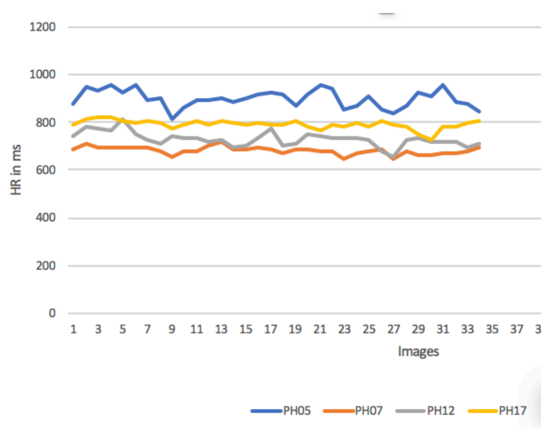
During and after the test participants commented on various aspects of the test and study in general. Most notable observations are quoted below:

One participant commented that he was excited when pictures of animals were shown because he was a biologist. A trigger occurred for this participant at the images of the animals and his excitement is reflected in his very low TMD scores of -1. A low TMD score means that the person is more positive.

Participants with more than 5 triggers showed signs of fatigue when filling in the questionnaires. Mostly rolling their eyes or groaning.

Heart rates of participants with zero triggers(N=4) are shown in Graph V.

GRAPH V. HR ZERO TRIGGER PARTICPANTS



5. DISCUSSION AND FUTURE WORK

5.1 Heart Rate reliability

The results in this study suggest that heart rate is somewhat of a suitable indicator when something is *not right* but not necessarily an accurate predictor when pinpointing specifics as there is no correlation with the negative images. Even though the results are statistically insignificant, in graph II there is a shorter IBI(in ms) during the negative images and longer IBI trend when positive images are shown. Furthermore increasing and decreasing trend lines may suggest that triggers(when the participant gets a questionnaire) happen with a slight delay with residual effects from the images prior to the trigger image. Further analyses and research is needed to study this "lag" phenomenon. Graph IV shows *pyramid* type of peaks suggesting these residual after effects.

Participants with zero triggers generally had the same comments regarding the images in that they were unfazed by the negative ones. A future study could precisely select a group with little to no predisposed notion of the images for example children.

Regarding mood improvement: participants had — on average — had a higher TMD score after the test was done suggesting a more negative mood state. Of course the mood scores do not have to directly reflect the images shown on screen. Participants were asked:*"how are you feeling at this moment?"*. So a negative mood score does not necessarily have to be a result of the images shown. But a high negative valance image can influence mood (Rolls, 2008).

5.2 Questionnaire

Manual logging of user data causes barriers in continuation of logging because of the high rate of preciseness the data input requires from the user (Cordeiro et al). Manual logging of ones mood throughout the session can be time consuming and as mentioned before can lead to discontinuation. The mood assessment questionnaire consisted of 40 items, all with a 5 point scale. This was a challenge for some participants. All participants - except for one - finished all the questionnaire sheets they were given. Some participants had wide varying TMD scores, suggesting that participants grew fatigued by the questionnaires and filling them in less precisely. Some (Harmon-Jones, C et al, 2016) advocate for more precise and shorter forms such as their Discrete Emotions Questionnaire. These leads to the continuing discussion regarding emotions and moods. Future research has to specify and relate short term emotions or latent mood developments. This research project could be repeated in different contexts and emotions dimensions to relieve *questionnaire fatigue.*

5.3 Future work

Heart rate is susceptible to energy expenditure of the subject. Ways to isolate this are crucial in future studies involving mood state developments and heart rate. One example is from Sumida et al (2013) who isolate it through sensors on a smartphone by extrapolation of energy expenditure from gyroscopic data. This is paramount if this type of research were to be repeated in a longer time frames or in a mobile setting.

Future research has to take in to account more variations in participants at both ends of the spectrum: people who are very susceptible to negative valence images an those who are not. Program parameters chosen in this research did not accommodate these individuals enough. Participants who did not have any triggers might have well be affected by the images but the program behind the test did not pick that up in real time. More and more complex parameters could partake those who are less sensitive to negative valence imagery.

The findings form this research may serve as a point of entry for future projects involving mood tracking. The data set can be analyzed and utilized in different ways, beyond the confines of this research project. Heart rate is a promising measure for mood tracking albeit with help from more data points.

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