Time use behavior in single and time-sharing tasks

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Abstract

Human errors in aviation, process plants and other critical industries can result in dire consequences and hence it is essential to understand the operator behavior and task characteristics in order to improve task performance and safety. The time available and how it is used by the operator are important factors in multi-task situations. Polychrons are people, who favor doing multiple tasks at the same time, while monochrons prefer doing tasks in series. In this study, the strategy, performance and workload of monochrons and polychrons were evaluated in a single and dual control tasks. The task difficulty and multiple task priority were independent variables. Results indicated that polychrons switched between two tasks more than monochrons and achieved better performance when the tasks were equally important and difficult. When the priority between the tasks was different, monochrons changed their emphasis to the more important task even though polychrons did not change their strategy as dramatically as the monochrons. In addition, monochrons indicated significantly higher workload and difficulty than polychrons. Results of this study can be important for the development of training programs of personnel involved in time-critical operations.

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Keywords: Complex control; Hill-climbing; Monochron/polychron; Time use; Control strategy; Performance; Task characteristics

1. Introduction

People play an important role in controlling complex systems such as air-traffic, airplanes and power plants (Hollnagel et al., 1988; Morris and Leung, 2006; Rasmussen, 1983; Sheridan, 1981). In these situations, monitoring and controlling multiple tasks is required. How one controls or monitors a task and the related outcome are very critical in complex situations with system faults, generally, attributed to human error (Reason, 1990) and in most cases caused by heavy workload (Morris and Leung, 2006) or “design” errors. Research has shown that people tend to use their self-designed methods to complete a task even though more efficient methods may exist (Coventry, 1989; Sanjram and Khan, 2011). This could be as a result of people achieving the same or similar results using personal strategies, which have been found to be beneficial in learning (Chen and Liu, 2011; Evans and Waring, 2011; Mampadi et al., 2011; Pretz et al., 2010), primarily because cognitive style governs the way a person processes and organizes information. Thus, Lewis (1990) suggested that the habitual responses of individuals be identified when controlling complex systems as they may not be very apparent or elicited verbally. In emergency situations, doing the right thing at the right time is very important since incorrect or non-optimal operations may result in heavy damage to plants, operations and personnel (Reason, 1990). Some operators show significant weaknesses while monitoring and processing multiple tasks under time pressure and limited resources (Reason, 1990). In a control task, when differing types of information are necessary and continuously available, it is essential that they be tracked in terms of the time available, and their priority (Iani and Wickens, 2007). In spite of the need for matching task demand with individual time usage preferences, little research has been carried out on individual preferences or the way people work, especially in complex control systems even though some individuals would...
perform better in multi-tasking situations (Bluedorn and Jaussi, 2007; Jansen and Kristof-Brown, 2005).

Time use is related to how people manage time while handling many things in multiple task situations. Hall (1959, 1989) characterized time systems as monochronic (M) or polychronic (P). When people perform multiple tasks, some people do one task at a time whereas others attend to do many tasks concurrently (i.e., in parallel). Hall and Hall (1990) defined “Monochronic time (as) paying attention to and doing only one thing at a time. Polychronic time (refers to) being involved with many things at once”. These two types of task handling are called monochronic and polychronic behaviors and those exhibiting these two types of extreme behavior are known as monochrons and polychrons. Poposki and Oswald (2010) offered a definition of individual polychronicity indicating it was preference for shifting attention. König and Waller (2010) provided a more precise definition with polychronicity being the preference for doing many things at the same time while the behavioral aspect is referred to as multitasking. The usage of time has been studied by many researchers (Bowman et al., 2010; Branscome and Grynovicki, 2007; Francis-Smythe and Robertson, 1999; Harris and Wiggins, 2008; Ishizaka et al., 2001; Kaufman et al., 1991; König and Waller, 2010; König et al., 2005; Lindquist et al., 2001; Lindquist and Kaufman-Scarborough, 2004, 2007; Zhang and Goonetilleke, 2004; Zhang et al., 2005) to understand people’s multitasking behaviors in many different fields such as management psychology, shopping behaviors, marketing and process control and in many different cultures. Some studies (Ishizaka et al., 2001; Branscome and Grynovicki, 2007; König et al., 2005) reported the results where they attempted to find a relationship among monochronicity, polychronicity and performance. However, they did not find significant differences between monochrons and polychrons. A study on dual process-control tasks (Zhang et al., 2005) showed that strategy and performance differ between monochrons and polychrons when the tasks had equal importance. In general, researchers believe that monochrons may be better suited for work with strict time constraints such as in transportation (Conte et al., 1999), while polychrons may be suited for work that needs rapid adaptation to changing demands and which requires doing many things at a time while ‘balancing’ time use, such as in firefighting and emergency room tasks (Kaufman-Scarborough and Lindquist, 1999).

As an individual factor, which relates to multitasking behavior and performance, the use of time appears to be an important issue in process control. Task characteristics of difficulty and priority might play an important interacting role in control strategy and performance (Hall, 1989; Ishizaka et al., 2001; North and Gopher, 1976; Wickens and Seidler, 1997). The various interactions among monochronicity/polychronicity, difficulty and priority have not been carefully investigated. Based on the current knowledge one may hypothesize, with two tasks, monochrons may focus more on the important task and ignore the other when the priorities change or may tend to focus on one task when difficulty levels of the tasks change; polychrons may attempt to perform both tasks irrespective of their importance. Furthermore, when there is mismatch between the inherent time characteristic of an individual with that of the task demands, it can be hypothesized that the mental workload (Hart and Staveland, 1988) of the individual to be higher or in the other extreme case, the individual would feel bored. Therefore, the main objective of this experiment is to investigate the strategy, performance and workload changes of monochrons and polychrons with different task difficulty and priority in a dual task situation. In addition, a person with superior performance in one task may have an effect when he/she performs multiple tasks. Thus, the differences between monochrons and polychrons when performing a single task were evaluated as well in order to validate the results of the dual tasks.

2. Methodology

2.1. Participants

Four hundred and sixty-five students from the Hong Kong University of Science and Technology were invited to complete the monochronic/polychronic questionnaire “work and life survey” (Plocher et al., 2002), which included two monochronic/polychronic scales the Modified Polychronic Attitude Index 3 (MPAI3) (Lindquist et al., 2001) and Inventory of Polychronic Values (IPV) (Bluedorn et al., 1999) scales. The monochronic/polychronic scores were then calculated based on the average value of all the items of each scale. There were 18.9% (N=88) in the monochronic group (1 ≤ MPAI3 score ≤ 3 and 1 ≤ IPV score ≤ 3) 40.4% (N=188) in the neutral group (3 < MPAI3 score < 5 and 3 < IPV score < 5) and 9.5% (N=44) in the polychronic group (5 ≤ MPAI3 score ≤ 7 and 5 ≤ IPV score ≤ 7). Around 31% (N=145) had scores that were mismatched in their MPAI3 and IPV scores. Thirty-two Chinese (sixteen from monochronic group and sixteen from polychronic group) were then randomly selected to participate in the subsequent experiment. Each group comprised 8 males and 8 females. Ages of participants were recorded and each participant was paid HK$200 with an added bonus for performance at the end of the experiment.

2.2. Simulation software

A bivariate process control simulation software was developed in Visual C++. The hill-climbing task originally developed by Rigby (1972) has been used to study human behavior and performance in multivariate process control tasks (Berkowitz et al., 1983; Goonetilleke and Drury, 1989; Laughery and Drury, 1979). This type of task also represents supervisory control situations such as in air
traffic control where several aircrafts may be visible and tracked in multiple displays.

In this study, the simulation paradigm was based on the Goonetilleke and Drury (1989) study of optimization with moving optima. Modifications were made to that task to vary the difficulty level. Participants were given the task of reaching and tracking the summit of a hill on a topological $17 \times 17$ array. Each square on the array, displayed by a grid of lines, was defined by its $x$- and $y$-coordinates numbered from 1 to 17. When the participant clicked a square, the height of the hill at that point was displayed in the square. The program interface is shown in Fig. 1. The participants were required to find the hill-top as soon as possible and remain at the top using the minimum number of clicks. The hill height was a function of several parameters such as hill-top distribution, time related movement, history information and system damping. The hill height was a bivariate normal distribution with zero intercorrelation and both standard deviations equal to 6.0 (Eq. (1)).

$$f = Ae^{-(x^2+y^2)/2\sigma^2} + A_0$$

(1)

where $x$ and $y$ are coordinates in terms of the number of squares from hill-top, $A$ and $A_0$ are constants. The constant, $A$, was set to 1000 and the height of the hill was changed using differing values for $A_0$.

The hill-top distribution was randomly generated in every trial. The starting position of the hill-top could be in any square within the $17 \times 17$ grid. Participants were required to locate the hill-top and stay at the top. The whole hill moved, invisibly, one square at a time, either to the adjacent horizontal or vertical square, based on an exponential distribution. If the participant clicked the same square twice, the hill height at that square may not have been the same due to the moving hill. However, the hill-top distribution was the same during each trial. Moving direction was randomly chosen based on a probability distribution. Participants did not know the movement. The mean time interval of the exponential distribution was related to 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, one ‘square’ showed the hill height. Thereafter, participants clicked one square at a time in order to search the known hill-top height. When a square was clicked, the hill height was subjected one square at a time in order to search the known hill-top height. When a square was clicked, the hill height was subjected to display damping (Eq. (2)) and fluctuated prior to displaying the actual hill height. Damping here refers to a display delay prior to showing the height at each click.

Damping function in the Laplace domain is as follows:

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

(2)

where $\tau$ is the natural period of oscillation ($>0$) and $\zeta$ is the damping factor.

At any one time, the height of the current click and the heights of the previous 6 clicks were shown on the display. The number of steps (or clicks) and elapsed time were also displayed on the interface.

The software was run on a 2.4 GHz computer in a windows environment. The dual-control task (task 1 and task 2) simulating two independent processes was run on two synchronized computers with separated monitors. The distance between the centers of two screens was 28 in. The coordinates of each chosen square (from 1 to 17 for horizontal—$x$ and vertical—$y$) and its height on both computers were recorded whenever there was an input.

![Fig. 1. Interface of the multivariate process control simulation task.](image)
2.3. Design of experiment

The experiment was a full-factorial design that included a single task session and a dual task session. The experimental settings are shown in Table 1 and the dependent variables (Table 2) are discussed in the following sub-sections.

2.3.1. Single task session

A full-factorial design with two monochronic/polychronic groups and four task difficulty levels of hill movement mean time interval of 60s (difficulty level 1), 15s (difficulty level 2), 3s (difficulty level 3) and 1s (difficulty level 4) formed the basis of the experiment. The design and task settings are shown in Table 1. The dependent variables were control strategy, performance and the subjective measures of workload and difficulty (Table 2). Control strategy was measured by the total number of clicks ($C$), while performance was determined by mean height ($\bar{h}$) (Eq. 3). The subjective measures included workload as determined from the NASA-TLX scale ($NASA_s$) (Hart and Staveland, 1988) and the Damos’ difficulty rating scale ($diff_s$) (Damos, 1985). A counter-balanced design was used for the monochronic and polychronic groups. Hence, there were 16 different settings for performing sequences for the 16 monochrons and the 16 polychrons. The sequences of the four settings and the hill-top heights on the single task were randomly arranged prior to the experiment.

$$\bar{h} = \frac{\int_0^{180} h(t) dt}{180}$$

where $h(t)$ is the scaled height (with 1000 as the standard peak) as a function of time.

The hill-top height was different in every setting to eliminate any memory effects and was changed by adjusting $A_0$ in Eq. (1) in intervals of 10 within the range from $-100$ to $50$ (4 for single hill settings and 12 for dual hill settings). At the start of each trial, one square was opened with a value of 200 less than the hill-top height. There were eight trials for each setting and each trial took three minutes.

2.3.2. Dual task session

Participants were required to monitor the two hills on two separate computers and track the hill-tops at the same time. A full-factorial within-subject experiment was conducted including two monochronic/polychronic groups, four task difficulty levels of hill movement having mean movement time intervals of 60 s (difficulty level 1), 15 s (difficulty level 2), 3 s (difficulty level 3) and 1 s (difficulty level 4), and three priority levels between the two tasks (equal, 3 times the other and 6 times the other) (Table 1). The priority was defined as to how many times one task was more important than the other. Task 1 (main task) was always set to have an equal or higher priority than task 2 (secondary task).

The sequences for the 12 settings and the hill-top heights on the dual task were randomly arranged based on a pre-
experiment trial run. Similar to the single task, the hill-top height was different for each setting. A starting square was exposed with a value of 200 less than the hill-top height. Each task setting had eight trials. Each trial lasted three minutes.

The control strategy, performance and subjective measures were the dependent variables (Table 2). The control strategy variables included the number of switches between the two tasks (Nj), the mean number of clicks on task 1 (τ1j) and the mean number of clicks on task 2 (τ2j), the total number of clicks on task 1 (C1) and task 2 (C2). Number of switches (Nj) was determined as the number of clicking changes from task 1 to task 2 or vice versa. c12 (or c21) represents the number of clicks on task 1 (or task 2) before switching to task 2 (or task 1). τ1j and τ2j were the mean number of clicks on one task prior to switching (the mean of all c12 and the mean of all c21, respectively). C1 and C2 were the sum of all τ1j and the sum of all τ2j, respectively. As in the single task session, the workload measure from NASA-TLX (NASA) (Hart and Staveland, 1988) and task difficulty rating (dij) (Damos, 1985) were the subjective measures.

The performance variables included mean height on task 1 (허j1) and task 2 (허j2) (Eq. (4)), weighted mean height (허w) (Eq. (5)). The performance score for each hill (Pj) (Eq. (6)) was calculated based on the mean hill height, 허j (calculated using Eq. (4)) and was normalized to a range of 0–100%. The weighted performance score (Pw) was calculated using Eq. (7) based on the performance scores of each hill (P1 and P2). The variables, P1, P2 and Pw, were shown to each participant at the end of each trial and formed the basis for the bonus payment. They were not used in any analysis.

\[
\text{허j} = \frac{\int_0^{180} \text{허}(t) dt}{180} \tag{4}
\]

where 허(t) is the scaled height (with 1000 as the standard peak) as a function of time; j=1 for task 1 and 2 for task 2

\[
\text{허w} = \frac{\text{허}1 \times \text{priority} + \text{허}2}{1 + \text{priority}} \tag{5}
\]

\[
P_j = \begin{cases} 
\frac{(허j - A_0 - 600)}{400} \times 100 & \text{if } 허j \geq 600 \\
0 & \text{if } 허j < 600 
\end{cases} \tag{6}
\]

where j=1 for task 1 and 2 for task 2

\[
P_w = \frac{P_1 \times \text{priority} + P_2}{1 + \text{priority}} \tag{7}
\]

2.4. Procedure

Each participant performed the experiment in a quiet, temperature-controlled chamber (around 23°C) having two computers. The total experimental time was around 14 h for each participant and was distributed over a period of six days.

On the first day, the NASA-TLX scale weightings were obtained. Thereafter, the subject was trained on the control task. The experimenter introduced the simulation program and then asked the participant to practice the single task and dual task. The aim of the training was to let the participants learn how to use the simulation program and familiarize themselves with the task environment and equipment. Each participant was asked to finish two 3-min practice trials with six different training task settings. The participant was asked to rate the task using the NASA-TLX scale and difficulty rating scale. The performance score of each hill and the priority-weighted performance score were shown to the participant at the end of each trial.

During the next four days, the formal tests of the dual-control task were conducted. Each participant had to complete three of the 12 settings (Table 1) on each day. The performance scores were shown and subjective rating scales were administered at the end of each trial. The single hill task was completed on the last day. Participants performed four task settings (Table 1). Similar to the dual task, the performance score was shown and the workload and difficulty rating were elicited from participants.

3. Results and analysis

3.1. The monochronic and polychronic scores

The mean age of monochronic group was 22.94 years and standard deviation was 4.06. Polychronic group had a similar age range (Mean=22.94 years and STD=2.62). The monochronic/polychronic scores based on the MPAI3 and the IPV scales were calculated and the simple statistical data of the scores is shown in Table 3. The Pearson correlation coefficient between the MPAI3 and IPV scores was 0.96 (p < 0.0001).

3.2. Single task

An ANOVA on trials showed no significant differences among the eight trials for all the dependent variables. Hence all eight trials were used in the subsequent analyses.

3.2.1. Analysis of variance for total number of clicks (C)

A two-way (M/P x difficulty) ANOVA showed that there were significant M/P (F(1,1016)=12.9, p=0.0004, eta-squared=0.0065) and difficulty effects on C (F(3,1016)=302.56, p<.0001, eta-squared=0.4687) but no significant interaction (F(3,1016)=0.01, p=0.9983, eta-squared=0.0). Monochrons had a lesser number of clicks (mean=54.49) compared to polychrons (mean=59.04). The SNK tests on difficulty showed that total number of clicks at all 4 difficulty levels were significant.

<table>
<thead>
<tr>
<th>M/P score</th>
<th>M/P group</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>STD</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPAI3 M</td>
<td>1.7</td>
<td>3</td>
<td>2.65</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>5</td>
<td>6.7</td>
<td>5.52</td>
<td>0.42</td>
<td></td>
</tr>
<tr>
<td>IPV M</td>
<td>2.6</td>
<td>3</td>
<td>2.78</td>
<td>0.16</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>5</td>
<td>6.6</td>
<td>5.43</td>
<td>0.47</td>
<td></td>
</tr>
</tbody>
</table>
levels were significantly different from each other (mean values of level 1, level 2, level 3 and level 4 were 29.20, 48.72, 71.54 and 77.61, respectively).

3.2.2. Analysis of variance of performance (\(\bar{h}\))

A two-way (M/P × difficulty) ANOVA showed that there were significant effects on M/P (\(F(1,1016)=4.1, p=0.0435\), eta-squared=0.008) and difficulty (\(F(3,1016)=1430.8, p<0.0001\), eta-squared=0.8076) but no significant interaction (\(F(3,1016)=0.8, p=0.5129\), eta-squared=0.0004) for \(\bar{h}\). Monochrons had higher mean height (mean=931.43) compared to polychrons (mean=928.08). The SNK tests on difficulty indicated that participants’ mean height dropped with increasing difficulty and all the four difficulty levels were significantly different from each other for \(\bar{h}\) (mean value of level 1, level 2, level 3 and level 4 were 985.29, 969.47, 918.27 and 846.00, respectively).

3.2.3. Analysis of variance for workload rating (NASA_s and \(d_{off,s}\))

A two-way (M/P × difficulty) ANOVA showed that there were significant effects on M/P (\(F(1,1016)=151.8, p<0.0001\), eta-squared=0.0981) and difficulty (\(F(3,1016)=124.9, p<0.0001\), eta-squared=0.2423) but no significant interaction (\(F(3,1016)=1.4, p=0.2330\), eta-squared=0.0028) for NASA_s. Monochrons had a higher workload (mean=39.08) compared to polychrons (mean=29.97). The SNK tests on difficulty indicated that all four difficulty levels were significantly different from each other (mean value of level 1, level 2, level 3 and level 4 were 24.98, 30.78, 38.76 and 43.57, respectively).

In terms of \(d_{off,s}\), results showed that there were significant effects on M/P (\(F(1,1016)=128.9, p<0.0001\), eta-squared=0.0584), difficulty (\(F(3,1016)=351.0, p<0.0001\), eta-squared=0.4773) and interaction (\(F(3,1016)=2.8, p=0.0396\), eta-squared=0.0038). The M/P × difficulty interaction plot is shown in Fig. 2. Monochrons indicated a significantly higher difficulty rating compared to polychrons at all four difficulty levels (\(p<0.05\)).

3.3. Dual tasks

The strategy and performance variables in the control task were analyzed using programs written in Matlab (Version 6).

3.3.1. Outlier detection

Outliers were detected with the generalized squared distance multivariate normality test (Johnson and Wichern, 1998). The squared distances of all dependent variables for every trial of all 12 settings (Table 1) were calculated and there were no outliers with values greater than \(\chi^2 (0.005, 25)=46.93\). Hence, the data of all 32 participants were used in the analyses. An ANOVA showed no significant differences among the eight trials for all the dependent variables. Hence all eight trials were used in the subsequent analyses.

3.3.2. Illustrations of M/P differences

Fig. 3 shows representative examples of control strategies of subject 8 (a monochron) and subject 5 (a polychron) with clicking sequence and clicking positions. These two subjects were not selected for any particular reason. The monochron had fewer number of switches between task 1 and task 2 compared to the polychron (number of switches is 3 for the monochron and 48 for the polychron). As a result, the mean number of clicks on one task before switching to another (\(\bar{c}_{12}\) and \(\bar{c}_{21}\)) was higher for the monochron when compared to the polychron. The corresponding performances of the monochron and the polychron are shown in Fig. 4. The monochron started tracking the hill-top on task 1, then switched to task 2 after 70 s and returned back to task 1 around 110 s. The hill height of task 2 decreased at first and increased thereafter when the monochron started to work on task 2, but then dropped again after the monochron left task 2. Since the monochron spent most of time on task 1, the hill height on task 1 was much higher than task 2. However, the polychron switched more number of times and tracked both tasks together. As a result, the hill heights on both tasks were more evenly distributed for the polychron.

3.3.3. Analysis of variance on monochronicity/polychronicity with priority and difficulty

The three-way ANOVA on monochronicity/polychronicity, priority and difficulty for dual task is shown in Table 4. Most of the main effects were significant at \(p<0.0001\). The significant two-way interactions (M/P × priority and M/P × difficulty) and three-way interaction (M/P × priority × difficulty) were further analyzed.

3.3.3.1. Analysis of variance for control strategy (\(N_s, \bar{c}_{12}, \bar{c}_{21}, C_1\) and \(C_2\))

There were significant M/P × priority and M/P × difficulty interactions for the number of switches (\(N_s\)) (Fig. 5). Monochrons and polychrons were
significantly different for all priorities and difficulties at $p < 0.05$. Polychrons had higher number of switches than monochrons. With increasing priority, the number of switches was the same for monochrons while it reduced for polychrons. Difficulty levels had a different effect with a reduced number of switches for monochrons and an increased number for polychrons at higher difficulties.

There were significant three-way interactions for $\tau_{12}$ and $\tau_{21}$ (Table 4). The interaction plots are shown in Fig. 6. Monochrons had significantly higher mean number of clicks on task 1 and task 2 ($\tau_{12}$ and $\tau_{21}$) than polychrons for all the 12 settings ($p < 0.05$). $\tau_{12}$ and $\tau_{21}$ generally increased with increasing task difficulty and priority. It was more pronounced for monochrons than polychrons.

There was significant M/P $\times$ priority interaction on $C_1$ and M/P $\times$ priority $\times$ difficulty interaction on $C_2$ (Fig. 7). In general, polychrons clicked more than monochrons in both tasks for each priority setting. With increasing priority level, the number of clicks on task 1 increased for monochrons while it was relatively the same for polychrons. For all 12 priority and difficulty combinations, polychrons had significantly higher number of clicks on task 2 ($p < 0.05$). The number of clicks for polychrons increased drastically when moving from low priority and difficulty level to high priority and difficulty level ($C_2$ (equal priority, difficulty level 1) $= 27.63$ and $C_2$ (6 times priority, difficulty level 4) $= 57.13$) compared to monochrons ($C_2$ (equal priority, difficulty level 1) $= 20.66$ and $C_2$ (6 times priority, difficulty level 4) $= 23.27$).

### 3.3.3.2. Analysis of variance for performance ($\bar{h}_1$, $\bar{h}_2$ and $\bar{h}_n$)

There was a significant M/P $\times$ priority $\times$ difficulty interaction on $\bar{h}_1$, M/P $\times$ priority and M/P $\times$ difficulty interactions for $\bar{h}_2$ and $\bar{h}_n$. The interaction plots are shown in Figs. 8 and 9. The value of $\bar{h}_1$, $\bar{h}_2$ and $\bar{h}_n$ decreased with
increasing difficulty level. In most cases monochrons have the same mean height on task 1 compared to polychrons. On the other hand, polychrons had better performance in task 2 compared to monochrons. The weighted performance ($h_w$) between monochrons and polychrons was significantly different with equal priority.

![Fig. 4. Examples of performance (6 times priority, difficulty level 3): (a) Hill height of a monochron (subject 8, MPAI3 score=3) and (b) Hill height of a polychron (subject 5, MPAI3 score=6).](image)

Table 4
The three-way ANOVA on monochronicity/polychronicity, priority and difficulty for dual task.

<table>
<thead>
<tr>
<th>Source</th>
<th>DF</th>
<th>M/P</th>
<th>Priority</th>
<th>M/P × priority</th>
<th>Difficulty</th>
<th>M/P × difficulty</th>
<th>Priority × difficulty</th>
<th>M/P × priority × difficulty</th>
<th>Error</th>
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<td>6</td>
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<td>3048</td>
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<tr>
<td>$F$ value</td>
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<td>3.67**</td>
<td>3.61**</td>
<td>3.54**</td>
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<td>1.17</td>
<td>1.07</td>
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<tr>
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<td>0.0015</td>
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<td>$\tau_{12}$</td>
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<td>234.52*</td>
<td>163.6*</td>
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$N_s$, the number of switches between the two tasks; $\tau_{12}$, the mean number of clicks on task 1; $\tau_{21}$, the mean number of clicks on task 2; $C_1$, the total number of clicks on task 1; $C_2$, the total number of clicks on task 2; $\bar{h}_1$, mean height on task 1; $\bar{h}_2$, mean height on task 2; $\bar{h}_w$, weighted mean height; NASA, NASA-TLX workload; $d_{off}$, task difficulty rating.

* $< 0.0001$.
** $< 0.05$. 
between the two tasks and only at higher difficulty levels (levels 3 and 4).

3.3.3.3. Analysis of variance for workload rating (NASA and diff). The three-way ANOVA showed significant M/P and difficulty effects on NASA-TLX (Table 4). Monochrons had higher workload (mean = 46.07) compared to polychrons (mean = 36.19). The SNK tests showed that all four difficulty levels were significantly different from each other (means level 1, level 2, level 3 and level 4 were 31.71, 37.82, 45.91 and 49.07, respectively). There was a significant M/P × difficulty interaction for \( d_{df} \) (Fig. 10). Monochrons had significantly higher difficulty rating than polychrons at all difficulty levels at \( p < 0.05 \). As the task became more difficult, the difference...
in the difficulty rating of monochrons and polychrons decreased.

4. Discussion and conclusions

A simulated control task was performed by 16 monochrons and the 16 polychrons. The dual-task was a full factorial three-way (M/P × priority × task-difficulty) design while the single task was a two-way (M/P × task-difficulty) full factorial design. The control strategy, performance and subjective measures were calculated and analyzed. The differences between monochrons and polychrons are listed in Table 5. The ANOVA results indicated that polychrons had a significantly higher total number of clicks when compared to monochrons in the single task. Since there was display delay in showing the hill height at the chosen location at every click, monochrons had lower number of clicks and possibly preferred to acquire more information about hill height by allowing the hill height to stabilize after which the actual height is shown. There were performance differences between the two groups, as measured by mean height, with monochrons significantly better than that of polychrons (p = 0.0435) for the single task. This result suggests that monochrons can achieve better performance in single task settings compared to polychrons. Therefore, differences in performance between monochrons and polychrons in the dual-control task should be the result of using different strategies and not due to the single task performance. Surprisingly, even though the performance of monochrons was better for single task, monochrons indicated a significantly higher workload and difficulty level than the polychrons.

The dual-control task was performed to investigate how priority between two tasks and task difficulty affected monochrons and polychrons. The results of the current study are in agreement with Zhang et al. (2005) where there were significant differences in strategy as well as performance between the monochronic and polychronic groups in dual-process-control tasks. In Zhang et al. (2005), monochrons switched 13.8 times on average while polychrons switched 36.14 times on average between two processes. Similarly, the control switching back and forth between the two tasks of monochrons and polychrons were comparable. This provides justification of the external validity of monochronicity/polychronicity effect in dual tasks. The result agrees with the claim of Frei et al. (1999) that polychrons may switch quickly between multiple tasks as they attend to more than one task. Polychrons often switched tasks around every 5 s and had a higher number of clicks on both tasks compared to monochrons. The mean number of clicks before a switch was higher for
monochrons when compared to polychrons. These results indicate that monochrons attempted to reach the hill-top of one process or get the process under control before switching to the other. On the contrary, polychrons had a tendency to “climb” both hills at the same time.

Monochrons spent more time on one task compared to polychrons. The better performance of polychrons could also have been due to their ability to deal with disturbances (Kerstholt et al., 1996) and more frequent sampling of the two systems (Kerstholt and Passenier, 2000). Similar to the single task, monochrons indicated a higher value on the NASA-TLX workload (Hart and Staveland, 1988) and difficulty rating (Damos, 1985) even though the performance measures did not show any inferiority in some task situations. This is in accordance with various studies (Hall, 1990; Kaufman-Scarborough and Lindquist, 1999) where researchers have claimed that monochrons may get frustrated under time pressure in multitask situations.

The monochronic/polychronic strategies varied with task priority and difficulty. There were significant main effects of priority and difficulty on most of the variables. In addition, there were significant M/P \times \text{priority} \times \text{difficulty} interactions on mean number of clicks and total number of clicks. This means that the differences between monochrons and polychrons on strategy could be the same or significantly different under different task conditions. As a result, the performances of monochrons and polychrons on the dual-control task changed with the conditions. When the priority was the same and at the least difficult condition (level 1), polychrons had higher control switches compared to monochrons. Even though polychrons preferred to click more than monochrons, their mean number of clicks were less for both tasks since they had high number of switches. As a result, polychrons achieved a higher mean hill height on task 2 but monochrons were able to achieve the same mean hill height on task 1 and weighted mean height as polychrons.

The effect of task priority on strategy has been discussed in the literature (North and Gopher, 1976; Wickens, 1977; Wickens and Seidler, 1997; Wickens et al., 2003). The general conclusion is that participants spend more time on the primary task than on the secondary task (Harris and Christhilf, 1980; North and Gopher, 1976). However, no research to date has investigated the effects related to monochrons and polychrons. The results show that an increase in priority, results in more emphasis to the important task by monochrons. However, polychrons did not change their strategy with task priority as dramatically as the monochrons. With increasing priority, polychrons reduced the number of switches, but it did not change for monochrons. The mean number of clicks on task 1 showed an increase for polychrons, but it was not as significant for monochrons. Thus, the mean number of clicks on task 2 for monochrons decreased significantly but was the same for polychrons. In addition, with increasing priority, monochrons had more clicks on task 1 but less on task 2. However, polychrons did not change their total number of clicks with priority. This indicates that monochrons changed their emphasis to the important task with increasing task priority, while the polychrons did not change their strategy with task priority as dramatically as the monochrons. These results are consistent with previous
comments made by several researchers (Slocombe, 1999; Waller et al., 1999) where monochrons focus on the primary task and ignore the secondary task if there is no time for it (Hall, 1989). As a result of more focus on task 1, the performance on task 2 of monochrons reduced with increasing priority. On the other hand, polychrons did not give up on the secondary task even though it had a lower priority (Hall and Hall, 1990), and therefore, there was no extra emphasis on either one of the tasks with differing priority.

Task difficulty was another important factor on performance in both single task and dual tasks (Andre and Heers, 1993; Wickens and Seidler, 1997). The task difficulty effects of monochronic/polychronic behavior were clearly seen. With increasing task difficulty, polychrons made more switches while those of monochrons reduced. But, monochrons had significantly higher mean number of clicks on task 1 and task 2 before switching over to the other task. However, polychrons did not have an increase as much as monochrons. In addition, polychrons had higher clicks on both tasks but monochrons had higher clicks on task 1. The clicks increased for task 2 for the equal priority case. As a result, the performance of monochrons and polychrons on task 1 were not significantly different. However, polychrons achieved much better performance on task 2 compared to monochrons, given that monochrons only used shorter time on task 2. Considering the weighting of task 1, the difference between monochrons and polychrons on total weighted hill heights was only present in difficulty levels 3 and 4. This indicated a difference in total performance between monochrons and polychrons at certain difficulty levels suggesting a difficulty threshold. This may be why Ishizaka et al. (2001) did not find any relationship between performance of monochrons and polychrons in multitasks.

The monochronic/polychronic behavior under extreme situations is noteworthy. When both priority and difficulty increased to the highest level (6 times priority and difficulty level 4), the strategies of monochrons and polychrons were significantly different. In this setting, both tasks were very difficult and task 2 was relatively un-important compared to task 1. Monochrons tried to concentrate on the main task 1 and clicked 74.88 times, and only 23.27 times on task 2. However, polychrons used 70.67 clicks on task 1 and 57.13 on task 2 on average. In a trial, monochrons switched fewer times (mean \( N_c = 6.71 \)) compared to polychrons (mean \( N_c = 39.07 \)). Therefore, monochrons had highest mean number of clicks on task 1 in all 12 settings (3 priorities \( \times 4 \) difficulties). Interestingly, the mean hill height on task 1 was not significantly different between monochrons and polychrons. Since polychrons spent more time on task 2 than monochrons, the mean hill height on task 2 for polychrons was significantly higher.

This study has important implications in designing tasks for the two different groups of people and personnel selection for complex tasks. In catastrophic situations, where people may have to direct their attention to the most important task, monochrons seems to be more suitable since they tend to prioritize and focus on the primary task. However, if the tasks at hand have equal priority, polychrons seem to be able to handle the situation better. The study would also be useful for predicting, improving and training individuals to control multiple tasks having differing levels of difficulty and priority especially when an operator has the ability to access important information in a predetermined way that is coherent with the cognitive processing of information. In aviation, for example, many tasks having differing priority and difficulty are present and the way in which a traffic controller or an airplane pilot handles them is very important. More research is needed to elicit any potential relationship between accidents or deterioration of performance and individual time usage behaviors.

Two extreme groups of monochrons and polychrons performed a single and a dual task experiment under varied conditions of task priority and task difficulty. The neutral group of people that lie between the extreme behavior of monochrons and polychrons were not tested. This group may exhibit some interesting behavior such as adopting a mixed strategy depending on the transient conditions. Thus, more study is needed especially since most Chinese are somewhat neutral. Further, the two tasks were identical. Generally, people face different types of tasks in various situations and it is necessary that performance, strategy and workload be evaluated in such situations as well. Overall, more studies are needed to develop a framework of performance to critically characterize monochrons and polychrons.

### Table 5

<table>
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<th>Monochrons</th>
<th>Polychrons</th>
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</thead>
<tbody>
<tr>
<td>Single task</td>
<td>Less clicks; Higher performance; Higher workload</td>
<td>More clicks; Lower performance; Lower workload</td>
</tr>
<tr>
<td>Dual tasks</td>
<td>Less switches between tasks; More focus on higher priority task, especially with higher difficulty; Lower total performance; Higher workload</td>
<td>More switches between tasks; Perform both tasks even though their priority and difficulty are different; Higher total performance; Lower workload</td>
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</table>
Acknowledgments

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References


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