O Job Can You Return My Mojo? Improving Human Engagement and Enjoyment in Routine Activities

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ABSTRACT

Unlike machines, we humans are prone to boredom when we perform routine activities for long periods of time. Workers' mental engagement in boring tasks diminishes, which eventually, compromises their performance. The result is a double-whammy because the workers do not get job satisfaction and their employers do not receive optimal return on investment. This paper proposes a novel way for improving workers' mental engagement and hence, enjoyment, in routine activities. Specifically, we propose to blend in routine tasks mild mental/physical challenges. To test our hypothesis, we chose to experiment on a monitoring task typical of security guard operations. We combined this routine task with an iPhone-based game to make it more enjoyable. The results from 10 participants show that their mental engagement and enjoyment were significantly higher during the combined task.

Author Keywords Human-Computer Interaction, human engagement and performance, computer games, stress monitoring, thermal imaging.

ACM Classification Keywords

H5.2. Information interfaces and presentation: User Interfaces – Evaluation/methodology, Input devices and strategies, Prototyping, Interaction styles.

General Terms

Experimentation, Human Factors, Performance.

INTRODUCTION

The industrial revolution in the 19th century has significantly changed people's lives. Then, the computer revolution in the 20th century changed things even further. Nowadays, machines perform many tasks for us on a daily basis. As a result, our primary roles have switched from machine operators to monitors. For instance, only few engineers are enough to run a major power plant by simply monitoring the processes involved in the generation of electricity. In another example, locomotive drivers regularly switch the locomotive computer system into auto-mode and assume a system-monitoring role in long distance travels. Similarly, airplane pilots use the autopilot mode and spend several hours simply monitoring the airplane systems in long-haul flights. Such monitoring activities quickly become boring, as they require minimal interaction and mental engagement from the users. It has been proved that the highly automated modern flight management systems decrease pilots' performance in long duration flights [9]. A study also conducted on truck drivers showed a negative correlation between boredom and performance [5]. In fact, boredom is one of the major factors in unsafe driving [4].

Another classical example of monotonous activity is the work of security guards, who are required to stare at the rarely interesting security video feeds for hours. Still, if they miss a single suspicious event, it could cost a lot to them and their employers. Recently, the Government Accountability Office (GAO) tested the effectiveness of private security guards at Government buildings. During their covert investigations they reported that guards failed to perform their security monitoring tasks because of lack of attention and interest [2]. Therefore, it is very important to improve on motivation and work enjoyment in such cases.

Researchers have studied the effect of interruptions on boredom at work. It appears that in certain tasks, interruptions may have a positive effect [7] [10]. In fact, interruptions facilitate performance on simple tasks, while inhibiting performance on more complex tasks [25]. Monitoring is a simple, but boring task, and innovative forms of interruption may render it more enjoyable.

One way to improve enjoyment is to increase the users' mental and physical interaction with the monitoring task. Sarter et al. and Zavalova et al. in their independent studies showed that playing an interactive role enhances users' performance [22] [30]. Hence, we propose to blend computer games in monotonous monitoring activities. This intervention will empower users to an interactive role rather than let them passively monitor the systems' activities.

There are several computer games designed to enhancing human behavior. For instance, computer games are widely used in teaching materials to endear learning [1] [19]. There is evidence that gaming may change people's behavior – a mighty difficult accomplishment [8]. For example, Lanningham-Foster et al.'s [13], Dance-Dance Revolution [12] and EyeToy [26] games have proved to be effective in obesity prevention. Khalid et al. designed a persuasive game about smoking cessation [11].

However, little has been done to use computer games in improving the enjoyment factor during monotonous monitoring activities. In this study, we designed and implemented a simple computer game that can be played via iPhone. Mobile phone-based games provide a ubiquitous framework. Hence, they can be played anytime, anywhere.

For our application, an important design factor is the intensity of mental engagement. The game should not be intensely engaging in a way that distracts users from their primary monitoring task. We designed a fruit catching game where the users try to catch apples and grapes falling from the sky. This mildly engaging game creates minimal divided attention, yet it provides some entertainment to users who perform a parallel monotonous task.

In fact, the proposed design aims to reinforce rather than detract attention from the monitoring task. To fulfill this goal, we overlaid the game on the monitoring screen. Thus, users still focus on the monitoring display while playing the game.

Boredom is a psychological state that is experienced during uninteresting activities. It can result in reduced ability to perform cognitive tasks [15]. Previous research proved that boredom plays a significant role in performance decline. In this research we propose a new way to reduce boredom by integrating entertaining activities into routine tasks. We included participants' feedback survey, performance and facial physiology to test our hypothesis.

Boredom brings physiological changes similar to those experienced during sleepiness and fatigue; these include lower heart and respiration rates [3]. Therefore, boredom can be tracked through monitoring of physiological variables. In this study, we used a thermal imaging-based system known as *StressCam* to monitor facial physiology [20] [28].

It monitors temperature changes on the supraorbital region, which are indirect indicators of changes in mental load. When a combination of game events demands interactive responses from the users, it raises their alertness, which elevates blood flow in the supraorbital vessels and frontalis muscle. This increase in local blood flow raises the supraorbital region's temperature, which can be captured through the thermal camera. Therefore, we used StressCam to determine the participants' psychological states through facial physiological measurements during passive and interactive monitoring roles.

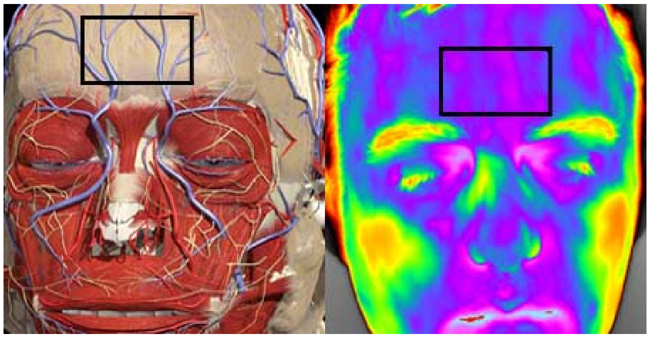
FACIAL PHYSIOLOGY AND MENTAL ENGAGEMENT

In recent years, Pavlidis and his colleagues have demonstrated the importance of the supraorbital region in sustained mental engagement [20] [17] [31]. Yun et al. have successfully applied this concept in developing a user-centric game design [28]. Shastri et al. have used supraorbital signals to quantify mental overloading of machine operators [24].

The supraorbital vessels are located superficial to the skin in the middle of the supraorbital region (see Figure 1 (a)). Thermal imprints of the vessels appear very clearly in thermal imagery (see Figure 1 (b)). Thus, thermo-physiological measurements in this region are feasible and provide an indication of the users' mental engagement and psychological state. Specifically, we quantify sustained engagement by computing the rate of the supraorbital temperature change over a certain period. Thus, its unit of measurement is °C/min.

STRESSCAM

StressCam was first developed in 2005 [20]. It is a high quality Thermal Imaging (TI) system. The centerpiece of the system is a Thermo Vision SC6000 Mid-Wave Infrared (MWIR) camera from FLIR [6]. The camera is a cooled type, which uses an Indium Antimonite (InSb) detector. It records electromagnetic energy with wavelengths between 3-5 μm. The system's mean thermal sensitivity is 0.025^0 C, its acquisition speed 25 frames per second (fps), and its spatial resolution 640x580 pixels. StressCam uses a MWIR 100 mm lens and is equipped with pan-tilt [21] and motorized focus mechanisms to locate the target. It also uses a differential blackbody for thermal calibration [23].



(a) **(b)**

Figure 1. Typical anatomical and thermal images of the face. The supraorbital area is delineated in black. (a) Facial anatomy [14] (b) Facial thermal image of a participant.

EXPERIMENTAL DESIGN

We selected monitoring of security video footage as a test bed. This task is notoriously boring and can be implemented with little experimental cost. Still, the findings can be extended to other monotonous monitoring scenarios, such as monitoring industrial process control systems.

We used a pre-recorded mock security video footage of one hour in length. It was recorded with a Sony DCR-SR40 camcorder in three office spaces (see Figure 2). The footage contained mostly normal office activities, and on average about three suspicious activities per room, including stealing activities (e.g., stealing books, laptop and some documents) as well as property damage activities (e.g., destroying a poster).

We designed and implemented a simple fruit catching game that runs on the Mac platform. The design is based on a client-server architecture, whereby the game runs on the server (Mac) and is controlled via an iPhone (the client). Specifically, the player controls the position of the fruit basket via an iPhone based game controller (see the overlaid basket in Figure 2). The goal is to catch wanted objects (e.g., good apples and grapes) and avoid unwanted objects (e.g., bad apples and snakes) that are falling from the top of the game display (see the overlaid red apple in Figure 2). Positive versus negative scores are assigned for catching good objects versus bad objects respectively. The game displays only one falling object at a time, which allows the users to clearly view the background security footage. Overall, the game design aims to bring some entertainment to the users without sacrificing their monitoring performance. The use of iPhone provides a ubiquitous game controller.

A total of 11 participants (10 males and 1 female) volunteered for this study. Their age ranged from 18 to 45. The experiment featured two trials spaced one week apart. In one trial the participants were asked to monitor the hour-long security video footage and document any suspicious activities (‘*without game*’ trial). This trial simulated a boring activity. In the other trial, the participants were asked to perform the same task while playing the fruit catching game (‘*with game*’ trial). This trial introduced an interactive role for the users. A total of 5 participants were assigned the ‘*without game*’ trial during their first visit and the ‘*with game*’ trial during their second visit. The reverse order applied to the remaining 6 participants. This randomization ensured unbiased results. Since we used the same security footage in both trials, the weeklong gap was necessary to weaken the memory.

Figure 2. Security video footage and the overlaid game.

Figure 3 illustrates the experimental setup. Before the experiment began, the participants were asked to complete a biographic questionnaire. After completing the questionnaire, they were asked to relax for 3 minutes. We let the participants listen to soft/calm music during the relaxation phase. This helped to isolate effects of other stress factors that the participants may have carried from earlier in the day.

Then, the participants were presented with pictures of individuals who were authorized to access the three offices. This information served as the prior knowledge, which in most cases is available to security guards. Next, the participants were asked to perform the monitoring task for an hour. They were required to note down every suspicious activity that they noticed in the security footage. We used this information to compare their performance in each trial. The participants’ facial thermal signature was recorded throughout the monitoring phase. The thermal data was later used to analyze the participants’ physiological responses. A QuickCam Orbit AF web camera from Logitech concomitantly recorded video footage of the participants throughout the monitoring phase. This proved useful in visual verification of sleepiness in some instances.

The participants were asked to complete the following feedback survey upon completion of each trial:

1. **Motivation:** How motivated have you been regarding this task?

2. **Entertainment:** How much did you enjoy the task?
3. **Mental demand:** How mentally demanding was the task?
4. **Performance:** How successful were you in finding suspicious activities?
5. **Effort:** How hard did you have to work to accomplish your level of performance?
6. **Physical demand:** How physically demanding was the task?

The feedback questionnaire was designed based on the NASA Task Load Index [16] and the scores used to analyze the participants' subjective responses.

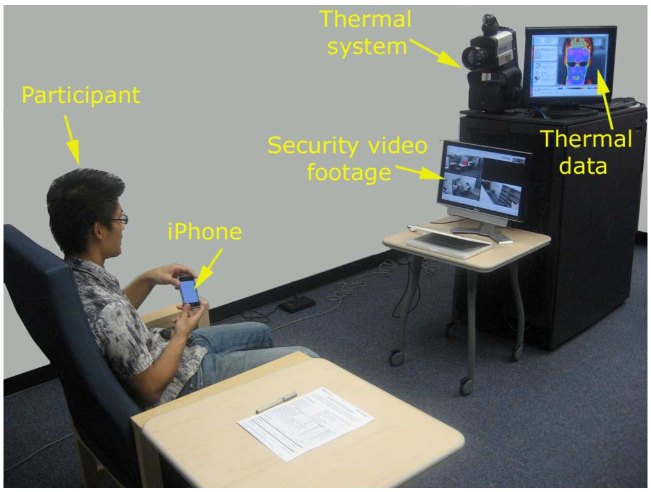


Figure 3. Experimental setup: Participant, imaging, and gaming equipment.

It is important to understand the rationale behind the lengths selected for the relaxation and monitoring sessions. The length of 3 minutes for the relaxation period was determined based on previously conducted experiments of the same type. Too short a relaxation period would not allow the participants to sufficiently cool down, while too long a relaxation period and they may fall asleep. The length of 60 minutes for the monitoring period was a trade-off between the following two practical requirements: Data sufficiency to conclude the experiment and accommodation of the participants' busy schedule. Every participant spent on average 1 hour and 30 minutes per visit. Thus, the total time commitment was 3 hours for every participant.

METHODOLOGY

On the initial frame of every thermal clip, we manually selected a Tracking Region of Interest (TROI) such that it encompassed the supraorbital region as shown in Figure 4. The TROI was then tracked over time via a facial tissue tracker [29]. The tracker handled well various head poses, partial occlusions, and thermo-physiological tissue variations. The tracker estimated the best matching region in every next frame of the thermal clip. Based on these estimates the mean temperature of the Measurement Region of Interest (MROI) was computed for every frame. The MROI was selected to be smaller than the TROI and strictly within the supraorbital region for the measurement to make sense (see Figure 4). Intentionally, the encompassing TROI was selected to cover a wide area with contrasting features including the colder eyebrows and hair, as well as the hotter periorbital region. This ensured higher stability for the tracker and resulted into less noisy MROI signals.

Thus, a 1D supraorbital temperature signal was extracted from the 2D thermal data. However, due to imperfections in tissue tracking and systemic noise, the 1D measurement still carried substantial noise. We suppressed the noise to a large degree by using a Fast Fourier Transformation (FFT) based noise reduction technique [27]. Then, we modeled the noise-cleaned signal by fitting a linear polynomial. Eventually, every signal was represented by the rate of temperature change (slope of the polynomial). This temperature change was the result of altered blood supply in the supraorbital region - an indirect, but objective, quantification of mental engagement [20].

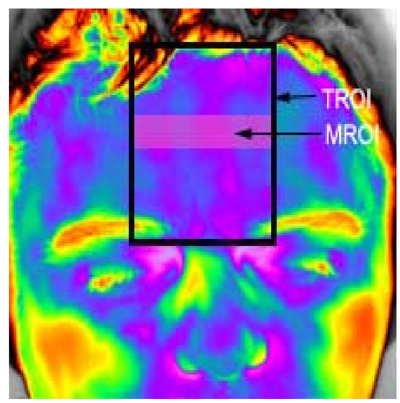


Figure 4. The supraorbital signal was extracted from the mean thermal footprint of the pink colored region (MROI).

We also have derived three variables from the participants' performance data: Correct identification, false positive, and false negative. The *correct identification* variable represents the number of correctly identified suspicious activities. The *false positive* variable represents the number of normal activities that were misclassified as suspicious activities. The *false negative* variable represents the number of suspicious activities that were misclassified as normal activities.

Finally, we have derived six subjective variables from the six survey questions we asked the participants: Motivation, Entertainment, Mental demand, Performance, Effort, and Physical demand.

We performed statistical analysis on the participants' supraorbital signals, performance variables, and subjective variables. Specifically, for each of the experimental variables we performed a paired T-test to examine their significance in discriminating the monitoring task in the '*without game*' trial from the '*with game*' trial. We also performed hypothesis testing to prove that supraorbital slopes in the '*with game*' trial are higher than those in the `*without game*' trial.

EXPERIMENTAL RESULTS

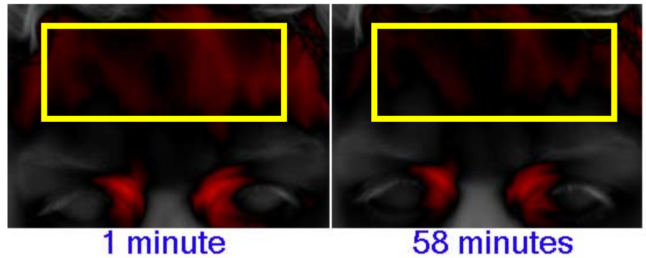
To recap, data from three channels were analyzed to validate our hypothesis that integrating a meek interactive activity to the boring task improves the users' enjoyment and mental engagement without sacrificing their performance. First, we used the rate of change of the supraorbital temperature to determine the participants' mental engagement. Second, we used performance data, which indicated the impact of the game on the quality of the monitoring work. Third, we used subjective feedback data to evaluate the participants' enjoyment while performing the task.

For participant-10 we did not get the thermal data for the '*without game*' trial due to an operator error. Thus, we excluded this participant from any further consideration and applied our analysis on the remaining 10 participants.

Figure 5 shows a visualization of the thermal signature of the supraorbital region when participant-11 performed the monitoring activity without playing the game. Since this was a boring activity that required no interaction from the participant, he quickly assumed a passive monitoring role. As a result, his supraorbital temperature declined throughout the trial. This is a sign of mental disassociation from the current activity. This result is in agreement with his subjective feedback, which indicated that the participant was bored while performing the task (see the subjective feedback shown in Figure 7). Also, we noticed from the visual data that the participant was dozing at many occasions during this trial. In contrast, we did not find any single occasion of sleepiness during his '*with game*' trial.

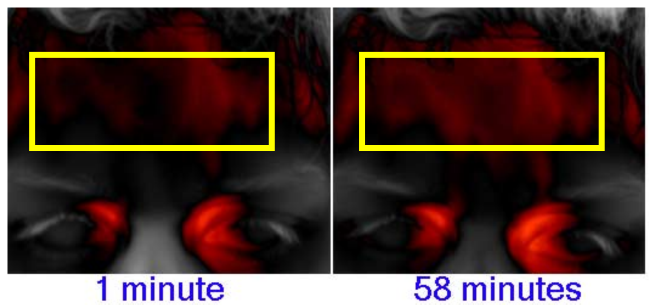
Figure 6 shows a visualization of the thermal signature of the supraorbital region when participant-11 performed the monitoring task while simultaneously playing the game. This trial required interactive response from the participant. Hence, the participant remained mentally engaged. As a result, his supraorbital temperature was elevated towards the end of the trial as compared to the beginning. This result is in par with his subjective feedback, which indicates that he was more motivated and entertained in the '*with game*' trial (see the subjective feedback shown in Figure 7).

Thus, qualitative analysis of the physiological data indicates that the participant was more mentally engaged in the monitoring task during the '*with game*' trial. His subjective feedback supports this qualitative result confirming that he enjoyed the monitoring task in the '*with game'* trial more than the '*without game'* trial. The *correct identification* values shown in Figure 7 demonstrate that improved mental engagement and hence, enjoyment was achieved without sacrificing performance.



(a) (b)

Figure 5. (a) The supraorbital region, delineated in the yellow colored rectangle, at the beginning of the '*without game*' trial. It represents normal blood flow. (b) The supraorbital region at the end of the same trial. The light red region is indicative of low mental engagement or sleepiness.



(a) (b)

Figure 6. (a) The supraorbital region, delineated in the yellow colored rectangle, at the beginning of the '*with game*' trial. It represents normal blood flow. (b) The supraorbital region at the end of the same trial. The bright red region is indicative of strong mental engagement.

The supraorbital signals in Figure 7 reveal the participant's psychological state at every point in time. An important observation is about the global trend of the supraorbital signals in the two trials. The global ascending trend in the `*with game'* trial (see the blue curve in Figure 7) confirms that the participant was engaged in the game. In contrast, the signal has global descending trend during the `*without game'* trial (see the red curve in Figure 7), which indicates disassociation due to boredom. It is interesting to observe that the signal in the `*without game'* trial features an ascending trend for the first 15 minutes of the experiment, which indicates some mental engagement. However, this temperature increase (approximately 0.15 °C) is dwarfed by a much larger temperature decrease (approximately 0.30 °C) in the remainder of the trial. Since the participant was exposed to the monitoring task for the first time, he showed some interest in the beginning of the trial. However, he quickly lost his interest due to the monotonous nature of the task.

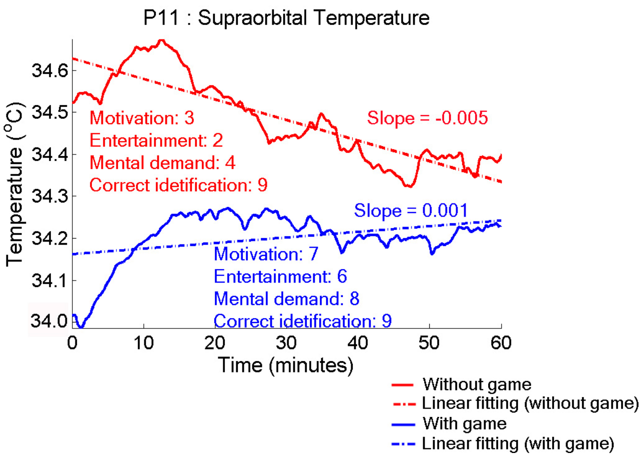


Figure 7. The graph illustrates objective and subjective data of mental engagement for both trials; performance data, too. The values of the subjective variables (Motivation, Entertainment and Mental demand) range from 1 to 9. The Correct identification performance variable has maximum value equal to 10.

On the other hand, the signal in the `*with game'* trial features an ascending trend (approximately 0.25 °C) for the first 20 minutes of the trial and then it stabilizes for the remainder of the trial. The signal architecture denotes sustained mental engagement. Specifically, the participant's engagement was higher at the beginning of the trial as he was exposed to a novelty in the monitoring task. He then maintained his engagement for the remaining of the trial because he enjoyed the interactive game playing activity.

We believe that the novelty factor plays an important role in engagement. If the participant plays the same game for a longer period of time or repeatedly, then it may become less engaging to him/her. One possible solution is to give users an assortment of mildly engaging games, from which they can choose on occasion. The novelty factor, however, is out of the scope of this research and will be considered in the future. In the present effort, we focused on understanding the impact of an interactive activity in a routine monitoring task.

The results we presented for participant-11 are representative for all participants but one. Participant-2 did not exhibit significant difference in her mental engagement and enjoyment in the `*with game'* trial versus the '*without game*' trial. During the debriefing, the participant revealed that she did not find the particular game very engaging. This case actually shows that the primary routine task can only be made enjoyable if the secondary interactive activity is interesting to the user.

The hypothesis we are interested in testing is if the '*with game*' trials have statistically significant higher supraorbital slopes than the respective '*without game*' trials. Table 1 shows the power analysis results for all 10 participants for whom we have complete data.

Participant	T-statistic	P-value	Better with game?
P1	16.04	≈0	YES
P2	–12.63	≈1	NO
P3	80.12	≈0	YES
P4	36.57	≈0	YES
P5	55.78	≈0	YES
P6	46.65	≈0	YES
P7	86.27	≈0	YES
P8	12.37	≈0	YES
P9	13.74	≈0	YES
P10	Missing "Without Game" data		
P11	87.60	≈0	YES

Table 1. Power analysis results for supraorbital signals.

To further test the validity of our hypothesis, we performed statistical analysis on the performance and subjective variables. Specifically, we were interested to examine whether the variables can reveal any statistically significant difference between the two trials. For every variable, we first computed the difference in the values between the two trials. Then, we performed paired-T test on the differences of each variable.

Table 2 summarizes the test results for the performance variables. It shows that all variables have favorable response with the game, but the difference was not statistically significant with 95% confidence interval. Thus, even with the improved mean, we cannot conclude that playing the game has improved participants' performance on surveillance. However, it is worth to note that the p-values were quite small in *correct identification* and *false negative* cases, which indicates the possibility of obtaining significant difference with more samples. Also, it is equally important to mention that the performance did not decline for any of the participants during the `*with game'* trial. Thus, the game play did not create any adverse effects on the participants' performance.

Variable	Mean Difference	T-ratio	P-value	Better with game?	Statistical Significant?
Correct identification	–0.36	–1.90	0.09	YES	NO
False positive	0.27	0.64	0.54	YES	NO
False negative	0.36	1.90	0.09	YES	NO

Table 2. Paired T-test results for the performance variables.

Table 3 summarizes the test results for the subjective variables. It shows that all subjective variables except for *self-reported performance* have positive response with the game. The differences were statistically significant in *entertainment* and *mental demand* with 95% confidence interval. This result shows that the game made the monitoring job more entertaining and mentally engaging for the participants. It is worth to note that the p-values for *effort* and *physical demand* were quite small, which indicates the possibility of obtaining significant differences with more samples. The game interaction required the participant to put more effort and physical activity. Therefore, the participants' responses were higher for these two variables.

Variable	Mean Difference	T-ratio	P-value	Better with game?	Statistically Significant?
Motivation	–0.82	–1.24	0.242	YES	NO
Entertainment	–1.64	–4.85	0.001	YES	YES
Mental demand	–1.91	–4.18	0.002	YES	YES
Performance	0.18	0.61	0.553	NO	NO
Effort	–1.27	–1.85	0.094	YES	NO
Physical demand	–1.18	–1.76	0.109	YES	NO

Table 3. Paired T-test results for the subjective variables.

In conclusion, we can claim from this statistical analysis that combining a mild interactive activity with a boring routine activity can improve the users' mental engagement and entertainment without sacrificing their performance.

DISCUSSION AND CONCLUSIONS

Our work demonstrates the feasibility of applying a mild mental activity to a boring routing task for improving user enjoyment. We analyzed facial physiology, subjective feedback, and performance data of 10 participants to validate our hypothesis. Our analysis confirms that an interactive gaming activity can improve users' mental engagement and entertainment in a monotonous monitoring task.

Our study used as test bed, monitoring of security footage – a specific boring activity. However, the proposed model can be extended to other monotonous monitoring tasks. For instance, the proposed system can reduce boredom of airplane pilots who spend several hours monitoring the airplane systems in the autopilot mode. To the best of our knowledge, this is the first experimental research effort towards applying mild interactive games in monotonous monitoring tasks.

The major limitation of this work is the insufficient game choices presented to the participants. We used only one game in the study due to limited resources. Therefore, the participants were forced to use the game whether they liked it or not. As a consequence, the game was moderately interesting to some of the participants and therefore, their performance was suboptimal in the experiment. We plan on developing an assortment of ubiquitous games for future studies. However, we must emphasize that developing mildly engaging, yet interesting games requires significant effort in terms of game design.

Another limitation of this effort is that it is fixed on gaming as the only interactive paradigm for arousing the interest of participants. In reality, this is one of many potential paradigms that can be used to good effect.

This model may not work for boring activities that have an innate interactive element. A case in point is the data entry task. The data entry task is indeed a boring task but has a different profile than passive monitoring tasks. Therefore, it introduces some practical difficulties that need further consideration.

The current feasibility study opens new potential directions of research in the area of user entertainment enhancement in routine activities. We plan on extending this research on a longitudinal study where participants will repeat the same tasks many times in longer trial periods. This will provide more insight into the problem. Especially, the impact of the novelty factor on boredom will be thoroughly tested in such a study.

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REFERENCES

1. Aldrich, C. *Simulations and the future of learning: An innovative (and perhaps revolutionary) approach to e-Learning*. Pfeiffer, San Francisco, CA, USA, 2004.
2. CNN News. http://www.cnn.com/2009/POLITICS/07/07/federal.buildings.security/
3. Cox, R. *Sport Psychology: Concepts and Applications,* Brown and Benchmark Publishers, Madison, WI, USA, 1994, 92-132.
4. Dahlen, E.R., Martin, R.C., Regan, K., and Kuhlman, M.M. Driving anger, sensation seeking, impulsiveness, and boredom proneness in the prediction of unsafe driving. *Accident Analysis & Prevention 37*, 2 (2005) 341-348.
5. Dropy, A. Individual differences in boredom proneness and task effectiveness at work. *Personnel Psychology 35*, 1 (1982) 141-151.
6. FLIR Systems. http://www.flir.com.

7. Fisher, C.D. Effects of external and internal interruptions on boredom at work: Two studies. *Journal of Organizational Behavior 19*, 5 (1998) 503-522.
8. Fogg, B.J. *Persuasive technology: Using computers to change what we think and do*. Morgan Kauffmann Publishers, San Francisco, CA, USA, 2003.
9. Frederick-Recascino, C.M. and Hilscher, M. Monitoring automated displays: Effects of and solutions for boredom. In *Proc. Digital Avionics Systems* 2001, 1, 5D3/1-5D3/5.
10. Jett, Q.R. and George J.M. Work interrupted: A closer look at the role of interruptions in organizational life. *Academy of Management Review 28*, 3 (2003) 494-507.
11. Khaled, R., Barr, P., Fischer, R., Noble, J., and Biddle, R. Factoring culture into the design of a persuasive game. In *Proc. OZCHI '06*, ACM Press (2006), 213-220.
12. Konami Digital Entertainment. http://www.konami.com/games/ddr/
13. Lanningham-Foster, L., Jensen, T.B., Foster, R.C., Redmond, A.B., Walker, B.A., Heinz, D., and Levine, J. A. *Energy expenditure of sedentary screen time compared with active screen time for children*. Pediatrics 118, 6 (2006) 1831-1835.
14. Moxham, B.J., Krish C., Berkovitz B., Alusi G., and Cheeseman T., *Interactive head & neck (CD-ROM)*, Primal Pictures, 2002.
15. Muchinsky, P. *Psychology Applied to Work,* Wadsworth/Thomson Learning, Belmont, CA, USA, 2000, 459-486.
16. NASA Task Load Index. http://humansystems.arc.nasa.gov/groups/TLX/
17. Pavlidis, I., Dowdall, J., Sun, N., Puri, C., Fei, J., and Garbey, M. Interacting with human physiology. *Computer Vision and Image Understanding*, *108*, (2007), 150-170.
18. Palvidis, I. and Levine, J. Thermal image analysis for polygraph testing. *IEEE Engineering in Medicine and Biology Magazine*, 21, 6 (2002), 56-64.
19. Prensky, M. *Digital Game-Based Learning*. McGraw-Hill, 2001.
20. Puri, C., Olson, L., Pavlidis, I., Levine, J., and Starren, J. StressCam: Non-contact Measurement of Users' Emotional States through Thermal Imaging. In *CHI '05 Extended Abstracts*. ACM Press (2005), 1725-1728.
21. Quickset International. http://www.quickset.com
22. Sarter, N. and Woods D. How in the world did we ever get into that mode? Mode error and awareness in supervisory control. *Human Factors* 37, 1 (1995) 5-19.
23. SBIR Inc. http://www.sbir.com
24. Shastri, D., Pavlidis I., and Wesley A. A method for monitoring operator overloading, In *Proceedings of HCI International*, Springer (2009), 169-175.
25. Speier C., Vessey I., and Valacitch J.S. The effects of interruptions, task complexity, and information presentation on computer-supported decision-making performance. *Decision Sciences 34*, 4 (2003) 771-797.
26. Sony Computer Entertainment. www.us.playstation.com/PS2/Games/EyeToy_Play/ogs/
27. Tsiamyrtzis, P., Dowdall, J., Shastri, D., Pavlidis, I., Frank, M., and Ekman, P. Imaging facial physiology for the detection of deceit. *International Journal of Computer Vision 71*, 2 (2007), 197–214.
28. Yun C., Shastri D., Pavlidis I., and Deng Z., "O' game, can you feel my frustration?: Improving user's gaming experience via StressCam", In *Proc. CHI '09,* ACM Press (2009), 2195-2204.
29. Zhou Y., Tsiamyrtzis P., and Pavlidis I. Tissue tracking in thermo-physiological imagery through spatio-temporal smoothing, In *Proc. MICCAI '09*, Springer (2009), 1092-1099.
30. Zavalova, N., Lomov, B. and Pomomarenko, V. The active operator principle and the distribution of functions between man and machine, *Voprosy-Psikhologii* 17, (1971) 3-12.
31. Zhu Z., Tsiamyrtzis P., and Pavlidis I., The segmentation of the supraorbital vessels in thermal imagery, in *Proceedings of the 5th IEEE International Conference on Advanced Video and Signal Based Surveillance*, IEEE Press (2008), 237-244.