TIME ORIENTATION EFFECTS ON HUMAN PERFORMANCE IN PROCESS CONTROL

Yan Zhang [1], Ravindra S. Goonetilleke[2*], Tom Plocher[3], and Sheau-Farn Max Liang[4]
[1,2] Dept. IEEM, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong.
[3] Honeywell Laboratories, Minneapolis, MN.
[4] Department of Industrial Engineering & Management, National Taipei University of Technology, Taiwan, ROC.
* ravindra@ust.hk

Researchers have alluded to cognitive differences between monochronic and polychronic (M/P) persons. This study was aimed at finding such differences in a process control setting. A total of 22 participants were classified as monochronic or polychronic using the Modified Polychronic Attitude Index 3 scale. Thereafter, each participant was asked to monitor and control two processes, which were either first or second order, at the same time using the Control Station software. The objective was to bring and keep both processes within the control limits at anyone time. The dependent variables were mean error, root mean square of error, number of switches between two processes, and number of magnitude changes. A 2 (process order) * 2 (Monochronic or polychronic group) * 5 (trials) ANOVA showed significant differences between monochronic and polychronic individuals. The results also showed that the mean error and root mean square of error of the polychronic group were significantly smaller than that of the monochronic group. There were no significant differences in the performance variables for the two process orders. Given the differing time orientations among cultures, these results have important implications for the selection and training of personnel in multitasking situations.

INTRODUCTION

Time orientation seems to be an important consideration when designing task environments. Hall (1959, 1983, 1990) classified people as monochronic or polychronic, with monochronic behavior or monochronicity referring to doing one task at a time while polychronic behavior or polychronicity implying doing many tasks at a time. Monochronic and polychronic (M/P) behavior is also thought to be related to the amount of time-sharing required in a job (Frei et al., 1999). If this argument is true, polychronic persons might be able to switch attention between multiple tasks and as a result, may be able to handle many jobs or series of tasks better than monochronic persons.

The aim of this study was to evaluate performance and strategy differences of monochronic and polychronic people in a multi-task process control setting. A 2 (process order, first or second) * 2 (Monochronic or polychronic group) * 5 (trial) factorial experiment was used.

METHODOLOGY

Participants

Forty-two Hong Kong Chinese students completed an online questionnaire. Based on their Monochronic/Polychronic (M/P) score, a total of 22 participants were selected for the experiment.

Simulation Software

The Control Station software (Cooper and Dougherty, 2001) was used for the simulation. A schematic of the two-process control task is shown in Figure 1. The process output (O) was based on the process dynamics, operator input (I) and the disturbance dynamics. The process output was graphically displayed and the user entered the required input using either the mouse or keyboard. Since process order can change task difficulty and affect performance (Wickens, 1986), both the processes were either first-order or second order so that task difficulty was different between the two conditions (Table 1).

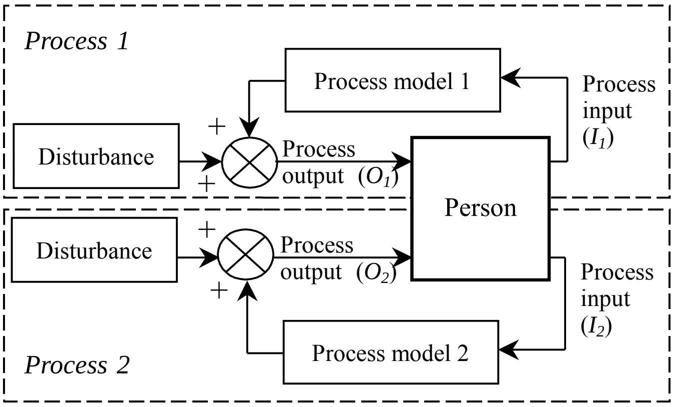

Figure 1. Control system schematic

Table 1. Control system characteristics of the two experimental conditions

	Condition 1		Condition 2	
	Process 1	Process 2	Process 1	Process 2
Order	1	1	2	2
Process Model (in Laplace domain)	$\frac{1.2e^{-4.5s}}{s}$	$\frac{0.85e^{-5s}}{s}$	$\frac{1.2e^{-4.5s}}{s(s+1)}$	$\frac{0.85e^{-5s}}{s(s+1)}$
Initial value	100	0	100	0
Disturbance	Model = 1/(s+1) Psuedo Random Binary Sequence: mean value was 4, amplitude from mean was ±4, and average Pulse Duration was 40 ± 1 in time units			

Procedure

First, the participants completed the Modified Polychronic Attitude Index 3 (MPAI3) questionnaire (Lindquist et al., 2001). The M/P score was calculated as the mean of the three items of MPAI3 scale. Eleven participants whose score was in the range 1 to 3 were assigned to the monochronic group, while eleven participants whose score was in the range 5 to 7 were assigned to the polychronic group.

All 22 participants received between 45 and 60 minutes training on the first and second order processes. The training session ended when each participant understood the control process and knew how to operate the system.

The starting value of the two process outputs was set to 100 and 0 and the participant was required to maintain each process output between 49 and 51 during the experiment. The participants were allowed to switch between the two processes at any time. Each participant had 5 trials for each condition and each trial took approximately 6 minutes. The participants were allowed to take breaks in-between trials. The two conditions were balanced among all the participants. The total experimental time for each participant was approximately 70 minutes.

RESULTS AND ANALYSIS

The dependent variables were the total number of switches between the two processes; total number of input magnitude changes within a trial; overall mean error and overall root-mean-square error (or mean RMS error). Thus, the number of switches and number of magnitude changes can be considered as strategy measures.

The error for process i at time unit j (sampling time) was calculated as follows:

$$error_{ij} = \begin{cases} (49 - O_{ij}) & \text{if } O_{ij} < 49; \\ (O_{ij} - 51) & \text{if } O_{ij} > 51; \\ 0 & \text{if } 49 \leq O_{ij} \leq 51. \end{cases} \qquad i = 1, 2 \quad j = 1, 2, \ldots T$$

The mean error of each process ($\bar{e}_1$ and $\bar{e}_2$) was then calculated over the 6 minutes. The overall mean error was the mean of $\bar{e}_1$ and $\bar{e}_2$. Similarly, the RMS error of each process ($RMSe_1$ and $RMSe_2$) was calculated separately and the overall RMS error was the mean of $RMSe_1$ and $RMSe_2$.

A three factor (M/P group, process order, trial) ANOVA was performed and the results are shown in Table 2. The results showed that all four dependent variables were significantly different ($p < 0.05$) between the two M/P groups. The (M/P group*order) interaction also showed a significant effect for the number of switches. In addition, the results showed that mean error and RMS error were significantly different among the 5 trials. A *post- hoc* Duncan test showed that trial 1 was significantly different from trial 2, 3, 4 and 5 for overall mean error (Table 3). Thus, the ANOVA was repeated excluding trial 1 (Table 4). In this analysis, even though there was no significant trial effect, the main effect of M/P group was still significantly different for all four dependent variables (M=13.80, P=36.14 for number of switches; M=160.19, P=320.74 for number of magnitude changes; M=10.69 and P=7.45 for overall mean error and M=12.76 and P=10.09 for mean RMS error). The M/P group*order interaction was also significant and is shown in Figure 2.

Table 2. ANOVA results for all trials

		Number of switches	Number of magnitude changes	Overall mean error	Mean RMS error
Source	*DF*	*F Value (Pr > F)*	*F Value (Pr > F)*	*F Value (Pr > F)*	*F Value (Pr > F)*
M/P	1	**222.05** **<.0001**	**94.21** **<.0001**	**17.33** **<.0001**	**57.24** **<.0001**
Order	1	0.29 0.5904	0.04 0.8403	0.87 0.3514	0.01 0.9293
M/P *Order	1	**3.89** **0.0499**	0.00 0.9482	0.01 0.9389	0.01 0.9376
Trial	4	0.89 0.4703	0.77 0.5468	**12.62** **<.0001**	**9.09** **<.0001**
M/P *Trial	4	0.10 0.9828	0.06 0.9936	0.86 0.4897	0.95 0.4355
Order *Trial	4	0.34 0.8525	0.35 0.8429	0.23 0.9216	0.39 0.8176
M/P*Order *Trial	4	0.10 0.9831	0.18 0.9482	1.41 0.2327	0.72 0.5808
Error	200				

Table 3. Duncan Grouping for trial differences

	Trials				
	1	2	3	5	4
Overall Mean error	14.64	10.12	8.76	8.75	8.65
Mean RMS error	13.80	12.15	11.32	11.19	11.03

Table 4. ANOVA results excluding trial 1

		Number of switches	Number of magnitude changes	Overall mean error	Mean RMS Error
Source	*DF*	*F Value Pr > F*	*F Value Pr > F*	*F Value Pr > F*	*F Value Pr > F*
M/P	1	**218.59** **<.0001**	**106.33** **<.0001**	**41.26** **<.0001**	**54.50** **<.0001**
Order	1	0.28 0.5993	0.06 0.8010	0.46 0.4985	0.01 0.9037
M/P *Order	1	**4.25** **0.0410**	0.09 0.7618	2.43 0.1211	0.20 0.6586
Trial	3	0.58 0.6259	0.21 0.8876	1.94 0.1257	1.90 0.1313
M/P *Trial	3	0.12 0.9487	0.11 0.9565	0.40 0.7551	1.27 0.2866
Order *Trial	3	0.54 0.6542	0.30 0.8232	0.18 0.9101	0.50 0.6831
M/P*Order *Trial	3	0.13 0.9412	0.11 0.9532	0.31 0.8194	0.61 0.6091
Error	160				

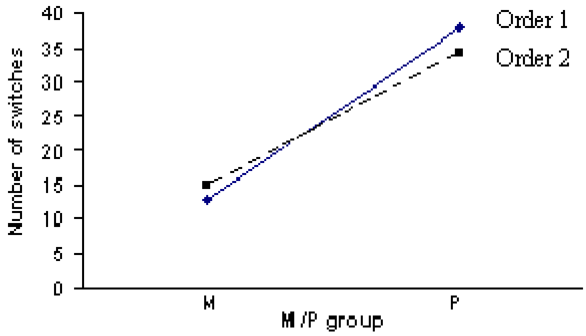

Figure 2. The M/P group*order interaction for number of switches

The correlation coefficients among the four dependent variables, for trials 2 to 5, are shown in Table 5.

Table 5. Pearson Correlation Coefficients among the dependent variables for the last 4 trials of the first order system (N=88). The second order system correlations are in brackets.

	Number of switches	Number of magnitude changes	Overall mean Error	Mean RMS error
Number of switches	1 {1}			
Number of magnitude changes	0.75 {0.73}	1 {1}		
Overall mean error	-0.52 {-0.43}	-0.40 {-0.24*}	1 {1}	
Mean RMS error	-0.62 {-0.56}	-0.53 {-0.39}	0.90 {0.89}	1 {1}

*p = 0.02; all others p < 0.01.

DISCUSSION AND CONCLUSION

Similar to many other process simulations, some amount of learning was present during the experimentation even with extensive training. As shown by the ANOVA, this effect was short-lived however.

The correlation analysis shows that the number of switches and the number of magnitude changes is negatively correlated with the two error measures. In other words, a higher number of switches seem to show a lower overall error. This result is a clear reflection of the primary difference between monochronics and polychronics. The number of magnitude changes and the number of switches were significantly lower for the monochronic persons when compared to polychronics, resulting in a significantly higher performance error for monochronics. The relatively strong correlation between the number of switches and the number of magnitude changes is not very surprising. Every switch should have been associated with a magnitude change even though a magnitude change was not necessarily as a result of switching between the processes.

The number of switches variable indicates that polychronics switch between the two processes more often. In other words, polychronics are able to control both processes at the same time (in parallel) as opposed to monochronics who tend to control the two processes somewhat sequentially.

The lack of a significant difference between the first and second order processes is to be expected. As shown in Table 1, the second order process in condition 2 was a second order lag system (exponential lag). Systems with exponential lags do not necessarily degrade tracking performance (Wickens, 1986) even though a pure second order system may have shown somewhat different results as they tend to be very sluggish, especially if the gain is low.

Overall, the results showed that there were significant differences in strategy as well as performance between monochronic and polychronic persons in a dual-process control task. The results support some of the previous claims about differences between polychronics and monochronics. Further study is needed to identify task difficulty thresholds at which the performance between monochronics and polychronics change from being the same to significantly different. Once these basic performance characteristics of time orientation are understood, it may be possible to identify specific training interventions and operator aids that improve performance, so that human-machine interactions in control tasks may be optimized.

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REFERENCES

Cooper, D. and Dougherty, D., 2001. Control Station: An interactive simulator for process control education. International Journal of Engineering Education, 17 (3). 276-287.

Frei, R.L., Racicot, B. and Travagline, A., 1999. The impact of monochronic and Type A Behavior patterns on research productivity and stress. Journal of Managerial Psychology, 14(5), 374-387.

Hall, E.T., 1959. The silent language. New York: Fawcett Publications.

Hall, E.T., 1983. The dance of life: the other dimension of time. New York: Anchor Press.

Hall, E.T., 1990. The hidden dimension. New York: Anchor Press.

Lindquist, J.D., Knieling, J. and Kaufman-Scarborough, C., 2001. Polychonicity and consumer behavior outcomes among Japanese and U.S. students: A study of response to culture in a U.S. university setting. In: Proceedings of the Tenth Biennial World Marketing Congress. City Hall Cardiff, UK.http://www.crab.rutgers.edu/~ckaufman/polyJapanese.html.

Wickens, C.D., 1986. The effects of control dynamics on performance. In: Boff, K.R., Kaufman, L. and Thomas, J.P. (Eds.), Handbook of perception and human performance, Volume II, cognitive processes and performance, Chapter 39. New York: John Wiley and Sons.