The cultural effects of time usage and process complexity on control performance

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Abstract

Past research has classified people as monochrons (M) or polychrons (P) depending on their use of time. When people encounter many tasks, monochrons do one thing at a time while polychrons do many things at once. This study attempts to investigate how task difficulty and task priority influence the strategy and performance of monochrons and polychrons. A hill-climbing task was used to simulate a bivariate process control task. Participants were requested to find the optimum (hill-top) of two differing hills and remain at the top using the minimum number of clicks. The Modified Polychronic Attitude Index 3 scale (Lindquist et al., 2001) and Inventory of Polychronic Values scale (Bluedorn et al., 1999) were used to classify the participants as monochrons or polychrons. A full-factorial within-subject experiment with 2 time-use groups, 4 task difficulties, 3 priorities, and 8 trials was conducted. The strategy and performance measures of each individual were calculated. Results showed that the strategies and performances were significantly different between monochrons and polychrons in the different task conditions. In general, the switching between the two tasks was less for monochrons compared to polychrons. Overall performance of polychrons was significantly better than that of monochrons. In addition, two and three-way interactions among the M/P group, difficulty and priority for both strategy and performance were significant. The results of this study may be used to determine the optimal performance of people having differing usages of time.

1 Introduction

Globalization of companies is making culture related research more and more important. Hall (1989) has shown differences in the use of time among cultures and has classified people of various cultures as monochrons (M) or polychrons (P). When people perform multiple tasks, monochrons use a serial approach while polychrons do many things at once. Our studies (Zhang et al., 2003; Zhang and Goonetilleke, 2004) have shown that culture as well as individual differences is a contributor, in varying degrees, towards people's use of time. Zhang et al. (2003) showed that monochronicity/polychronicity imposes significant effects on the strategies and performance in multi-tasking situations. Attention allocation to different tasks could be influenced by task characteristics such as priority (North and Gopher, 1976; Wickens, 1977; Wickens and Seidler, 1997; Wickens et al., 2003) and difficulty (Andre and Heers, 1993; Wickens and Seidler, 1997). Hence, researchers have alluded to the fact that the use of time may be related to these two factors. As a result, the objective of this study was to investigate how task difficulty and task priority might affect the strategy and performance of monochrons and polychrons. A dual hill-climbing task (Goonetilleke and Drury, 1989) was used to simulate two process control tasks.

2 Methodology

2.1 Participants

Chinese students from the Hong Kong University of Science and Technology completed a web based time-usage questionnaire based on Modified Polychronic Attitude Index 3 scale (MPAI3, Lindquist et al., 2001) and Inventory of Polychronic Values scale (IPV, Bluedorn et al., 1999). Monochrons were those persons whose scores in both MPAI3 and IPV scales were between 1 and 3, while polychrons were those whose scores in the two scales were between 5 and 7. Three monochrons and three polychrons participated in the experiment. Age, gender, and background of the participants were recorded. Each participant received a ‘base’ payment of HK$200 and a bonus payment, based on the overall performance.

2.2 Stimulus Material

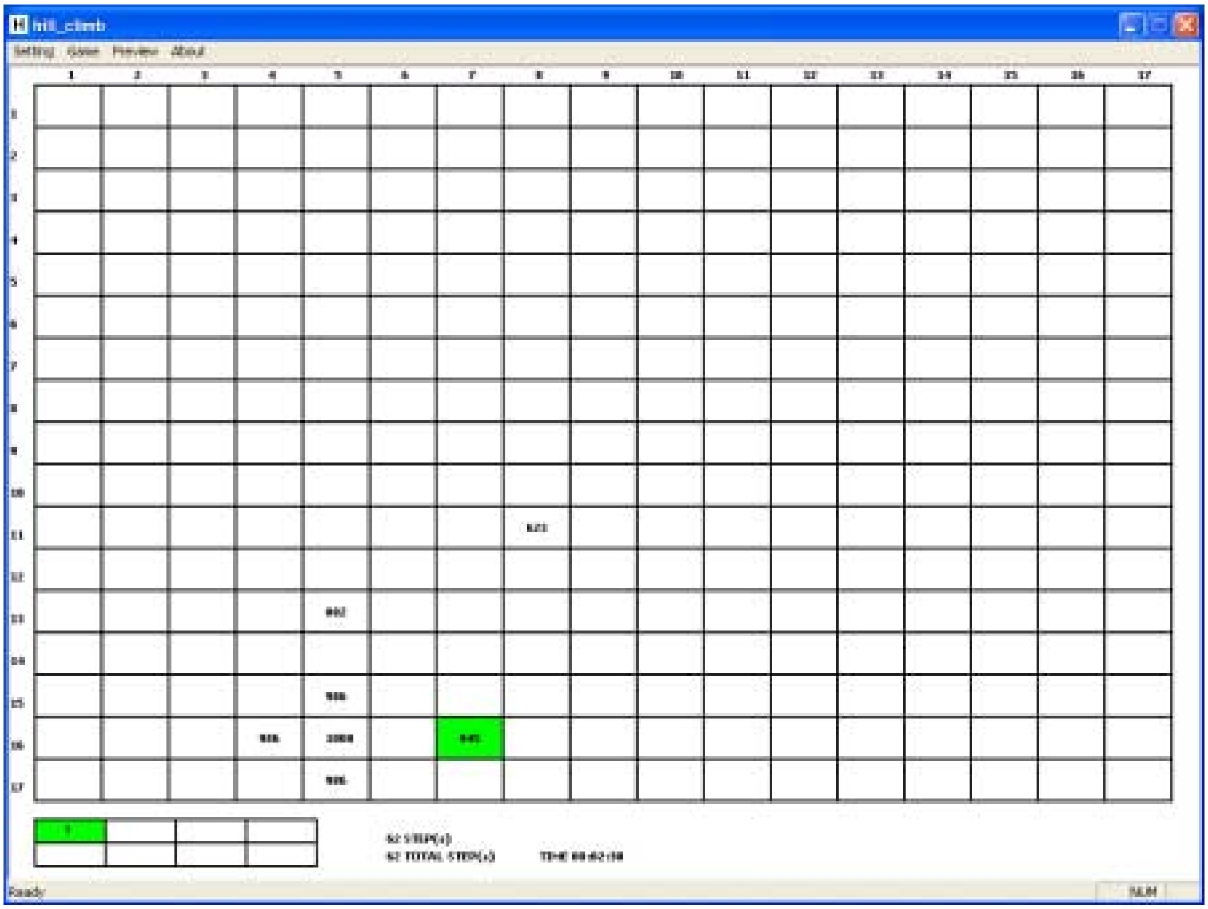

Figure 1: The hill-climbing task interface

A hill-climbing task was used to simulate a bivariate process. The hill height, f was determined using Equation 1 and displayed on the screen (Figure 1).

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

where
x and y are the deviations from hill-top (number of squares),
A =1000 and σ =6,
The height of hill peak was varied by varying A_0.

The software was programmed using Visual C ++. The hill climbing paradigm and its suitability was based on the work of Goonetilleke and Drury (1989) in relation to optimization with moving optima. The software was able to record the coordinates of each chosen grid and its height whenever there was an input (Figure 1). The dual hill-climbing task simulated two independent processes (task 1 and task 2) and was run on two synchronized Pentium IV 2.4 GHz computers with different settings. The output of each hill was displayed on separate monitors.

The starting position of the hill-top was in any position within the 17 * 17 grid (Figure 1). Participants were required to search the hill-top and stay on the top as the whole hill moved one square at a time unknown to the participant. The movement was generated using an exponential distribution. The mean time interval of the exponential distribution controlled the task difficulty. For example, if the time interval was relatively small, the hill would move faster and thus it would be relatively difficult to keep track of the hill-top. The experiment started with one square showing the hill height. Thereafter, the participant was expected to click one square at a time until he/she found the known hill-top height. Display damping (Equation 2) was present and hence there were hill height fluctuations prior to displaying the actual hill height at each click. The damping function in the Laplace domain was as follows:

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

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

The number of clicks (steps) made and the elapsed time were displayed at the bottom of the screen (Figure 1).

2.3 Design of Experiment

The experiment was a full factorial within-subject design with 2 different time-use groups, 4 task difficulties, 3 differing priorities, and 8 trials. The control strategy and performance were the dependent variables. The control strategy variables included the mean number of clicks just prior to switching and the number of switches between two tasks. The performance variables included the mean height, root mean square error of height, and weighted mean height. Mental workload (Hart and Staveland, 1988), task difficulty (Damos, 1985) and participant's mood (Adaval, 2001) were also obtained.

The experiment was separated into two phases: training and evaluation. Each phase had different task settings. The total experimental time was around 10 hours for each participant and was distributed over five consecutive days.

2.3.1 Training Phase

In the training session, the experimenter introduced the hill-climbing paradigm to participants. Participants acquired the basics on how to use the program and familiarized themselves with the task environment and equipment.

2.3.2 Evaluation Phase

A dual hill-climbing task was performed. Participants were required to monitor the two hills on two separate computers and track the hill peaks at the same time. The performance score (P) displayed to each participant at the end of each trial was calculated based on the mean hill height, H_j (calculated using Equation 5) and was normalized to a range of 0 to 100% (Equation 3). The mean time interval between movements of the four difficulty levels were 60s (level 1), 15s (level 2), 3s (level 3) and 1s (level 4) from easiest to most difficult respectively. The priority was defined in terms of how many times one task (one hill) was more important than the other. The task settings are shown in Table 1. The hill-top height was different in every setting to eliminate any memory effects and was changed by adjusting A_0 in Equation 1 in intervals of 10 within the range -100 to 50. Once the task was completed, the priority-weighted performance score (P_w) (calculated using Equation 4) was shown to the participant together with the performance scores of each hill (P_1 and P_2 calculated using Equation 3).

$$P_j\ \% = \begin{cases} \dfrac{(H_j - A_0 - 600)}{400} \times 100 & \text{if} \quad H_j - A_0 \geq 600 \\ 0 & \text{if} \quad H_j - A_0 < 600 \end{cases} \qquad j = 1 \text{ for task 1 and 2 for task 2} \qquad (3)$$

$$P_w = \frac{P_1 \times priority + P_2}{1 + priority} \quad (4)$$

2.4 Procedure

The experiment was conducted in a quiet, temperature-controlled chamber with two computers, over five consecutive days. On the first day, the NASA-TLX scale weightings were obtained. Each participant was asked to finish two 3-minute practice trials for six different training task settings. The performance score was shown at the end of each trial. On the remaining four days, each participant performed three of the 12 settings (Table 1) on each day. The twelve settings were randomly assigned. There were 8 trials in each setting and each trial time was fixed at 3 minutes. At the end of each trial, the NASA-TLX (Hart and Staveland, 1988) scale, task difficulty scale (Damos, 1985) and the mood scale (Adaval, 2001) were administered.

Table 1: The settings for dual hill-climbing task

Settings	Difficulty level	Priority
1	1	Equal
2	2	Equal
3	3	Equal
4	4	Equal
5	1	3 times
6	2	3 times
7	3	3 times
8	4	3 times
9	1	6 times
10	2	6 times
11	3	6 times
12	4	6 times

3 Results and Analysis

The dependent variables were strategy and performance. Strategy was related to the number of switches between the two tasks (*S*), the mean number of clicks (C_1) on hill 1 (task 1) prior to switching to hill 2 (task 2) and the mean number of clicks on task 2 before switching to task 1 (C_2). The performance variables includes mean height (Equation 5) on task 1 (H_1) and task 2 (H_2), root mean square error of the heights (Equation 6) on task 1 ($rmsH_1$) and task 2 ($rmsH_2$), weighted mean height (H_w) as shown in Equation 7. The subjective workload from NASA-TLX, task difficulty, *D* (Damos, 1985) and the participant mood in relation to feeling happy (*Happiness*) and feeling good (*Goodness*) (Adaval, 2001) were also collected.

$$H_j = \frac{\sum_{i=1}^{n-1} h_i \times (t_{i+1} - t_i)}{180} \quad (5)$$

where
n = total number of moves including hill moves and clicks
h_i = scaled (with 1000 as the standard peak) instantaneous height at ith move
t_i = time at ith move
j = 1 for task 1 and 2 for task 2

$$rmsH_j = \sqrt{\frac{\sum_{i=1}^{n-1} [(1000 - h_i) \times (t_{i+1} - t_i)]^2}{180}} \quad (6)$$

j = 1 for task 1 and 2 for task 2

$$H_w = \frac{H_1 \times priority + H_2}{1 + priority} \quad (7)$$

An ANOVA on trials showed no significant differences among the 8 trials for all the dependent variables. Hence all 8 trials were used in the subsequent analyses. The intercorrelation matrix is shown in Table 2. The *M/P score* (MPAI3) was negatively correlated with the NASA-TLX weighted rating (r = -0.59), C_1 (r = -0.57) and C_2 (r = -0.52), while positively correlated with the number of switches, S (r = 0.71). This result seems to imply that polychrons tend to have lower mental workload ratings and switched between tasks more than the monochrons. Monochrons had higher number of clicks on one task before switching to the second task as shown by the negative correlation. The *Happiness* and *Goodness* scores are highly correlated (r = 0.88) with each other and they are positively correlated with the M/P score, showing polychrons had better mood than the monochrons when performing the dual-task.

Table 2: The correlation coefficients among dependent variables (dual task)

	M/P score	*NASA*	*D*	*Happi-ness*	*Good-ness*	*S*	C_1	C_2	H_1	H_2	$rmsH_1$	$rmsH_2$	H_w
M/P score	1												
NASA	-0.59	1											
D	-0.40	0.60	1										
Happi-ness	0.33	-0.55	-0.34	1									
Good-ness	0.42	-0.60	-0.40	0.88	1								
S	0.71	-0.46	-0.08*	0.07*	0.18	1							
C_1	-0.57	0.61	0.40	-0.38	-0.53	-0.49	1						
C_2	-0.52	0.51	0.32	-0.35	-0.36	-0.44	0.37	1					
H_1	0.10	-0.44	-0.55	0.31	0.31	-0.04*	-0.48	-0.33	1				
H_2	0.27	-0.5	-0.54	0.31	0.37	0.14	-0.64	-0.40	0.72	1			
$rmsH_1$	-0.17	0.45	0.50	-0.22	-0.25	-0.11	0.46	0.33	-0.89	-0.63	1		
$rmsH_2$	-0.39	0.46	0.41	-0.18	-0.27	-0.34	0.58	0.38	-0.45	-0.86	0.52	1	
H_w	0.17	-0.49	-0.57	0.32	0.35	0.02*	-0.55	-0.39	0.96	0.86	-0.86	-0.63	1

* correlation coefficients are not significant at p= 0.05

The ANOVA (Table 3) showed that there were significant differences between monochrons and polychrons for all dependent variables. Monochrons (mean = 47.77) had significantly higher workload rating (*NASA*) than the polychrons (mean = 29.46). Monochrons (mean = 64.84) had significantly higher difficulty (*D*) than the polychrons (mean = 44.42). Polychrons (mean = 1.13) had a significantly higher *Happiness* rating than the monochrons (mean = 0.61). Polychrons (mean = 1.13) had a significantly higher *Goodness* rating than the monochrons (mean = 0.26). The number of switches of monochrons (mean = 6.01) was significantly lower than that of polychrons (mean=39.25). Monochrons clicked on one task (C_1 = 13.35 and C_2= 7.24) significantly more than polychrons (C_1 = 2.48 and C_2= 2.26) before switching to the other task implying that monochrons attempted to attain the peak of one hill (keep one process under control) before switching to another. Polychrons on the other hand, attempted to "climb" both hills at same time. As a result, the mean height for task 1 (H_1) for Monochrons (mean = 897.3) was significantly lower than that for Polychrons (mean = 913.4). The mean height for task 2 (H_2) for Monochrons (mean = 837.56) was significantly lower than that of polychrons (mean = 898.63). The weighted mean height of polychrons (H_w = 910.14) was significantly higher than that of monochrons (H_w = 882.74).

Table 3: Three-way ANOVA on M/P group, priority, difficulty and their interactions (dual task)

Source	DF		*NASA*	*D*	*Happi-ness*	*Good-ness*	*S*	C_1	C_2	H_1	H_2	$rmsH_1$	$rmsH_2$	H_w
M/P group	1	F value	350.33	260.56	30.56	79.33	1217.8	432.44	223.33	17.17	103.63	31.67	139.14	55.02
		Pr >F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
priority	2	F value	0.76	2.91	0.69	1.37	0.28	9.34	6.4	6.57	3.49	8.34	2.28	6.73
		Pr >F	0.4667	0.0552	0.5019	0.2546	0.7524	0.0001	0.0018	0.0015	0.0311	0.0003	0.1035	0.0013
M/P group* priority	2	F value	1.57	2.02	0.30	2.55	0.12	9.47	4.88	3.95	0.25	1.72	0.33	5.66
		Pr >F	0.2100	0.1334	0.7438	0.0787	0.8882	<.0001	0.0079	0.0198	0.7818	0.1799	0.7181	0.0037
difficulty	3	F value	47.68	181.89	15.83	19.82	39.38	75.32	17.24	432.29	277.21	138.12	65.46	516.26
		Pr >F	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
M/P group* difficulty	3	F value	6.68	12.75	3.69	9.78	75.98	69.58	15.09	5.58	8.72	1.68	3.61	6.25
		Pr >F	0.0002	<.0001	0.0118	<.0001	<.0001	<.0001	<.0001	0.0009	<.0001	0.1712	0.0132	0.0004
priority * difficulty	6	F value	2.22	0.87	2.12	4.72	4.21	4.43	1.42	2.16	2.88	1. 23	3.35	0.96
		Pr >F	0.0399	0.5132	0.0498	0.0001	0.0004	0.0002	0.2056	0.0449	0.0091	0.2869	0.0030	0.4528
M/P group* priority* difficulty	6	F value	2.57	1.41	0.27	1.52	3.46	3.48	1.07	2.77	0.44	2.56	0.92	1.34
		Pr >F	0.0183	0.2069	0.9517	0.1699	0.0023	0.0022	0.3785	0.0116	0.8499	0.0186	0.4791	0.2352
Error	552													

The priority and difficulty effects are shown in Figures 2, 3 and 4. With higher difficulties, monochrons switched less between the two tasks while polychrons switched more between the two tasks (Figure 2). The performance (weighted mean height) of polychrons does not seem to be influenced by increasing priority even though priority had an effect on the performance of monochrons (Figure 3). Performance at low difficulty levels appears to be similar between monochrons and polychrons even though the polychrons' performance at higher difficulty levels was comparatively superior (Figure 4).

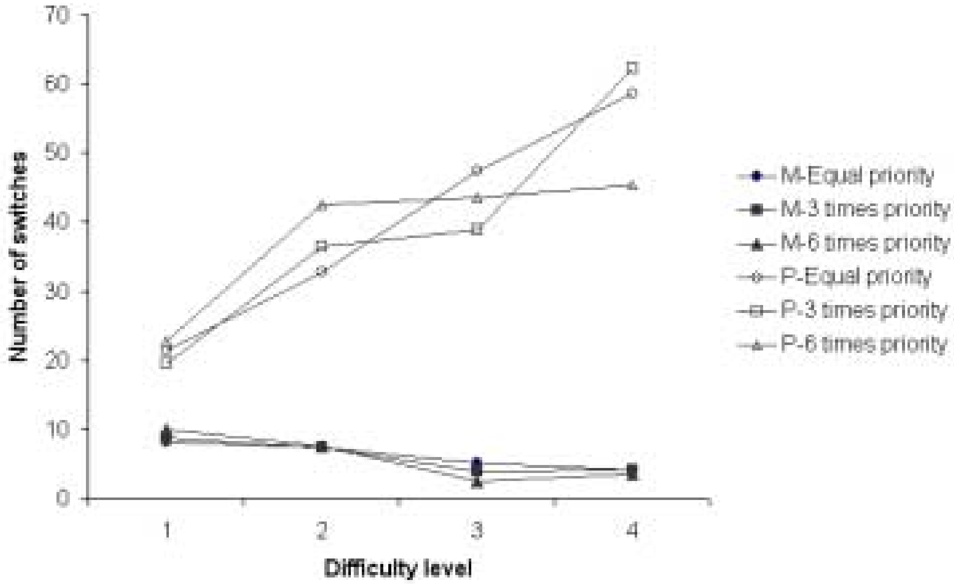

Figure 2: The relationship between the number of switches and task difficulty and priority for monochrons and polychrons

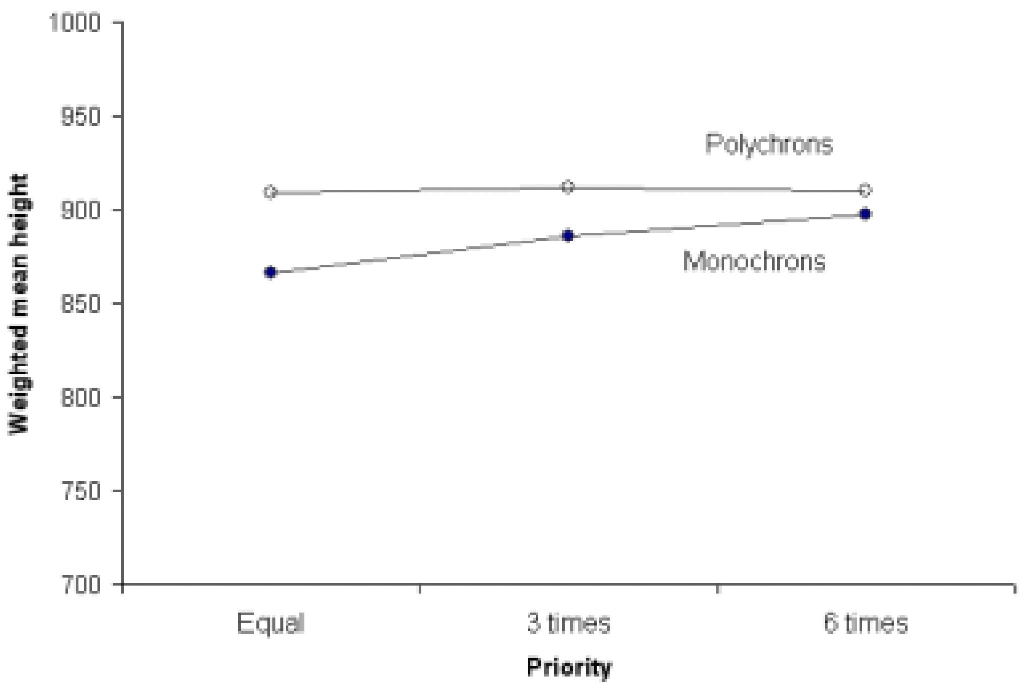

Figure 3: The relationship between the weighted mean height and task priority for monochrons and polychrons

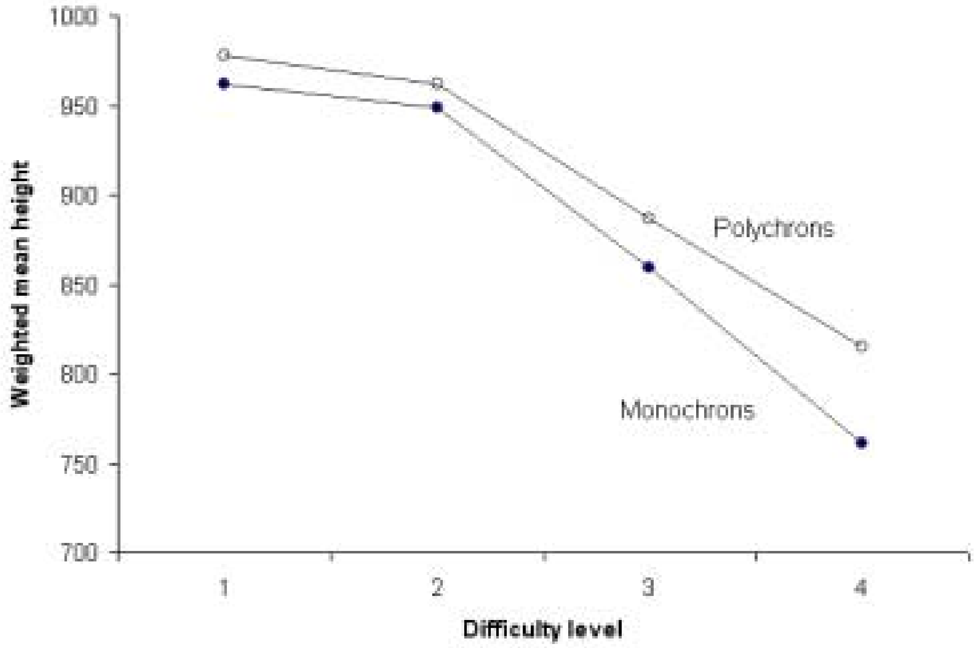

Figure 4: The relationship between the weighted mean height and task difficulty for monochrons and polychrons

4 Conclusions

Previous research has shown that polychrons have superior performance in multi-tasking situations (Zhang et al., 2003) as they are able to perform tasks in parallel as opposed to monochrons who prefer to attend to tasks serially. The results of this experiment are in agreement. The polychrons had a better mood (higher happiness and goodness rating) than the monochrons, indicating that they preferred the parallel approach.

There were differences in strategy as well as performance between the two groups. The switching back and forth between the two processes was less for monochrons compared to polychrons as monochrons attempted to reach the hill-top of one process (keep one process under control) before switching to the other. However, polychrons tended to “climb” both hills at the same time.

These results agree with previous studies in that individuals were motivated to perform multiple simultaneous tasks within tight schedules (Wright, 1988). The results showed that polychrons performed the dual hill-climbing task better than monochrons in general, but monochrons could have similar performance under certain conditions such as with low task difficulty (Figure 4). Above a certain level of difficulty differences between the two groups emerge. Furthermore, monochrons changed their emphasis to the more important task with increasing task priority (Figure 3). However, polychrons' performance does not show any extra emphasis with varying priorities thereby reducing the disparity between the two groups in the performance measures.

As outlined by Hall (1989), time usage is an important characteristic separating cultures. The results of this study can have important implications in organizations as well as day-to-day lives of people of various cultures or cultural groups as it allows for a good understanding of performance differences in differing task situations. The results from this study should be used with caution due to the small sample size. Further evaluations with a larger multi-cultural sample are needed.

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