An Exploration of the Utility of GSR in Locating Events from Personal Lifelogs for Reflection

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ABSTRACT
Digital personal lifelogs (PLs) enable many artifacts from a person's life to be automatically stored in a digital archive. These data sets can contain a wealth of potentially valuable information describing events from an individual's life. A key challenge for lifelog technologies is how to develop scenarios and applications which enable people to interact with these vast heterogeneous data sources in a meaningful way. One of the areas where individuals can gain from interacting with lifelog records of their life is in the process of self reflection. To date little attention has been given to applications which automatically extract content from lifelogs to support self reflection using lifelog content. One of the significant issues with reflection from lifelogs is discerning material which may be of interest in reflection from among the huge amount of available data. One way of determining the user's engagement with their situation is measuring their biometric response associated with their arousal level. Specifically it is known that an individual's galvanic skin response (GSR) can vary with their level of arousal. We hypothesize that situations of marked GSR variation are likely to be more significant for self reflection than other moments. We present an initial investigation, using 3 subjects' lifelogs, of the utility of lifelog items with marked GSR for self reflection. Our results indicate that GSR records may serve as a good enabling technology for applications supporting self reflection and awareness.

Categories and Subject Descriptors
K8.m. Computing Milieux: PERSONAL COMPUTING: Miscellaneous.

General Terms
Algorithms, Human Factors.

Keywords
Lifelog, personal digital archives, biometric data, galvanic skin response, self reflection, self awareness.

1. INTRODUCTION
Personal lifelogging technologies enable artifacts from a person's life to be automatically stored in a digital archive [1]. Personal Lifelogs (PLs) capture details of events from peoples' lives which can be used by the individuals in various ways or shared with others. When gathered over an extended period lifelogs become vast heterogeneous data archives. Lifelogs can contain everything from items read, written, or downloaded; to footage from life experiences, e.g., photographs taken, videos seen, music heard, details of places visited, details of people met, etc., along with details of location and social context. While applications to amass and organize data in lifelogs of this nature are not currently publicly available, we believe they will be in the future (See [1] for a discussion on this topic). Already people are storing increasing amounts of data in digital format.

A key challenge is thus the development of scenarios and applications which enable people to interact with them in a meaningful and effective way. One of the areas where individuals can potentially benefit from re-experiencing lifelogged events from their lives is in the process of self reflection. Self reflection is often opportunistic, triggered by something that someone mentions or an artifact seen, and can lead an individual to relive past events, possibly gaining further insight into them self as an individual. Self reflection is an important adult process leading to further self awareness and development [13]. Despite the tremendous benefits to be obtained from self reflection [2][3][4], it seldom occurs on a regular basis. The use of some digital content in the reflection process has been demonstrated in [14] where an application to enhance recorded personal diary content with mobile phone data and recorded emotional response was created; and in [8] where the utility of SenseCam images [12], gathered over a one week period, in aiding short-term self reflection was shown. In this study subjects manually looked through the SenseCam images after the one week capture period. Lifelog collections will however typically contain many rich sources of digital data, span long periods of time, and offer the potential for long-term self reflection.

While such lifelogs may afford new possibilities for reflection, due to their sheer volume and the number of years they may span, discerning information which may be useful for self reflection from within the possibly vast contents of such archives is challenging. Any such developed applications will require means to present possibly useful moments from within such archives for self reflection. In this paper we explore the role of biometric response in this process.

Significant or important events tend to raise an individual's arousal level, causing a measurable biometric response [11]. Events that can be recalled clearly or on which an individual is more likely to reflect are often those which are important or emotional in their lives [7]. It has been demonstrated that the strength of the declarative or explicit memory for such emotionally charged events has a biological basis with the brain, specifically involving interaction between the amygdala and the hippocampal memory system [6]. Variations in arousal level elicit physiological responses such as changes in heart rate or increased sweat production. Thus one way of observing an arousal response is by measuring the skin conductance response (SCR) (also referred to as the galvanic skin response (GSR)). The GSR reflects a change in the electrical conductivity of the skin as a result of

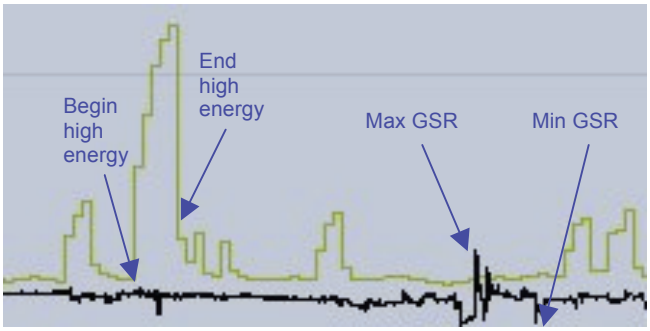

Figure 1. GSR (black line) and energy expenditure (green line) for a 1.5 hour time interval.

variation in the activity of the sweat glands. It can be measured if this change is only subtle and transient, and the individual concerned is not obviously sweating [7]. Current technologies enable the capture of a number of biometric measures on a continuous basis. For example using a device such as the BodyMedia SenseWear Pro II armband [5] which can continuously record the wearer's GSR. In previous work [10], we have shown that biometric response at the time of experiencing lifelog content can serve as an indicator of memorable-ness and future item importance for the individual. In this paper, we seek to explore an enabling technology for self reflection systems to discern whether such periods of marked biometric response can also serve as an indicator of periods in a lifelog which are useful for individuals in self reflection. For this initial exploration we examine the role of GSR in this process.

In this paper we explore our hypothesis and report our findings to date which may guide future research in this area. We describe a study designed to explore the use of biometric data in detecting useful lifelog items for self reflection. We describe the test-set gathered for these experiments, explain our use of biometric data to extract lifelog items for promoting reflection, detail the user study conducted to determine the utility of our approach and discuss our findings.

2. TEST-SET

In order to explore our hypothesis, a suitable test-set must be available. As part of our ongoing work on PLs we are gathering long term multimedia lifelog collections, stored locally on individuals PCs, from a small group of subjects [9]. For the current investigation we augmented these lifelogs for 3 postgraduate students within our research group (1 male, 2 females; from Asian and Caucasian ethnic groups), for a 1 month period, with capture of their GSR data. For our current experiment we chose to examine whether GSR data can be useful in identifying important and memorable for self reflection lifelog events from among computer items accessed, SMSs sent and received, phone calls, and SenseCam images [12] capturing an individual's activity. See [9] for full details on lifelog data capture. GSR and energy expenditure were collected using a BodyMedia armband [5] worn on the upper arm. Based on results from initial calibration experiments, GSR data was capture once per second. A problem in analysis of biometric data for the purposes of this experiment is to identify variation in biometric data which are likely to be associated with meaningful variations in arousal levels, as opposed to physical activity. Energy expenditure (sampled once per minute) correlates well with physical activity levels. Thus measured energy expenditure can be used to differentiate between high GSR biometric data levels resulting from physical activity and those arising from events experienced from the environment.

3. EVENTS FOR SELF REFLECTION

We wished to explore if useful periods for self reflection from a personal lifelog containing computer activity, mobile phone activity and SenseCam images can be located based on GSR increase. To remove the effect of physical activity on GSR levels (described in Section 2), GSR data captured during periods of energy expenditure above the average energy level * σ (σ = empirically determined scalar constant) were removed from the data set. To determine correlation between event utility in self reflection and GSR we attempted to extract 10 max, 10 average and 10 min[1] GSR lifelog periods, this corresponds to 5 SenseCam and 5 computer/mobile phone periods for each GSR level from each subject's lifelog. Figure 1 depicts a 1.5 hour time period of a subject's GSR and energy expenditure data. Sample max GSR, min GSR and high energy expenditure timeframes are highlighted on the graph. The procedure for extraction of these SenseCam and computer/mobile phone events was as follows:

1. *Determining begin and end timestamps of max GSR*: Begin and end timestamps for periods in a subject's GSR dataset where the GSR level was greater than a preset threshold for an empirically determined number of seconds were recorded. (threshold = average of GSR data * υ, υ = empirically determined scalar constant)

   Determining begin and end timestamps of min GSR: Timestamps were obtained by taking periods where GSR levels were less than a preset threshold for an empirically determined number of seconds. (threshold = average of GSR data / β, β = empirically determined scalar constant)

   Determining begin and end timestamps of average GSR: Timestamps were obtained by taking periods where GSR levels were greater than threshold1 and less than threshold2 for an empirically determined number of seconds. (threshold1 = average of GSR data - α, α = empirically determined scalar constant; threshold2 = average of GSR data + γ, where γ = α)

2. *Extracting events from the subject's lifelog:* The begin and end timestamps from step 1 were used to extract SenseCam, and computer/mobile phone events as follows: *if* computer or mobile activity occurred between the begin and end timestamps, these items were extracted, *else if* SenseCam images occurred between the begin and end timestamps, these images were extracted.

On completion of this process, we had sets of 15 SenseCam events and 15 computer/mobile phone events from each subject's lifelog. These sets of events were used to test our hypothesis, as described in the next section.

4. EXPERIMENT METHOD

The goal of this research is to establish if marked GSR can be used to locate periods in a lifelog which would be useful for self reflection applications to suggest to individuals from amongst the possibly vast volumes of data contained in such archives. Time stamped personal lifelog items of varying GSR were presented to subjects and questionnaires completed to determine if our approach extracted useful lifelog periods for self reflection. Post questionnaire interviews were then conducted. This method afforded subjects time to reflect on items/events and also

[1] Max GSR = periods of high GSR; average GSR = periods of average GSR; min GSR = periods of low GSR.

maintained privacy. This section describes the details of these procedures.

One month after the test-set collection period the subjects were presented with a set of events taken from their lifelogs. A total of 30 events were included: 5 computer or mobile phone activity events with the highest max GSR and 5 SenseCam events corresponding to the highest max GSR. For comparison purposes similar sets of events were extracted with average GSR and min GSR. For average GSR the 5 computer or mobile phone activity events and 5 SenseCam events closest to the subjects average GSR were chosen (as described in previous section). For min GSR the 5 computer or mobile phone activity events and 5 SenseCam events closest to the subject's lowest GSR were chosen (also described in previous section).

Each subject was presented with their set of 15 computer and mobile phone activity events (with date/time information) and 15 SenseCam events (with date/time information). Subjects were aware that the sets presented to them contained events with varying associated GSR levels and of the specific hypothesis we wished to test. However, they were not aware of the GSR associated with each event. Subjects were free to consult their lifelogs to obtain surrounding context for events. This facility was exploited by subjects, e.g. consulting email archives to obtain reasons for a meeting captured by SenseCam images.

The subjects completed *Questionnaire 1* for these 30 events (and returned the completed questionnaire to the investigator) [2]. Details of this questionnaire were as follows:

1. Is this event memorable? (yes/no).
2. Was the event/item important to you at the time? (yes/no).
3. Is the event/item important to you now? (yes/no).

Following this, the subjects were given, in digital format, all 10 max GSR events, and average and min GSR events which they rated as memorable or important in *Questionnaire 1*. In this phase of the study subjects were informed whether items had high, average or low GSR associated with them. Again subjects had the facility to consult their lifelogs to obtain surrounding context. They then completed *Questionnaire 2* for each of these events. Details of this questionnaire were as follows:

1. Why is this event memorable?
2. How do you feel on being re-presented with this event?
3. What memories does this event bring back?
4. Do you feel the same way about the event now?
5. What significance did the event have for you at the time?
6. What significance does the event have for you now?
7. Did this event allow for self reflection? How?

The purpose of questions 1-6 was to encourage subjects to think about the events. To allow time for self reflection, subjects were given 24 hours to complete this questionnaire. To maintain privacy subjects were not required to return this completed questionnaire to the investigator. However, informal post questionnaire interviews afforded subjects the opportunity to discuss and share their completed questionnaire. The interview was largely unstructured, but specifically asked the types of reflection enabled and problems encountered with reflection.

The following section discusses the findings of this study.

5. EXPERIMENT RESULTS

Generally we found that lifelog periods with max GSR which were presented to subjects allowed for self reflection and in some cases development of self awareness, regardless of whether the subject marked these items as important (as highlighted in [9] it is often the mundane that people reflect on). Self reflections from SenseCam events included:

'I enjoy meeting with this friend, I always feel good after it….'

'I really enjoyed this activity, even though it put a lot of extra work on me, actually on thinking about it I always feel elevated when working on these types of activities….'

Self reflection from computer/mobile phone activity included:

'On being presented with this computer item I remembered how much I enjoyed the task and how much I enjoy these types of tasks in general….'

'On seeing this email message from a good friend I started laughing, it was so funny, I enjoy this friend and value their friendship…. I really need to make more effort to maintain our friendship…..'

'Looked at the SenseCam images around the time of this phone conversation, which led me to remember the phone conversation…was waiting on important news…all the memories of this event came flooding back…thinking about all this (the event associated with the phone conversation) again makes me realize that I need to prioritize…..more.'

While the majority of extracted periods associated with max GSR afforded subjects the opportunity to self reflect, there were a few exceptions, details follow.

Lack of content for instant messages (IMs) impacted on one subject's ability to self reflect, however another subject who could recall the content of the IM events presented to them did not experience this problem. Naturally, future lifelogging tools need to capture the content of such personal communications.

Some random events, such as cooking dinner, while receiving high GSR, were not useful for self reflection. One subject felt that they could *force reflection* on these images (e.g. on cooking dinner and their eating habits), and pointed out that *if required they could force reflection on most things, but that it did not feel natural.* While we have no way of knowing what would cause such events to receive a marked biometric response, we postulate that it may be due to the thought process of the subject at the time, which is now not recalled or increase in temperature while cooking for example. Generally speaking the max GSR SenseCam events presented to subjects in this study which did not focus on interaction with other people, were not found to be useful for self reflection. However this might not always be the case because as highlighted in [8], regular events such as cycling, which one might say did not involve direct interaction with others, afforded self reflection. It is not clear if this was due to the sheer novelty factor associated with viewing one's life through the eye of the SenseCam for these subjects (who wore a SenseCam for a one week period), relative to our subjects who are long term SenseCamers; whether it is due to some other factors; and indeed how both their and our findings might change if the subjects were presented with SenseCam events from the distant past.

Marked GSR SenseCam events containing events which occurred regularly, e.g. regular work meetings with a colleague, received

[2] Detailed analysis of relationship between lifelog item importance and biometric response is provided in our prior work [10].

low importance and memorable-ness ratings in Questionnaire 1. One subject reported that these events were not useful for self reflection, due to lack of audio to distinguish the event, *the images* (of a work meeting) *are general, and depict an event that regularly occurs, so I can not determine what was being discussed and cannot reflect on this event*. However, another subject while not recalling the audio associated with a regular lunch date, reflected in general terms on these lunch dates and their personal relationship with the person. Audio recordings might prove useful for events of these types, and for enabling self reflection. However, in our research center we have found that most individuals are uncomfortable with audio recording, a finding which is probably true of the general populous.

Considering the average and min GSR lifelog events which subjects marked as memorable or important, we found that subjects generally did not find them useful for self reflection. This included events such as watching TV. The trigger for GSR values in this instance may for example be the content that is being viewed [7]. The average and min GSR lifelog events presented to subjects which allowed for self reflection were found to also have periods of associated high GSR (but did not rank in the top 5 GSR events presented to subjects in this evaluation). For example a code development task, or conference paper submission, or images depicting a colleague regularly engaged with. Subjects were reflecting on the code development task or relationship with the person, for example, as a whole.

These results suggest preliminary support for the use of max GSR as a jump in point to personal lifelog applications supporting self reflection. The next section discusses conclusions and some future work requirements.

6. CONCLUDING REMARKS

Self reflection and development of self awareness are important adult processes. In this paper we have explored the utility of using marked GSR as an indicator of personal lifelog periods which would be useful for self reflection. A definitive utility for the role of GSR as an enabling technology for lifelog applications supporting reflection and self awareness cannot be drawn from this preliminary study. However, it does show support for further investigation on this topic. We also hypothesize that the technique may have utility in other lifelog applications, for example in extracting items or events to present to an individual when browsing or searching a lifelog collection. It is acknowledged that this study was conducted on a limited number of subjects over a short period of time. Investigation using more participants, over a longer timeframe is required to further test our conclusions. Additionally, we would need to either capture more information to make these lifelogs useful for self reflection or possibly presenting related content, either contextually or semantically could overcome the content limitations revealed in this study. The presentation of a greater number of events to subjects for self reflection would also be beneficial in evaluating the technique presented in this paper. Also presenting subjects with a greater number of min and average GSR events beyond those which they found memorable or important (as was done in this study) might prove useful for comparison purposes.

Further, while removing of periods of physical activity allowed us to remove the effect of physical activity on GSR, it is possible that in doing this we also removed events which had potential utility in self reflection. Future work needs to consider other techniques for accounting for physical activity, through the use of dividing GSR by energy expenditure for example.

The subjects were reflecting on items and events that occurred only one month earlier, the utility of this technique for supporting self reflection applications over the longer term also needs to be investigated. As well as the types of data that will be useful for long term reflection. For example, for computer activity we found both interactions with other people (e.g., via email) and computer tasks engaged in by the subject to be equally beneficial for self reflection. However, whether data such as computer code, for example, will hold the same meaning or afford the same opportunity for reflection for subjects over the longer term needs to be investigated.

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