Eye scan patterns of the time use trait and its use in management

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ABSTRACT

The time use trait of monchronicity and polychronicity, which relates to one's ability to do one thing and many things at a time respectively, has been known for a long time. However, its implications on how people scan and attend to information are not so clear. This study is an attempt to investigate the attentional strategy differences between monochrons (M) and polychrons (P) under different task conditions using eye scan equipment. Two groups of participants (monochrons and polychrons) performed a dual control task having 3 task priorities and 4 task difficulty levels. The results showed significant differences in scanning patterns between monochrons and polychrons, among task priorities and/or task difficulty levels. Results of this study may be useful in semi-automated systems in order to achieve optimal performance.

Keywords: Time use, eye scanning, control strategy, multitasking

1. INTRODUCTION

In multi-tasking situations, different people manage their time quite differently. Hall (1959, 1989a) first identified this characteristic and categorized people as monochrons (M) or polychrons (P) where monochrons do one task at a time while polychrons attend to many tasks concurrently or in parallel. Recently, Zhang et al. (2005) showed that there are strategy and performance differences between monochrons and polychrons in a dual task control process. In that study, polychrons sampled both processes more frequently and were able to handle process disturbances, while monochrons attended to one task, and switched to the other task when the first one was completed. In another study, Zhang and Goonetilleke (2004) found that monochrons were able to concentrate and achieve better performance on their main task when compared to polychrons, who were hindered by interruptions and distracting signals that caught their attention. The objectives of this study are to investigate the attentional strategy differences of monochrons and polychrons and their changes with differing degrees of task difficulty and priority in a dual-task scenario.

2. METHODOLOGY

Participants

Thirty-two Chinese students from the Hong Kong University of Science and Technology participated in the experiment based on their Monochron/Polychron (M/P) scores obtained using the Modified Polychronic Attitude Index 3 (MPAI3) (Lindquist et al., 2001) and Inventory of Polychronic Values (IPV) (Bluedorn et al., 1999) scales. The M/P scores were the average value of all the items in each scale. The monochron group comprised 16 participants whose MPAI3 and IPV scores were greater than or equal to 1 and less than or equal to 3 while the polychron group had 16 participants as well (their MPAI3 and IPV scores were greater than or equal to 5 and less than or equal to 7)). Age and gender were recorded and each participant received a 'base' payment of HK$200 and a bonus payment, based on performance, at the end of the experiment.

Equipment and software

A hill-climbing paradigm was used to simulate a bivariate process control task (Laughery and Drury, 1979; Berkowitz et al., 1983; Goonetilleke and Drury, 1989). Such a process is very versatile as it allows one to investigate human performance at differing levels of difficulty, process history, process disturbances, process damping, etc. The hill height was a bivariate normal distribution as given below.

$$f = Ae^{\frac{-(x^2+y^2)}{2\times\sigma^2}} + A_0 \quad (1)$$

where x and y are coordinates in terms of the number of squares from hill-top and σ =6.0. A is a constant (=1000) and A_0 is another constant in the range -100 to 50.

The hill-top was randomly generated in every trial. The starting position of the hill-top could be in any square within a 17 × 17 grid. Participants were required to locate the hill-top and stay at the top throughout the experiment. The whole hill moved one square at a time based on an exponential distribution and was unknown to the participant. The mean time interval of the exponential distribution dictated task difficulty. Smaller time intervals resulted in faster hill movements and thus it was more difficult for participants to keep track of the hill-top. At the start of the experiment, the hill height at one grid location was shown. Thereafter, participants clicked one square at a time in order to find the given hill-top height. When a square on the grid was clicked, the hill height fluctuated prior to showing the actual hill height, according to the display damping function as given (in Laplace domain) below.

$$\frac{1}{\tau^2 s^2 + 2\tau\zeta s + 1} \times \frac{1}{s} \quad (2)$$

where τ is natural period of oscillation (=0.4) and ζ is damping factor (=0.5).

The height at the grid that was clicked and the heights of the previous six clicks were shown at any one time. The number of clicks (or steps) and elapsed time were shown on the display as well.

The hill-climbing simulation software was programmed using Visual C ++ and run on a Pentium IV 2.4 GHz computer in a windows XP environment. The software was able to record the coordinates of each chosen square (from 1 to 17 for x and y) and its height whenever the participant clicked on any one square. The dual-hill task simulated two independent processes (task 1 and task 2) and was run on two synchronized computers, and displayed on two separate monitors. Researchers have used visual scanning patterns such as time spent on each task, switching frequency and eye localization to determine the attention allocation strategy (Wickens and Hollands, 2000). Hence, visual scanning patterns were used for measuring attention allocation strategy. The Applied Science Laboratories (ASL) 5000 eye-tracking system with the Flock of Birds head tracker was used to measure the participant's eye position coordinates when performing the experiment.

Experimental Design

Participants were required to monitor the two hills on two separate computers and track the two hill peaks at the same time. A full-factorial within-subject experiment was conducted including 2 M/P groups, 4 task difficulty levels (these were difficulty level 1 which had a mean hill movement time interval of 60s; difficulty level 2 where it was 15s; difficulty level 3 had a time of 3s and the most difficult was level 4 with a 1s time) and 3 priority levels between the two tasks (i.e., equal priority, one 3 times the other and one 6 times the other). The priority was explained as the number of times task 1 was more important than task 2. Each task setting had eight trials with each trial lasting 3 minutes. The hill-top height was different in every setting in order to eliminate any short-term memory effects and was changed by adjusting A_0 (equation 1) in intervals of 10 within the range -100 to 50 (12 out of the 16 possible settings were randomly selected for the two hills). Fixation and dwell times were the dependent variables.

A counter-balanced design was used for both monochron and polychron groups. The sequences for the 12 settings (4 difficulties × 3 priorities) and the hill-top heights on the dual task were randomly assigned prior to the experiment.

Procedure

The participants were selected based on their MPAI3 and IPV scale and each participant performed the experiment in a quiet, temperature-controlled chamber with two computers. The total experimental time was around 12 hours for each participant and was distributed over five different days. On the first day, the experimenter introduced the hill-climbing program and eye tracking system to each participant. There were written instructions as well. Each participant was then required to practice the single task as well as the dual task with the eye tracking equipment. The purpose of this training period was to familiarize the participant with the hill climbing scenario, task environment and the other experimental equipment.

The formal tests were conducted in the remaining four days. Each participant completed three of the twelve settings on each day. The performance score on each hill and the priority-weighted performance score were shown to the participant at the end of each trial.

3. RESULTS AND ANALYSIS

Figure 1 shows the eye-movement strategy between the two tasks. When a participant spends time on one task, there can be many fixations. The number of eye transitions between the two tasks (N_e) was the summation of the eye transitions from task 1 to task 2 and vice versa. t_{1i} (or t_{2i}) represents the fixation duration on task 1 (or task 2) for the i^{th} fixation. Mean fixation duration on task 1 (or task 2) was the average durations of all fixations on task 1 (or task 2). Dwell time on task 1 (T_{1j}) and task 2 (T_{2j}) were also calculated for j^{th} dwell where "dwell" is defined as "the time period during which a fixation or series of contiguous fixations remain within an area of interest" (ASL, 2001)). Mean dwell time on task 1 (or task 2) was the average durations of all dwells on task 1 (or task 2). In addition, the total fixation duration on task 1 and task 2 was the sum of all dwell times on task 1 and task 2 respectively.

A three-way ANOVA performed with M/P, priority and difficulty as independent variables and scanning strategy as the dependent variables showed that there were significant M/P effects on all variables. Monochrons had fewer eye transitions between task 1 and task 2 compared to polychrons (mean of monochrons was 9.86 and mean of polychrons was 40.92). Monochrons had longer mean fixation duration on both tasks (mean on task 1 was 0.64 seconds and mean on task 2 was 0.57 seconds) compared to polychrons (mean of task 1 was 0.47 seconds and mean of task 2 was 0.43 seconds).

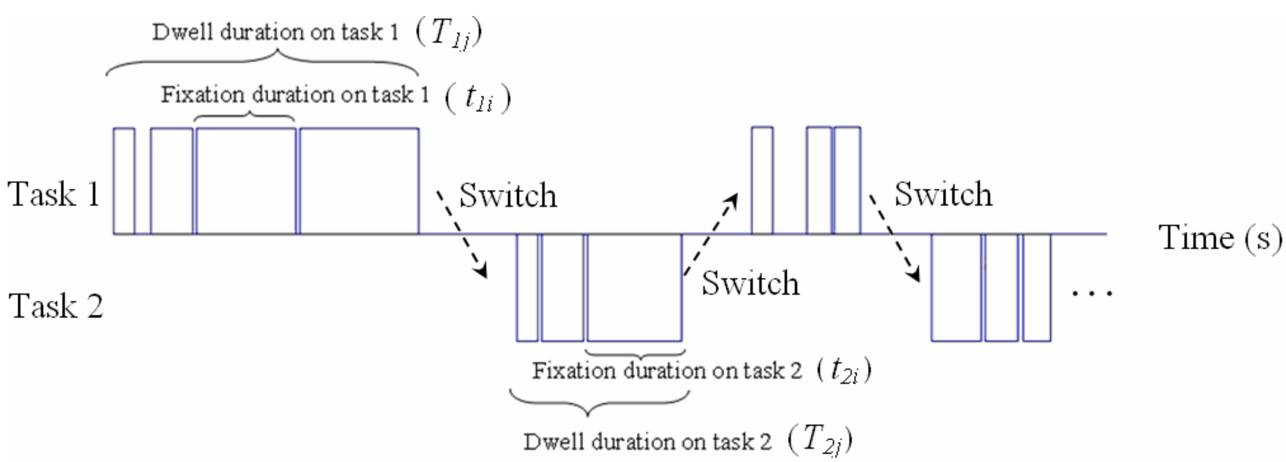

Figure 1 Eye transition pattern with time

Similarly, mean dwell times of monochrons for the two tasks (mean of task 1=40.25 seconds and mean of task 2=21.66 seconds) were longer than those of polychrons (mean of task 1=6.30 seconds and mean of task 2 is 4.12 seconds). In addition, monochrons spent more time on task 1 and less on task 2 (total fixation duration on task 1 was 103.20 seconds and the total fixation duration on task 2 was 56.78 seconds) compared to polychrons (mean of task 1 was 84.04 seconds and mean of task 2 was 62.69 seconds).

Priority and difficulty of tasks showed significant effects in addition to two-way and three-way interactions of some variables. Generally, when the priority of task 1 increased, monochrons had longer mean dwell time on task 1 and shorter mean dwell time on task 2. Similarly, with increasing priority, monochrons had longer total fixation duration on task 1 and shorter total fixation duration on task 2. The trend was more pronounced for monochrons than polychrons. Increasing difficulty resulted in an increase in the number of eye transitions for polychrons, and there was a reduction for monochrons. As difficulty increased, the mean dwell time on both tasks and total fixation duration on task 1 increased whereas total fixation duration on task 2 reduced. Even though the trends were the same for polychrons as well as monochrons, the rate of increase and the rate of decrease were smaller for polychrons.

4. DISCUSSION AND CONCLUSION

The results of this experiment are in agreement with the Zhang et al (2005) study wherein polychrons perform tasks in parallel compared to monochrons who prefer to attend to tasks one at a time. There were significant differences in the strategies adopted by monochrons and polychrons. The eye transitions between the two tasks were significantly lesser for monochrons when compared to polychrons. Other studies such as Frei et al. (1999) and Slocombe and Bluedorn (1999) also alluded to such a difference even though eye movements were not recorded in those studies. In fact polychrons switched so often that around every 5.2 seconds (mean dwell time) they would switch to the other task. However, monochrons stayed on one task a relatively longer time (mean dwell time = 31 seconds) before switching. In addition, based on total fixation durations it may be stated that monochrons paid more attention to task 1 but less attention to task 2 compared to polychrons. All these results clearly indicate the serial strategy of a monochron and the parallel strategy of a polychron.

Previous research has shown that attention allocation strategy can be influenced by priority and difficulty (Wickens and Seidler, 1997). In this study there were significant main effects and interaction effects with changes in priority and difficulty. In general, task priority and difficulty had strong effects on the monochron scanning patterns. When priority increased, monochrons focused their attention on the important task. They had longer dwell time before switching and had higher total fixation duration on the more important task 1. However, polychrons did not change their strategy with increasing task priority as dramatically as the monochrons as they seemed to divide their attention similarly between the two tasks. These results are consistent with the claims of Hall (1989b), Waller et al. (1999), and Slocombe (1999). With increasing difficulty, the switching between task 1 and task 2 increased for polychrons. It seems that polychrons truly attempt the tasks at hand irrespective of priority and difficulty. Even though the switching increased for polychrons, the mean dwell time on task 1 and total fixation duration on task 1 increased as well, with increasing difficulty. On the other hand, monochrons paid more attention to the important task with increasing task difficulty. Their switching between the two tasks reduced, while mean dwell time and total fixation duration on task 1 increased substantially.

Even though fitting a task to the person is the widely accepted norm, there are instances where training cannot resolve some of the inherent traits of people. This study investigated time usage and its effect on control behavior and the results are quite enlightening especially since the strategies adopted by monochrons and polychrons are quite contrasting. Operators and controllers have to be carefully selected for situations where task priority and task difficulty change in differing scenarios.

Depending on the optimal requirement, the control policies have to be carefully laid out if personnel selection is not an option. Polychrons would generally do well in multi-tasking situations of higher difficulty whereas monochrons may be more suitable for high priority situations as they will attend to the higher priority task first before addressing the other tasks. However, such an approach can result in a cascading effect as the lower priority tasks can become higher priority if not attended for too long. Polychrons also seem to prefer multiple displays in order to carry out their tasks. In concluding, it may be said that operators' or controllers' individual traits have to be carefully analyzed in order to achieve the required performance.

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