Research Brief

Time of day effect on performance at a user interface

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Abstract The paper investigates the effect of time of day at an Automated Teller Machine (ATM) interface. Two dependent variables, time taken and error rate were measured. 11 male students participated in the experiment which involved a set task at an ATM simulated on a PC in a controlled environment. Subjects were asked to perform the task at three different times of the day, 9.00am, 1.00 pm and 9.00 pm. The order of the sequence in which the subjects performed the task was randomized by Latin square design to minimize order effect. One-Way Analysis of Variance (ANOVA) on transaction time and error rate indicated significant difference ($p=0.001$ for both). There was no significant difference in time in the afternoon or evening. The same for error rate indicated least error rate in the morning with no significant difference between afternoon and evening. Thus designers when designing complex interfaces for 24 hours use like ATM, mobile, or even complex interfaces like control display unit of a hospital ICU should consider the fact that such interfaces are vulnerable to errors and slow responding, when tasks are carried out at different times of the day.

Keywords: ergonomics, interface, chronobiology,

Introduction

Life sequences are not inert but they are biological driven by an organic chronometer (Hastings, 1997). The major player for this is the Supra Chiasmatic Nuclei (SCN) located in the hypothalamus of the human brain. These nuclei are actually a cluster of about 10, 000 neurons positioned on either side of the midline above the optic chiasma, approximately 3cm behind the eyes. Any damage to these groups of neurons renders the organic chronometer chaotic and the different synchronous activity of physiological or psycho physiological activities in the human body becomes chaotic and asynchronous. But there are evidences in the literature (Hastings, 1998) that this biological clock in the body is also adaptable to a certain extent. Pati et al (2001) reported that as normally human sleep during the night and remain awake during the day time. Therefore human body and mind is not capable of adapting to work or activity at any other time. There is also evidence to suggest a relationship between human behavioral pattern and performance and circadian timing systems. Commonly people showing these patterns are labeled as morning type, evening type and evening type respectively (Hidalgo et al. 2002).

Variations in chronobiological patterns in 24 hour have been reported to affect physiological and motor functions in humans (Klein et al. 1991). Melhim (1993) reported that an experiment on anaerobic cycle tests at different times of the day. Highest mean peak power was observed at 1500 hours compared to 0300 and 0900 hours. Cable and Reilly (1987) reported relative VO2 max, VCO2, respiratory exchange ratio, minute ventilation etc to have a significant afternoon peak values. Studies on maximum performance for aerobic exercise (Hill and Smith, 1991) indicated a peak in value with slow increase from early morning to a peak in the time span of 1600 to 2200 hours. Hill et al. (1992) reported that total time to exhaustion, aerobic power and aerobic work was significantly greater in the afternoon compared to that in the morning.

In terms of objective study chronobiological variations have also been observed. Hill et al. (1988) in an experiment on two maximal graded exercise tests while using a 15 point Rated Perceived Exertion(RPE) scale of Borg observed significantly lower RPE values in the morning sessions compared to the afternoon sessions. Time of day effect on cognitive tasks has also been reported (Carrier and Monk, 2000). Tasks such as visual search, memory, semantic processing etc were found to improve in the morning and degraded in the early afternoon. Folkard (1975) observed improved speed and performance of logical reasoning tasks from 8.00 am to 14.00 pm which was then found to fall rapidly.

The study of literature above shows that there are variations in performance both physical and cognitive at different times of the day. There is still dearth of information as to what changes in such performances can occur at complex interfaces like Automated Teller Machine (ATM), vending machines etc given the fact that such interfaces are used by people not at any particular time of the day but for 24 hours. This research aims to answer these questions like are there any difference in performance at an interface at different times of the day or not. If there is then the designer should keep this in mind at the design stage itself. Or there is no such significant difference in performance as such. The current research focuses on interface of an ATM machine simulated in a controlled environment to get an idea into some of these questions.

Methodology

Subjects. Eleven, male students all right handed, with no history of any eye or other diseases, participated. The mean age was 24.3 years (SD=2.6), mean stature was 162.8 cm (SD=6.8) and body mass was 56.3 kg (SD=10.4).

Instruments. An ATM interface was coded using C++ program. The monitor of a PC was used as the ATM screen. The key board was interfaced in a manner to take direct inputs on the screen.

Design of experiment

Subjects were given three different tasks. First task involved keying a given PIN and then drawing a given sum of money. The next task was to again type the given PIN and check the balance. The last task involved recharging the mobile phone of a particular company for a given amount. The subjects did the task three times at different times of the day, at an interval of one week to minimize order/learning effect. Once in the morning at 9.00 am. The next in the afternoon at 1.00pm and the third in the evening at 9.00 pm.

All treatment combinations for each subject were ordered by Latin Square design to minimize order effect. All data collected was stored in the form of a text file for each subject, recording the time taken and the number of errors made in the entire transaction.

Results

All data was recorded in text file format on the computer hard drive during testing and imported into the statistical analysis software (SPSS: Statistical Package for Social Sciences SPSS V.14) subsequently for analysis.

Transaction time. The mean transaction time (Table 1) was maximum (86.2 seconds) in the evening followed by post lunch (77.8 seconds) and minimum (51.0) in the morning.

	Morning	Post lunch	Evening
Time (seconds)	51.0(SD=11.9)	77.8(SD=9.8)	86.2(SD=7.5)
Error rate	0.5(SD=0.7)	2.5(SD=1.3)	1.5(SD=0.8)

Table 1 Mean time taken (seconds) and error rate at different time of the day

As the data was normally distributed (Levene's test, p= 0.242), a One-Way Analysis of Variance (ANOVA) was performed on transaction time. ANOVA of transaction time (Table 2) revealed a significant (p=0.001) difference at different times of the day.

Source	Sum of Squares	df	Mean Square	F	Sig
Between groups	7433.339	2	3716.669	34.103	0.001
Within groups	3160.536	29	108.984		
Total	**10593.875**	**31**			

Table 2 One-Way ANOVA for transaction time

To differentiate between the levels of factors in the ANOVA, a Students-Newmans-Keuls test (Table 3) was performed on the time of the day. Transaction time in the morning was significantly different from transaction time post lunch or in the evening. As can be seen from the table, there was almost no difference in transaction time between post lunch or in the evening.

Conditions	Group 1	Group 2
Morning	51.0000	
Post Lunch		77.8182
Evening		**86.9000**

Table 3 Student-Newman-Keuls test for transaction time in morning, post lunch and evening

Error rate. The mean error rate (Table 1) was maximum in the post lunch (2.5), followed by evening (1.5). The error rate was minimum in the morning (0.5).

Again the data being normally distributed (Levene's test, p=0.105), a One-Way ANOVA was performed on error rate. ANOVA (Table 4) of error rate at different times of the day revealed a significant difference (p=0.001) at different times of the day.

Source	Sum of Squares	df	Mean Square	F	Sig
Between groups	73.048	2	36.524	34.359	0.001
Within groups	30.827	29	1.063		
Total	**103.875**	**31**			

Table 4 One-Way ANOVA for transaction error rate

To differentiate between the levels of factors in ANOVA a Students-Newmans-Keuls test (Table 5) was performed on the time of the day. Error rate was minimum in the morning and significantly different from that in post lunch or evening. As could be seen from the table that there was hardly any difference in error rate post lunch or in the evening.

Conditions	Group 1	Group 2
Morning	0.3636	
Post Lunch		3.3000
Evening		**3.7273**

Table 5 Student-Newman-Keuls test for transaction error rate in morning, post lunch and evening

Mean plots of transaction time and error rate. There was a 32% increase in mean transaction time from morning to post lunch (Figure 1) and a 36.9% increase in mean transaction time from morning to evening. The mean error (Figure 2) showed a 92.8% increase from morning to post lunch. The increase of mean error rate from morning to evening was by 91.2%.

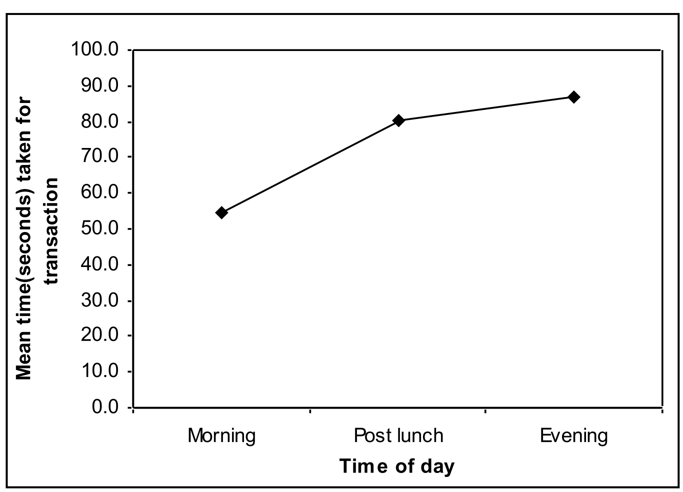

Figure 1 Mean time taken for transaction (seconds) Vs different time of the day

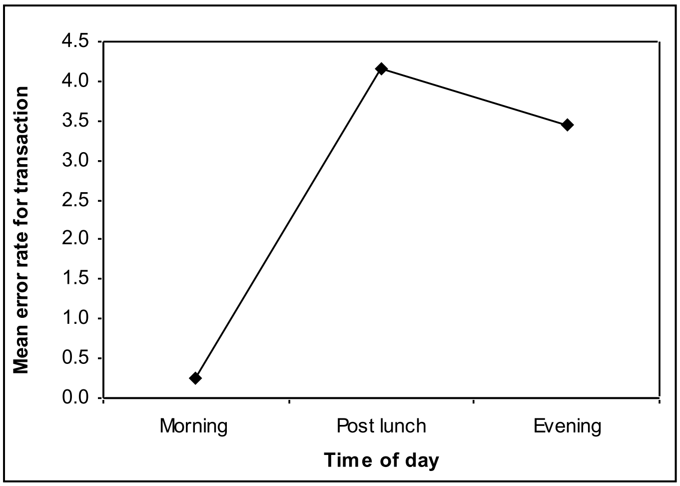

Figure 2 Mean error rate for transaction vs. different time of the day

Discussion

The findings of the current experiment with a dip in performance post lunch and in the evening and a relative improvement in the morning are in lines reported by others. Carrier and Monk (2000), Folkard and Hill (2000), Smith (1992) have reported that performance improves over the morning and then dips in the early afternoon which has been observed in the current experiment also. Performance at the ATM interface in the post lunch and in the evening did not show significant difference. There might be multiple reasons for this. The literature however contains very little information directly related to this issue. In a number of studies on drivers (Lenne et al, 1997, McFadden and Tepas, 1997) indicated post lunch dip in performance associated with increase accidents. The same was also reported in the evening as well at 10.00pm which closely resembles the time of the evening experiment in the current study. The same group reported that probably changing light levels or fatigue was responsible for such dip in performance in the evening which might be the case in the current experiment as well. Mc Dougall et al(2004) also supported the fact that humans are very slow response and vulnerable to errors when working at complex interfaces for 24 hours use like ATM machine, and this is especially true when such tasks are carried out in early afternoon or in the evening. This was the case in the current experiment as well.

Mc Dougal,l et al. (2004) indicated that time of day effect was most marked for understanding of icons (on highways by drivers), which required greater processing effort (e.g. visually complex and abstract icons. Possibly the task given to subjects in the current experiment was not that complex to bring about a significant different in performance in the post lunch and evening time.

Application

It seems clear from the current experiment that design process should pay particular emphasis on interface design on user performance. Till date lot of effort has gone into developing interface with reference to user preference, limitations, capacity, dimensions etc, but unfortunately very few of them have considered the time of day effect on interface performance. The results of this experiment categorically points out degradation of performance at the user interface at certain times of the day, and hence interface design and more specifically user testing (when the interface is still at the design stage) should be done at those specific times when the performance is at its worst. Thus designers when designing complex interfaces for 24 hours use like ATM, mobile, or even complex interfaces like control display unit of a hospital ICU should consider the fact that such interfaces are vulnerable to errors and slow responding, when tasks are carried in the early afternoon, and in the evening.

Conclusions

There is a significant time of the day effect on performance at the user interface with performance being better in the morning (9.00am) and degrading after lunch (1.00pm) and evening (9.00pm). Even error rates were found to increase significantly in post lunch period and evening compared to morning time.

Limitations. In the current experiment only three times of the day effect were observed. In reality complex interfaces are also operated in silent hours as well like 3.00am, midnight. All subjects used were male students only. At an interface females are also users. Not only that there are people of all age groups including senior citizens who have not been taken into account.

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