AffectCam: Arousal- Augmented SenseCam for Richer Recall of Episodic Memories

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Abstract
This paper describes the design and evaluation of AffectCam, a wearable system integrating SenseCam and BodyMedia SenseWear for capturing galvanic skin response as a measure of bodily arousal. AffectCam's algorithms use arousal as a filtering mechanism for selecting the most personally relevant photos captured during people's ordinary daily life, i.e. high arousal photos. We discuss initial findings showing that emotional arousal does improve the quality of memory recall associated with emotionally arousing events. In particular, the high arousal photos support richer recall of episodic memories than low arousal ones, i.e. over 50% improvement. We also consider how various memory characteristics such as event itself together with emotions and thoughts at the time of encoding, as well as its spatio-temporal context are differently cued by the AffectCam.

Author Keywords
Emotional episodic memories; recall; cues; arousal, SenseCam, galvanic skin response.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

Episodic memories lie at the core of our sense of identity, yet they become fragile when people suffer from debilitating memory impairments such as those caused by Alzheimer's illness. Cues for supporting episodic memories have been primarily verbal or visual [2], with a wealth of HCI studies showing that wearable cameras for automatic photo capturing such as SenseCam [13] are highly beneficial in supporting their recall. Despite its potential, one problem yet to solve is tackling the large number of over 1000 photos captured over a day of SenseCam use. These photos are difficult to browse in order to identify the most relevant ones for cueing the recall of specific episodic memories.

Findings from Experimental Psychology support the hierarchical organization of autobiographical memories and the significant role of emotions in their encoding, consolidating and retrieval [1][5][8]. Emotional arousal (rather than valence) through its ability to signal events' importance and self-relevance has been shown to particularly support recall. Although the integration of SenseCam images with physiological markers for the identification of events leading to emotional arousal has been previously suggested [13], such a system has not yet been developed.

This paper introduces AffectCam, a wearable system integrating SenseCam and BodyMedia SenseWear for capturing and using arousal as a filtering mechanism for selecting the most personally relevant SenseCam's photos.

Related work

The value of autobiographical memories for the enduring sense of self cannot be overemphasized [5]. This information on what the self was, is and can be [6] provides material for the generalizations about the self. Various models have been proposed with respect to the organization of autobiographic memories highlighting the value of emotional self-relevant information for organizing and cuing retrieval [1][8]. For example, Conway's model [5] emphasized the role of current goals of the working self in accessing autobiographic memories, while Linton [19] placed mood tone at the top of her hierarchical model. In addition, a wealth of studies has shown that emotional relevant events are more likely to be remembered [10],[15].

Various cues have been identified for prompting retrieval of episodic memories. Burt's findings [2] showed that *what and where* an event occurred, and *who* was involved are most efficient retrieval cue, while information on *when* it occurred being less recalled. Findings also showed that perceptual, sensory and semantic elements (and not contextual and temporal ones) are better recalled for emotional events, suggesting that emotional memories are more vivid but not more contextually-specific [14][21].

Among the various cues for prompting retrieval of autobiographical memories, an important one is arousal with intense memories being remembered longer and more vividly [24]. Evolutionary perspective also emphasizes the adaptive value of arousal [11], as emotional intensity has been associated with the appraisal of events' significance and relevance to one's goals [18].

Cahill's theory argues that emotional arousal of specific episodic events is conducive to quicker retrieval [2], as arousal signals event's importance, urgency and self-relevance [15]. Easterbrook's cue-utilization theory [10] also predicts that information central to the source of emotional arousal is better encoded then peripheral details.

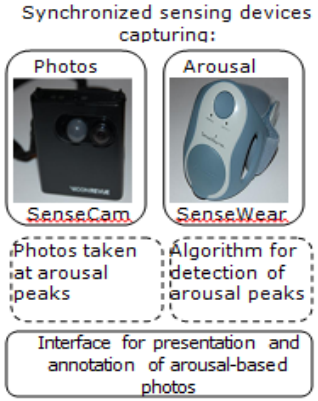

Figure 1: AffectCam system components

Figure 2: AffectCam interface

To summarize, emotions and in particular emotional arousal are important aspects in organizing and cuing episodic memories. However, most of the work exploring its role involved lab-based studies where emotions were induced through verbal or visual stimuli, with fewer studies focusing on emotion triggered by everyday autobiographical events [7]. This is nevertheless an important distinction, as the emotion at the time of encoding relates to one's involvement, empathy and goals at a more personal level than the engineered emotional cues with the lab setting [16]. This paper addresses this gap to further explore if the benefits of emotional arousal extend to everyday autobiographical events.

HCI work on memory aids

Most of the HCI research on episodic memories has focused on memory aids for supporting retrieval, with an emphasis on visual cues. A wealth of studies have shown SenseCam's benefits for supporting recall of episodic memories [2], both as remembering and knowing about the past [22]. Lee and Dey found that SenseCam photos should be recognizable or personally significant and that they capture four distinct types of cues: people, objects, places and actions [17]. Kalnikaite et al.'s [15] findings showed that visual cues promote better recall, whereas locational information supports inferences about patterns of behavior. Doherty et al. developed algorithms for automatic segmentation of visual lifelogs into events by computing event similarity and importance [8].

StartleCam's photos [12] are saved when events of interest are identified through changes in user's skin conductivity. The system was tested in a startle eliciting experiment on eleven participants exposed to audio bursts. Although StartleCam could be used in real life, its design is rather cumbersome and its evaluation does not provide support for the claim of improved recall.

System Overview

AffectCam system integrates two commercial wearable systems (Figure 1), i.e. SenseCam and BodyMedia SenseWear. SenseWear has been used to monitor emotional arousal in various HCI applications for stress management such as Affective Diary [23] and Affective Health [20]. Its embedded accelerometer and temperature sensors also made it a suitable candidate for systems such UbiFit for weigh management [4] and Houston for physical exercise [3].

Data fusion

AffectCam includes algorithms for multi-sensor data integration. A XML parser decomposes the SenseWear data file and retrieves the GSR readings, which are converted into vectors and stored in an object instance of the Java program. A simple algorithm was developed to parse the creation dates of photos taken by the SenseCam, and search the time stamps of the corresponding vector of the GSR readings from the SenseWear. For identifying the peaks of emotional arousal, another algorithm finds sequences of consecutive GSR readings where each value is higher than its predecessor, and creates a peak object consisting of start and end times of the peak, its height, differences between readings and score. The latter is computed by dividing the overall relative height of the peak by the number of readings in the sequence. To ensure minimal computations this algorithm for identifying peaks in GSR data is of constant complexity.

User Interface

The interface consists of two views for choosing recorded sessions and photo viewing that allows for browsing all photos within the data file Users could cycle through them and make annotations on the current photo (Figure 2).

Figure 3: High arousal photo
"*That was when I was getting ready to leave for the meeting. Getting all my stuff together. I don't know what I was feeling... Probably excited about mulled wine. That would have been just before half 11.*"
[Score 3: 1 for event, 1 for time, 1 for emotion]

Figure 4: Low arousal photo
"*I was looking… I don't think that's … I think that's… oh it's my work. I'm doing my work in the library at this point and there's my book in the corner. I think I'm just doing my work.*"
[Score 2: 1 for place, 1 for event]

Method

The aim of the study is to explore the value of arousal-stamped photos for cuing recall of episodic memory during the end of day review. This research tackles the following there research questions:

(i) Can arousal be used to filter the large number of SenseCam photos to a subset of photos able to trigger richer recall of personally significant events?
(ii) Do the SenseCam photos taken during events triggering high arousal support better recall of episodic memories than those of low arousal photos?
(iii) What specific aspects of episodic memories are better recalled for high arousal photos as opposed to low arousal ones? Is it thoughts and emotions as opposed to spatio-temporal context?

Sample and Procedure

The sample consisted of 14 participants, 7 males, 7 females, aged between 18-23 years old. For increased ecological validity, the experiment was conducted in participants' natural environment, during their normal daily activities. Arousal has not been artificially induced nor self-created, neither self-rated, but arising naturally through participants' engagement in their current tasks, and measured continuously, objectively and unobtrusively through the GSR sensor. This experimental design is unique, addressing the limitations of previous, predominantly lab-based studies on emotional autobiographical memories.

Participants were given a short induction session where both SenseCam and SenseWear sensors were described and invited to wear them for at least 6 hours during that day. At the end of the day, each participant was individually interviewed. During this second meeting, the data from both sensors was collected and input into the AffectCam system to identify top 4 high arousal (example in Figure 3) and 4 low arousal SenseCam photos (example in Figure 4). Each of these photos was given as cue for prompting the recall of the event captured by the photo, and participants were instructed to recall as many details about the event as possible.
The interviews were audio recorded and fully transcribed.

We looked at some specific measurements of episodic memory recall such as richness captured through a range of details including reference to the event taking place, event context such as place and time, as well as associated thoughts and emotions experienced during the event. Such coding of episodic memory recall has been previously employed, as part of the larger coding scheme used by Levine et al. in the Autobiographical interview [18] and Johnson's et al Memory Characteristics Questionnaire[14].

Thus, memory cued by each photo was segmented into informational details scored separately such as (i) event, (ii) thoughts, (iii) emotions, (iv) place, and (v) time. For each photos, we assigned one point for each of the five measured aspects if explicitly stated, or zero otherwise not. For instance, "That's in my room before the meeting when I was just writing some notes for the presentation" contains three details: an event (writing notes), a location (my room), and a time (before the meeting), and was scored 3 (1 point for event, 1 for location, 1 for time and 0 for thoughts and emotions). For each memory recall, participants received a score of minimum 0, when no details were recorded and maximum 5, when all 5 memory characteristics were recalled.

Findings

Arousal information as filtering mechanisms

Descriptive statistics of the data show that the average score of overall recall is much larger when cued by the high arousal SenseCam photos as opposed to low arousal ones. Employing arousal as a filtering mechanism has successfully led to an increase in the overall recall score above 50%. This also helps towards a significant reduction of the number of photos to a few most personally

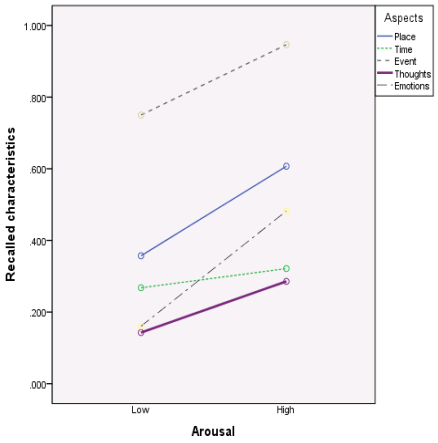

Figure 5: Mean number of recalled characteristics for high and low arousal photos

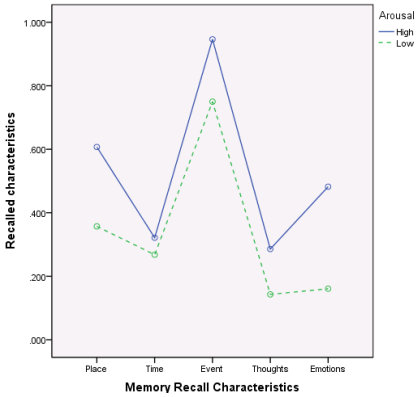

Figure 6: Mean number of each type of recalled characteristics

relevant. For example, from a 6 hours recording, participants have automatically gathered over 700 SenseCam photos which would considerable time to be browsed. Arousal-based filtering is a promising mechanism. In our study we selected only 1% of photos, showing that richer recall can be successfully supported. Future work shall focus on testing if these results hold true for 5% of the photos selected on the basis of arousal at the time of encoding.

We also employed a two-way 2x5 repeated measures ANOVA, with arousal (high, low) and recall characteristics (event, thought, emotion, place and time) as independent variables, and recall score as dependent variable. The presentation of findings is organized along the three research questions previously identified.

Richer episodic memory recall for high arousal photos
We consider the number of memory characteristics cued by the two sets of photos, i.e. high and low arousal. Figure 5 shows the mean number of recalled characteristics for each level of arousal, indicating a clear effect of arousal. On average, the number of recalled characteristics for high arousal SenseCam photos was significantly higher than for low arousal photos ($F(1,52)=20.56$, $p < 0.01$, $\eta^2 = 0.61$).

Better recalled characteristics of episodic memories
We also consider the mean number of each of the five memory characteristics recalled by participants. Figure 6 also shows a main effect, this time of memory characteristics, suggesting that the event itself, its place and associated emotions are recalled better than event's time and occurring thoughts, irrespective of arousal ($F(4,52) = 21.88$, $p < 0.01$, $\eta^2 = 0.63$). Further post-hoc analysis through paired t-tests, revealed that high arousal photos cue richer recall consisting of significant more accounts of emotions ($t(13) = 3.23$, $P < 0.001$), events' place ($t(13) = 2.88$, $p < 0.013$), events as description of what has occurred ($t(13) = 2.80$, $p < 0.015$), and thoughts experienced at the time of the event ($t(13) = 2.28$, $p < 0.04$). No significant difference was found between the recall cued by high and low arousal photos, in terms of the specific time when an event has occurred.

Discussion

The study findings suggest that emotional arousal does improve the quality of memory recall associated with emotionally arousing events. It showed that arousal can be an efficient mechanisms for reducing the large number of SenseCam photos, and that high arousal photos support richer recall of episodic memories than low arousal ones, i.e. over 50% improvement. The specific characteristics of memories that are better recalled confirm previous findings on memory cuing, i.e. events themselves and their associated emotions are better recalled for high arousal photos, whereas the temporal aspect of the event is equally recalled by the two sets of photos.

Our study also reveals two surprising findings. Firstly, there seems to be no difference between the recall of thoughts cued by the high and low arousal photos, although thoughts at the time of encoding are among the important characteristics of emotional memories [14].

Secondly, the contextual spatial aspect that previous work suggested that should not be better recalled for high arousal events, is in fact better recalled when cued by high arousal photos. While most of the previous work has focused on verbal cues, it may be the visual aspect of our SenseCam cues that offer explicitly localisation information, which therefore does not need to be recalled but merely recognised.

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