USAARL Report No. 92-16

Comparability of Two Cognitive Performance Assessment Systems

By

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February 1992

United States Army Aeromedical Research Laboratory
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SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 92-16	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory 6b. OFFICE SYMBOL (If applicable) SGRD-UAB-CS	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research and Development Command
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 577 Fort Rucker, AL 36362-5292	7b. ADDRESS (City, State, and ZIP Code) Fort Detrick Frederick, MD 21702-5012
8a. NAME OF FUNDING/SPONSORING ORGANIZATION 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code)	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)
Comparability of Two Cognitive Performance Assessment Systems (U)

12. PERSONAL AUTHOR(S)
Stephens, Robert L. and Verona, Robert W.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final	FROM _____ TO _____	1992 February	83

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	cognitive performance assessment, computers, LCD, CRT display
05	08		
06	10		

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This study compared two computerized cognitive performance assessment systems: a typical laboratory desktop computer system and a ruggedized, hand-held field-portable system. Identical cognitive performance assessment software was installed on the two devices in order to determine whether differences in the hardware configurations of the two devices influenced measures of cognitive performance. Data were collected on 24 subjects over a period of 1 week during which subjects performed six cognitive tasks twice a day on each of the computer systems. Results indicated a high degree of sensitivity of the cognitive tests to day and session effects. Also, there were tasks in which the type of device used to present stimuli and record data influenced the results obtained. Differences between the two devices in terms of their display characteristics seem to account for the influences.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT	21. ABSTRACT SECURITY CLASSIFICATION	
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Scientific Information Center	22b. TELEPHONE (Include Area Code) (205) 255-6907	22c. OFFICE SYMBOL SGRD-UAX-SI

DD Form 1473, JUN 86 *Previous editions are obsolete.*

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Acknowledgments

The authors would like to thank Ms. Jean Anderson for her dedicated assistance in conducting the study, analyzing the data, and preparing the report. Thanks to Mr. Clarence E. Rash for contributing his invaluable photometric expertise. Thanks also to Mr. Jim A. Chiaramonte, SPC4 Angelia Mattingly, 2LT Shawn Prickett, and PFC Hilda Pou for help in preparing the report. We also would like to thank all of the individuals who volunteered their time to participate in this investigation. Data collection and analysis were supported under Contract # DAMD17-86-C-6215.

Introduction

Statement of the problem

Current computer technology can provide the power and functionality of a desktop PC-compatible computer in a hand-held device which is capable of withstanding the harsh environments often encountered in military operational research settings. However, certain hardware characteristics have been modified to produce these devices. Liquid crystal displays (LCDs) have replaced the typical cathode ray tube (CRT) displays, and nonstandard keyboards have been employed. Furthermore, systems vary in the way they handle timing functions. All of these changes can potentially affect the stimulus or response characteristics of the cognitive performance tasks which are implemented on the different devices. Research is necessary to determine what effects, if any, these hardware differences will have on the stimulus presentation and subject response characteristics of performance assessment batteries (PABs) which are implemented on the different computer systems.

Background

In 1984, the U.S. Army Research and Development Command awarded a Small Business Innovative Research contract to a company called Information Management Group, Inc. of Melbourne, Florida (currently known as Paravant Computer Systems, Inc.) to develop a ruggedized hand-held computer for performance testing in operational settings. This effort, which has been documented previously (Caldwell and Young, 1990), resulted in the production of the RHC-88 hand-held, ruggedized, field-portable assessment system. For the system, Paravant also developed a C language version of the original Walter Reed PAB (Thorne et al., 1985) which is stored in programmable ROM on the device.

The Office for Military Performance Assessment Technology (OMPAT) has sought to standardize performance assessment methodologies throughout military research facilities. Their efforts have focused on the development of performance assessment software for desktop PC applications in laboratory settings. While significant progress has been made towards the standardization of laboratory performance assessment systems, standardization of field-portable assessment systems has not kept pace.

Military significance

U.S. Army personnel are required to operate in a variety of stressful environments. Since the effects of stress-inducing variables frequently require timely and accurate assessment,

proven standardized testing techniques are highly desirable. While much effort has been directed toward the development of computerized performance assessment batteries, most of these batteries have been adapted for administration on desktop computers. Such systems are useful in a controlled laboratory environment, but are not capable of withstanding the harsh environments often encountered when collecting data in field research settings.

The development of the RHC-88 hand-held computer provides a device well-suited to the task of performance data collection during field studies. The ruggedized design makes it capable of withstanding 1) the shock of a 4-foot drop onto concrete, 2) emersion in water up to 10 feet deep, and 3) environmental temperatures ranging from -27 degrees F to 145 degrees F. In brief, the device meets all the ruggedization specifications of Military Standard 810-D. Thus, subjects no longer have to be removed from their working environment for testing purposes.

Objective

The objective of the reported research project was to determine the comparability of two different computer systems used to administer the same cognitive performance assessment battery. Specifically, the subjects' performances were compared on selected subtests of the Walter Reed PAB (Thorne et al., 1985) as implemented on both a Zenith 248 PC-compatible desktop computer and a Paravant RHC-88 ruggedized hand-held computer. By having subjects perform the subtests on both systems, it was possible to determine if differences in the hardware characteristics of the two devices influenced subject performance. This information will help to establish the generalizability of results obtained in laboratory experiments to those obtained in field research environments.

Method

Subjects. Twenty-seven subjects were recruited for participation from the pool of soldiers on casual status at Fort Rucker. Each of these subjects was informed of all testing procedures and the general purpose of the study. They were informed that their participation was completely voluntary and that they could withdraw from the study at any time without penalty. After obtaining volunteer consent, each subject's vision was tested using an Armed Forces Vision Testing apparatus. All subjects had at least 20/20 near visual acuity (either corrected or uncorrected). Three subjects did not complete all sessions, and their data were not included in the analyses. The

remaining 24 subjects were between the ages of 19 and 45 (mean = 25.8 years, s.d. = ± 6 years).

Apparatus. The Walter Reed PAB software was installed on two different computer systems: 1) a Zenith 248 desktop computer and 2) a Paravant RHC-88 ruggedized hand-held computer. Four Zenith 248 PCs were equipped with 640 Kb of RAM storage, a 20 Mb hard disk drive, two 360 Kb floppy disk drives, an EGA graphics adapter, a Zenith color monitor, and a standard Zenith keyboard. Four Paravant RHC-88 ruggedized, PC-compatible, hand-held computers were equipped with 512 Kb of static RAM storage, 1 Mb of dynamic RAM storage, 384 Kb of user ROM storage, a high-contrast graphics LCD display, an RS-232 communications port, a real-time clock and calendar, and color-coded alphanumeric keys for response entry.

Procedure. The testing was conducted in a 15 X 15 foot room with sound attenuating dividers partitioning the subjects and devices from each other. The partitions precluded the subjects from viewing each other's computer screens and attenuated the keyboard noise. At each of the four Zenith testing stations, the computer was arranged on a two-level table with the 13 inch color monitor atop the computer console on the rear upper level and the keyboard on the forward lower level. The subject sat on a chair facing the monitor and wall. At each of the four Paravant testing stations, the subject sat on a chair with the computer in his lap facing the center partition with his back toward the wall to reduce the glare from the overhead lighting. The room lighting was provided by overhead fluorescent lamps with half of the normal bulbs removed to reduce the light level and improve the computer screen visibility.

Subjects were recruited for a 1-week period. When a subject first arrived at the laboratory, he was randomly assigned to one of the two orders of presentation (hand-held first or desktop first). Each subject received two sessions per day: one in the morning (0800) and one in the afternoon (1300). Each session consisted of one administration of the battery on each of the two systems. These administrations were separated by a 1-hour break. To minimize the effects of fatigue and boredom, subjects were allowed to watch television or recorded movies during the break. The selected subtests included a mood scale, a pattern comparison task, a logical reasoning task, a serial addition/subtraction task, a digit recall task, a four-choice reaction time task, and a six-letter search task.

The mood scale consisted of the sequential presentation of 36 adjectives which the subject was to rate on a 3-point scale according to how accurately each described his current mood. A 1 represented "not at all" like current mood and three represented "mostly or generally" like current mood. Ryman, Biersner, and

Rocco (1974) developed the mood scale and performed a factor analysis which extracted six unique factors: "anger," "happiness," "fear," "depression," "activity," and "fatigue."

The pattern comparison task had a spatial memory component. It involved the presentation of a random pattern of asterisks displayed for 1.5 s and followed, after a 3.5-s retention interval, by a second pattern which was either the same or different. The subject decided as quickly as possible, and then entered either an "S" for "same" or a "D" for "different." The pattern consisted of 14 dots arranged in a matrix. On approximately half the trials, the pattern changed when three randomly selected dots exchanged horizontal positions while their vertical positions remained unchanged.

The logical reasoning task involved the simultaneous presentation of the letter pair "A B" or "B A" and a statement which correctly or incorrectly described the letter pair. The subject indicated as quickly as possible whether the statement was an accurate or inaccurate description of the letter pair by pressing either the "S" key or the "D" key, respectively.

In the serial addition/subtraction task, the subject viewed the sequential presentation of two single digit numbers and a "+" or a "-" sign. Following the presentation, the subject was prompted for a response by the presentation of a question mark. The subject's task was to perform the indicated computation and enter a response as quickly and as accurately as possible. If the result of the computation was less than 0, the subject was instructed to add 10 to the result and enter the sum. If the result was greater than 9, the subject was instructed to subtract 10 from the result and enter the difference. Thus, the required response was always an integer between 0 and 9, inclusive.

The digit recall task involved the presentation of nine random digits which were displayed in a row across the center of the screen for 1 s. After a 3 s blank retention interval, eight of the nine original digits were displayed again in a different order and the subject indicated as quickly as possible which of the original nine digits was missing by entering the missing digit on the keyboard.

The four-choice serial reaction time task involved the presentation of four boxes arranged in a square at the center of the screen. At random, one box was filled. The subject pressed the corresponding key on the keyboard as quickly as possible thereby initiating the next trial.

The six-letter search task involved the presentation of 6 target letters at the top of the screen, along with a search string of 20 letters in the middle of the screen. The subject's

task was to determine as quickly and as accurately as possible whether all six target letters were present in the search string or not. If all six were present, in any order, the subject pressed the "S" key for "same." If any one of the six target letters was missing, the subject responded by pressing the "D" key for "different." Both strings changed with each trial.

The order of presentation of the two systems remained the same for each subject throughout the week of testing. Order of presentation of the two systems was counterbalanced across subjects. That is, during a session, half of the subjects received the desktop system during their first administration of the battery and the hand-held system during their second administration. The remaining subjects received the opposite order of presentation. Feedback regarding accuracy of performance was provided after each response during the first five sessions (i.e., through the Wednesday morning session). During the remaining sessions, feedback was eliminated.

Results

Initial screening of the data included graphs of the mean percent correct, mean reaction time for correct responses, mean speed, and mean throughput across subjects with associated standard deviations for each of the subtests used on both administrations of the Walter Reed PAB. Further, each subject's performance was compared to the average to determine the presence of outliers or spurious scores. Based on the results of the initial data screening, three variables were selected for further analysis: transformed percent correct [using the arcsine square root transformation (Winer, 1971)], reaction time (RT) for correct responses (s), and throughput (correct responses/min).

Initial screening of the data revealed an error in assignment of subjects to groups. The ratio of officers to enlisted was not equal for the two orders of presentation. Therefore, subsequent analyses were performed after combining the data from both groups. Furthermore, two software-related problems were not discovered until the data analysis had begun. First, the level of difficulty for the various sessions was not constant. Thus, while trials were identical across subjects for a particular session, the possibility of a confound between day order and level of difficulty exists. Second, no provision was made to equate the chance probability of a correct answer with the reciprocal of the number of possible responses. For example, providing the same response for all stimuli in a subtest that required either of two responses, "same" or "different," could yield from 10 percent to 90 percent correct instead of a balanced 50 percent chance for a correct answer.

Following initial screening, a series of separate univariate repeated-measures factorial analyses of variance (ANOVAs) was performed on the selected variables with day, session, and computer as the within-subjects factors. For tests in which the sphericity assumption was violated, degrees of freedom were corrected using the Greenhouse-Geisser epsilon value (Grieve, 1984). Significant interactions were examined using simple effects analyses and pairwise linear contrasts. Significant main effects also were examined using pairwise linear contrasts. Results for six of the seven tasks are presented below. Data from the mood questionnaire will not be discussed in this report.

Pattern comparison

The pattern comparison data were analyzed using transformed percent correct, reaction time for correct responses, and throughput as dependent variables. Complete data were available for all 24 subjects. The significance tables are listed in Appendix A.

Transformed percent correct. ANOVA for the transformed percent correct measure revealed significant interactions between day and session ($F(4,92)=3.88$, $p=0.0059$) and between day and computer ($F(4,92)=5.62$, $p=0.0004$). The day by session interaction is depicted in Figure 1, and the day by computer interaction is depicted in Figure 2. The day main effect was significant also ($F(4,92)=3.03$, $p=0.0215$).

Simple effects analysis for the day by session interaction revealed a statistically significant session simple effect ($F(1,23)=24.49$, $p=0.0001$) for Friday (i.e., Day 5). Performance decreased from morning (2.45) to afternoon (2.16) on Friday (Day 5). There also were significant day simple effects for both morning sessions ($F(4,92)=3.28$, $p=0.0145$), and afternoon sessions ($F(4,92)=3.57$, $p=0.0094$).

Contrasts for the day simple effect across morning sessions indicated accuracy increased significantly between Monday (Day 1) morning and Thursday (Day 4) morning. In addition, accuracy at the Tuesday (Day 2) morning session was lower than Wednesday (Day 3), Thursday (Day 4), and Friday (Day 5) morning sessions. None of the other contrasts were significant.

Contrasts for the day simple effect across afternoon sessions indicated accuracy for the Friday afternoon session (2.16) decreased significantly relative to Tuesday (2.39), Wednesday (2.44) and Thursday (2.38) afternoon sessions. None of the other contrasts were significant.

Simple effects analysis for the day by computer interaction revealed significant computer simple effects on Monday

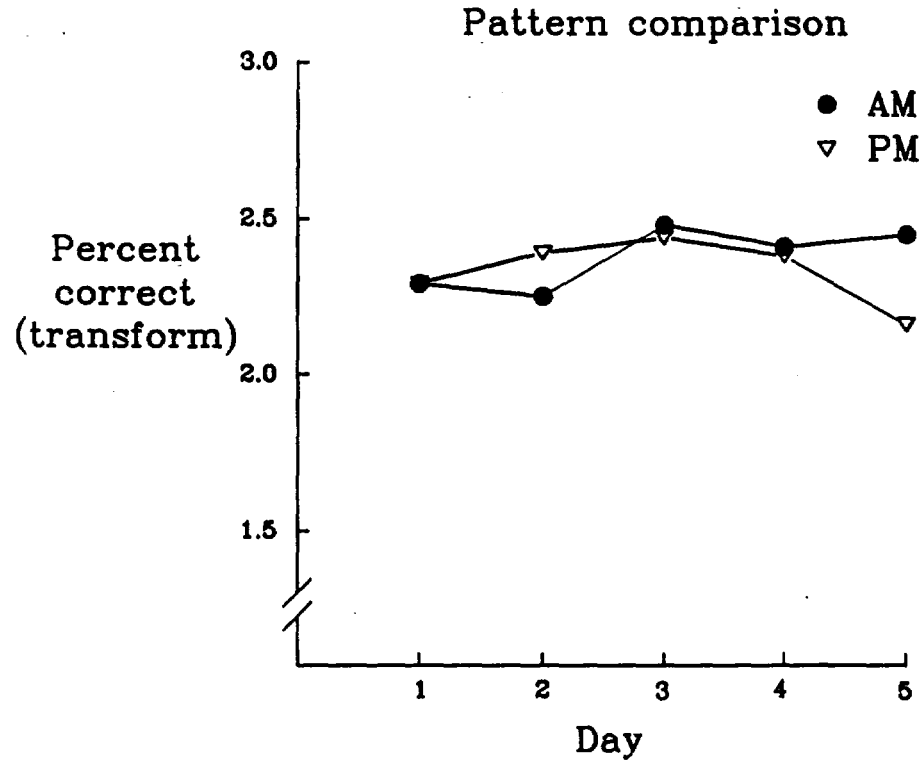

Figure 1. Day by session interaction for transformed percent correct on the pattern comparison task.

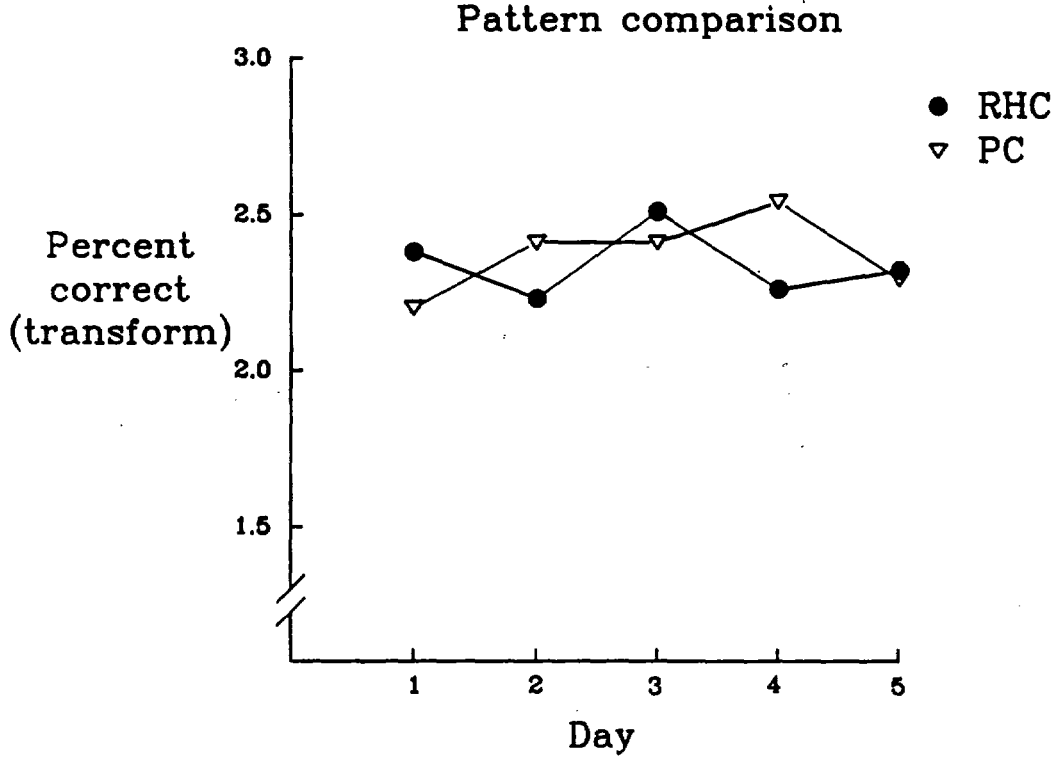

Figure 2. Day by computer interaction for transformed percent correct on the pattern comparison task.

(F(1,23)=6.22, p=0.0203) and Thursday (F(1,23)=12.46, p=0.0018). Transformed percent correct scores were higher for the hand-held (2.38) than the desktop (2.20) on Monday while scores on the hand-held (2.26) were lower than the desktop (2.54) on Thursday. Transformed percent correct scores also differed significantly among days for the hand-held computer (F(4,92)=3.61, p=0.0088) and for the desktop computer (F(4,92)=5.02, p=0.0010).

Contrasts for the day simple effect for the hand-held computer showed statistically significant increases in accuracy from Tuesday (2.23) to Wednesday (2.51) while accuracy decreased from Wednesday to Thursday (2.26). None of the other contrasts were significant.

Contrasts for the day simple effect for the desktop computer showed significant increases in scores from Monday (2.20) to Tuesday (2.41), Wednesday (2.41) and Thursday (2.54). However, accuracy dropped significantly from Thursday (2.54) to Friday (2.29). None of the other contrasts were significant.

The day main effect is depicted in Figure 3. Contrasts for the day main effect showed statistically significant increases in transformed percent correct scores on Wednesday (2.46) relative to Monday (2.29) and Tuesday (2.32). However, accuracy decreased from Wednesday to Friday (2.30). None of the other contrasts were significant.

Mean RT for correct responses. ANOVA for the mean RT for correct responses revealed a significant interaction between day and session (F(2.86,65.82)=6.47, p=0.0008). Mean RTs on Monday decreased from morning (1.60 s) to afternoon (1.32 s), and on Tuesday RTs again decreased from morning (1.29 s) to afternoon (1.20 s), (F(1,23)=12.39, p=0.0018) and (F(1,23)=7.57, p=0.0114), respectively. See Figure 4.

Simple effects analysis revealed significant day simple effects for both morning sessions (F(2.37,54.42)=7.49, p=0.0007) and afternoon sessions (F(2.04,46.85)=3.99, p=0.0246). Contrasts showed reductions in mean RT from Monday morning (1.60 s) through Tuesday (1.29 s), Wednesday (1.21 s), and Thursday (1.37 s) mornings, to Friday (1.35 s) morning. RTs on Wednesday morning were faster than both Tuesday and Thursday morning RTs. Contrasts for the afternoon sessions indicated RTs on Monday afternoon (1.32 s) also were longer than on Tuesday afternoon (1.20 s). However, RTs Thursday afternoon (1.44 s) were longer than Tuesday, Wednesday (1.26 s), or Friday (1.30 s) afternoon RTs.

The day main effect was statistically significant (F(2.09,48.08)=5.86, p=0.0047). Contrasts indicated RTs on Monday (1.46 s) were longer than on Tuesday (1.24 s) and

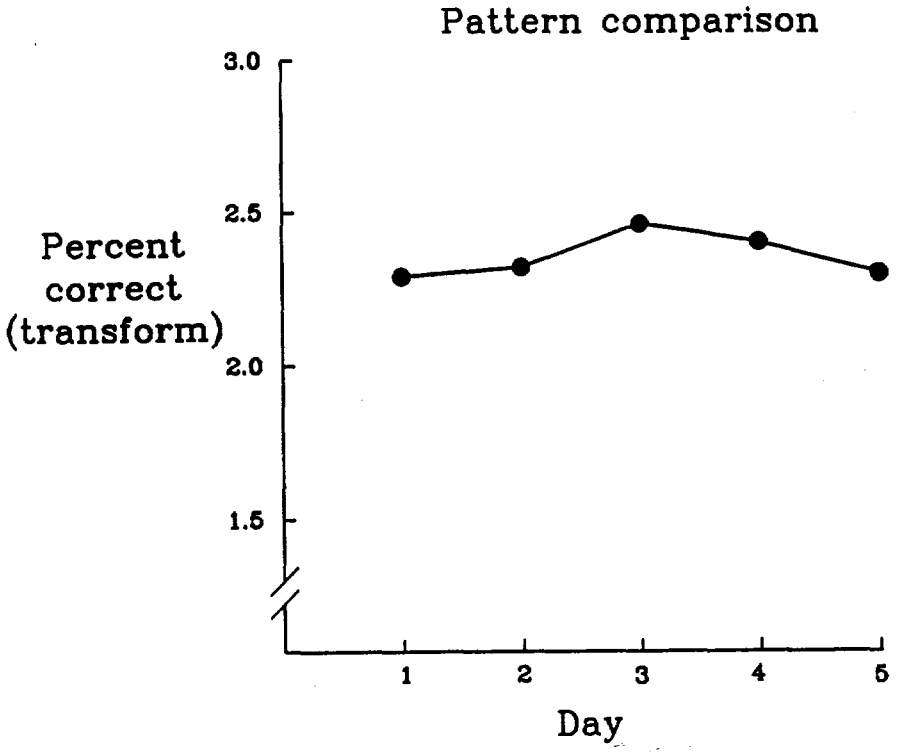

Figure 3. Day main effect for transformed percent correct on the pattern comparison task.

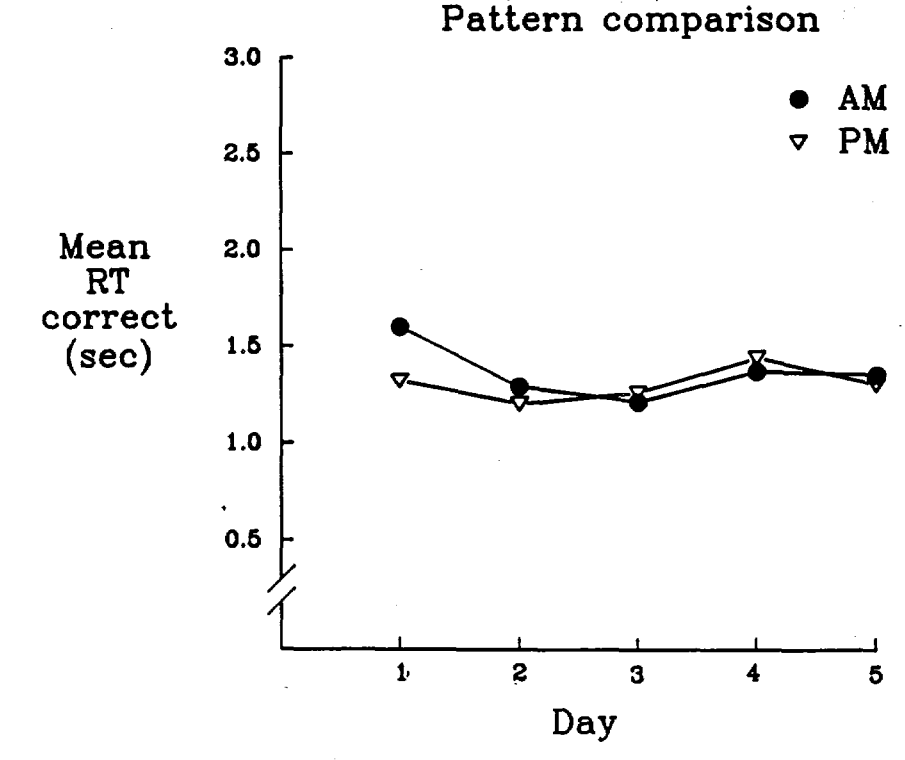

Figure 4. Day by session interaction for the mean reaction time for correct responses on the pattern comparison task.

Wednesday (1.23 s). By Thursday, RTs increased (1.40 s) relative to Tuesday (1.24 s) and Wednesday (1.23 s), but dropped again on Friday (1.33 s). See Figure 5.

For the session main effect ($F(1,23)=4.49$, $p=0.0450$), the mean reaction time during the morning session was 1.36 s, and 1.30 s during the afternoon session. For the computer main effect ($F(1,23)=16.01$, $p=0.0006$), the mean RT for the hand-held computer was 1.41 s and 1.26 s for the desktop computer, an 11 percent reduction.

Throughput. The day by computer by session interaction was statistically significant for throughput on the pattern comparison task ($F(3.06,70.33)=2.93$, $p=0.0385$). These data are illustrated in Figure 6.

Simple effects analysis revealed a simple two-way interaction between session and computer on Wednesday ($F(1,23)=5.18$, $p=0.0325$) which was accounted for by a lower throughput for the hand-held (47.05) than the desktop (59.70) on Wednesday afternoon.

Also, the day by computer simple interaction for afternoon sessions was statistically significant ($F(2.87,66.12)=2.81$, $p=0.0486$). This was due to lower throughput values for the afternoon sessions on the hand-held than on the desktop on Monday (53.18 vs 46.40), Tuesday (50.63 vs 58.14), Wednesday (47.05 vs 59.70), and Friday (48.96 vs 55.32) afternoons. A statistically significant day simple effect for afternoon sessions on the desktop computer ($F(2.71,62.33)=3.44$, $p=0.0258$) also contributed to this simple interaction. Contrasts for this simple effect showed throughput on Monday (53.18) was lower than on Tuesday (58.14) or Wednesday (59.70). However, throughput dropped on Thursday afternoon (49.39) relative to Monday and Wednesday afternoons.

Finally, the day by session simple interaction for the hand-held computer was significant ($F(4,92)=3.61$, $p=0.0089$). This interaction was accounted for by the increase in throughput from morning (41.25) to afternoon (46.40) on Monday, and by the significant differences in throughput among days for the hand-held computer morning sessions ($F(2.59,59.60)=5.81$, $p=0.0024$). Contrasts for the hand-held computer morning sessions showed throughput on Tuesday (47.96) was significantly higher than Monday (41.25) and Thursday (44.39), while throughput on Wednesday (51.30) was significantly higher than Monday (41.25), Tuesday (47.96), Thursday (44.39), and Friday (46.56).

The statistically significant main effects included day ($F(2.49,57.21)=3.94$, $p=0.0177$), session ($F(1,23)=5.74$, $p=0.0251$), and computer ($F(1,23)=28.08$, $p<0.0001$). The mean throughput for

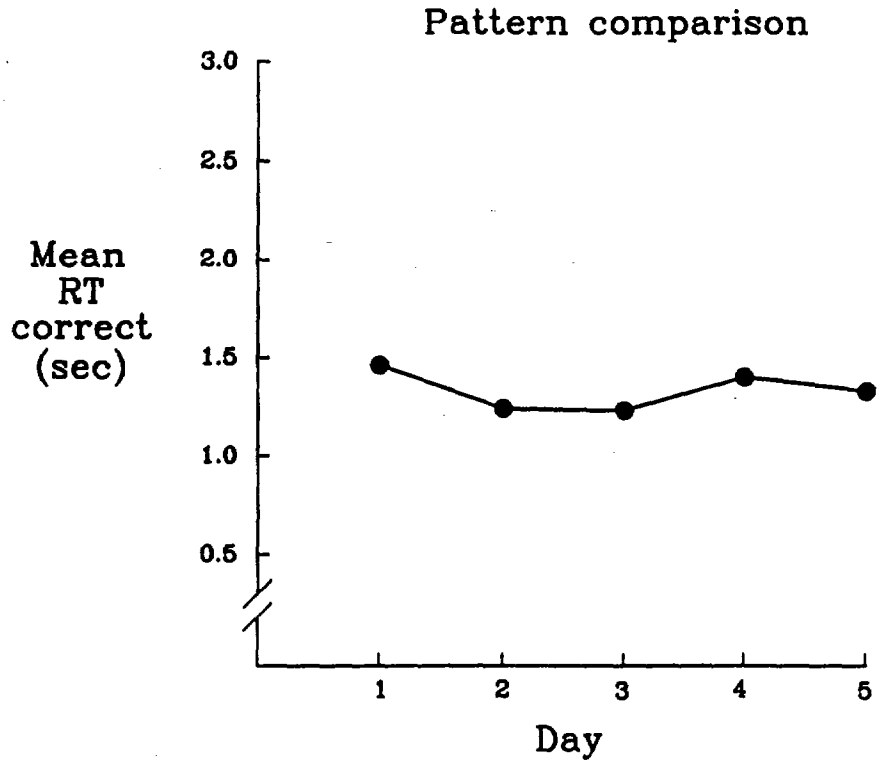

Figure 5. Day main effect for the mean reaction time for correct responses on the pattern comparison task.

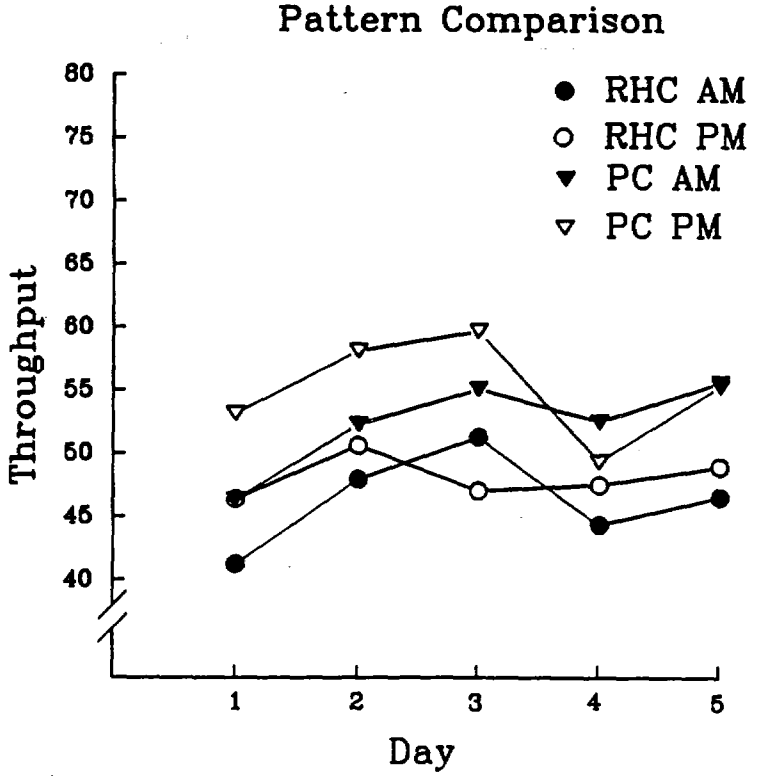

Figure 6. Day by session by computer interaction for throughput on the pattern comparison task.

each day is shown in Figure 7. Contrast analyses showed throughput increased from Monday (46.81 correct responses/min) to Tuesday (52.26) and Wednesday (53.29). Throughput on Thursday (48.47) was lower than Tuesday, Wednesday, or Friday (51.61). The mean throughput for all morning sessions was 49.34 correct responses/min and 51.63 for all afternoon sessions. The mean throughput for the hand-held computer was 47.20 correct responses/min and 53.77 for the desktop computer.

Logical reasoning

Complete data were available for all 24 subjects for the logical reasoning task. The significance tables are listed in Appendix B.

Transformed percent correct. The day by session interaction was the only significant interaction for the logical reasoning transformed percent correct variable ($F(4,92)=2.81$, $p=0.0301$). These data are presented in Figure 8. The day main effect, illustrated in Figure 9, also was statistically significant $F(2.79,64.22)=17.12$, $p<0.0001$).

Simple effects analysis for the interaction revealed significant differences between the Monday morning (2.34) and afternoon (2.51) scores ($F(1,23)=7.63$, $p=0.0111$), and among the days for the morning ($F(2.62,60.20)=16.35$, $p<0.0001$) and afternoon ($F(4,92)=7.52$, $p<0.0001$) sessions. Contrasts for the day simple effect for the morning sessions showed that accuracy was significantly lower on Monday morning (2.34) than on Tuesday (2.64), Wednesday (2.70), Thursday (2.74) and Friday (2.71) mornings. For the afternoon sessions, accuracy again increased significantly on Wednesday (2.69), Thursday (2.73) and Friday (2.78) afternoons relative to Monday (2.51) afternoon. Finally, accuracy was lower on Tuesday afternoon (2.60) than on Thursday (2.73) and Friday (2.78) afternoons.

Contrasts for the day main effect indicated that, regardless of session or computer, accuracy on Monday (2.43) was significantly lower than on Tuesday (2.62), Wednesday (2.70), Thursday (2.74) or Friday (2.75). Furthermore, accuracy was lower on Tuesday (2.62) than on Wednesday (2.70), Thursday (2.74) and Friday (2.75).

Mean RT for correct responses. ANOVAs for the mean RT for correct responses on the logical reasoning task resulted in statistically significant session by computer ($F(1,23)=9.09$, $p=0.0062$) and day by session ($F(4,92)=26.01$, $p<0.0001$) interactions, and a significant day main effect ($F(2.19,50.31)=16.09$, $p<0.0001$). These effects are illustrated in Figures 10 through 12, respectively. In addition, the main

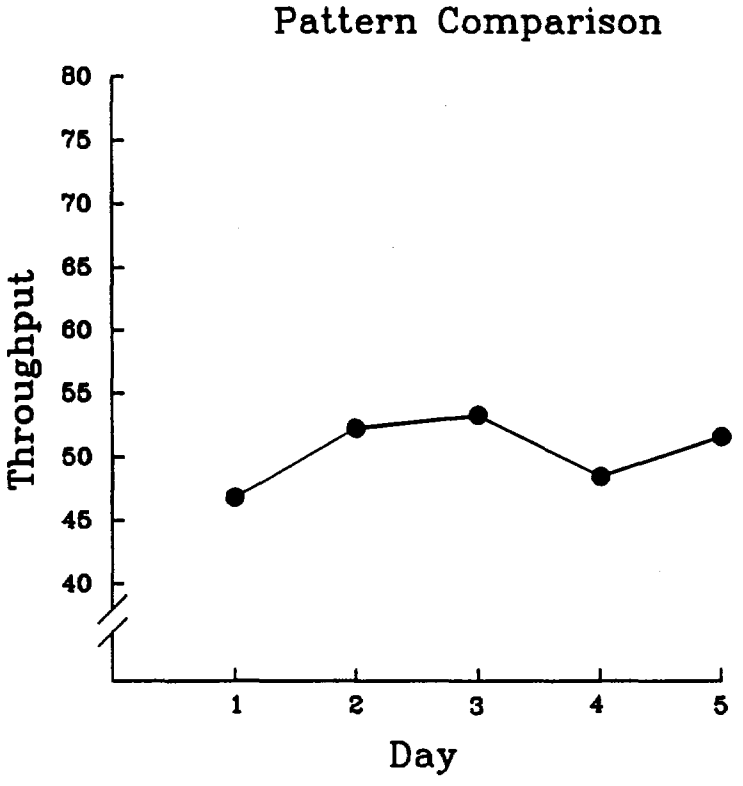

Figure 7. Day main effect for throughput on the pattern comparison task.

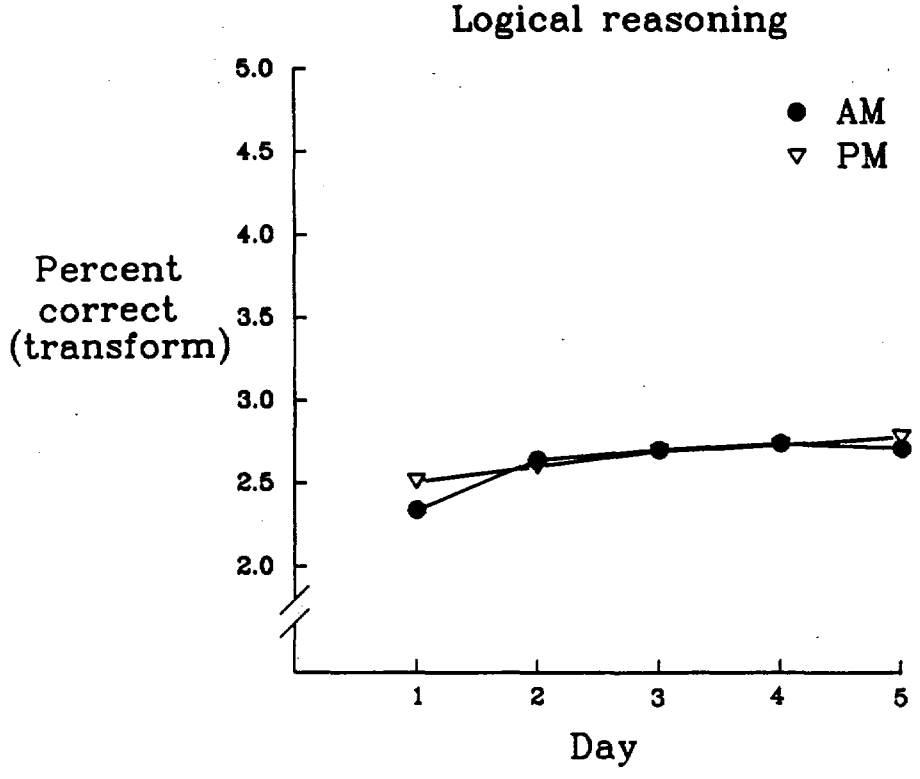

Figure 8. Day by session interaction for transformed percent correct on the logical reasoning task.

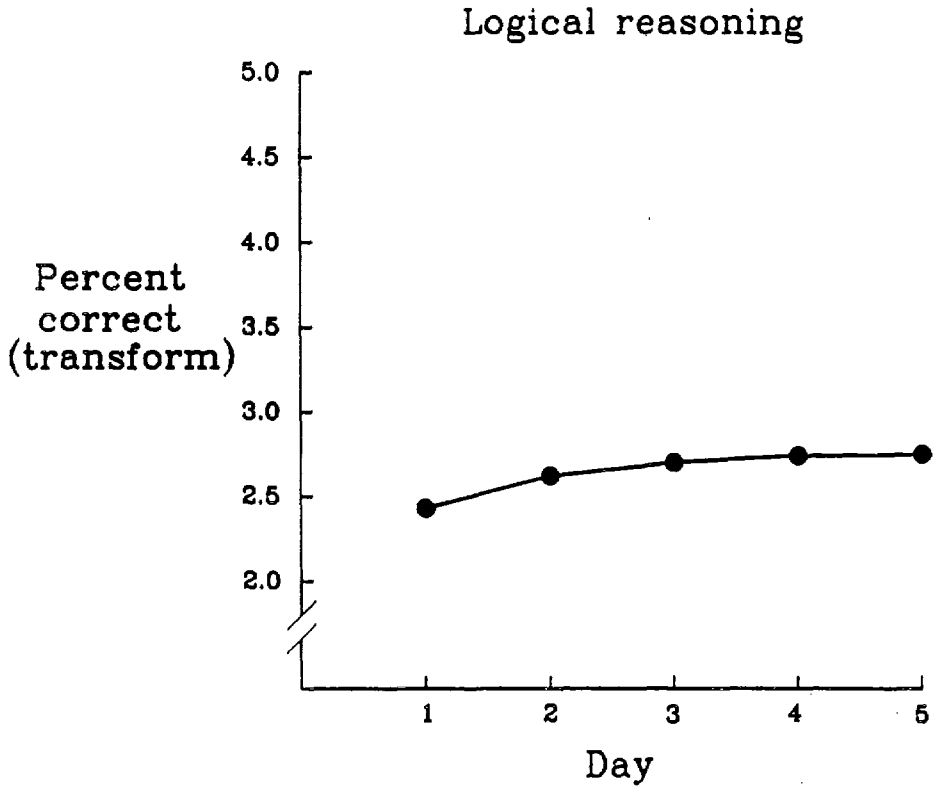

Figure 9. Day main effect for transformed percent correct on the logical reasoning task.

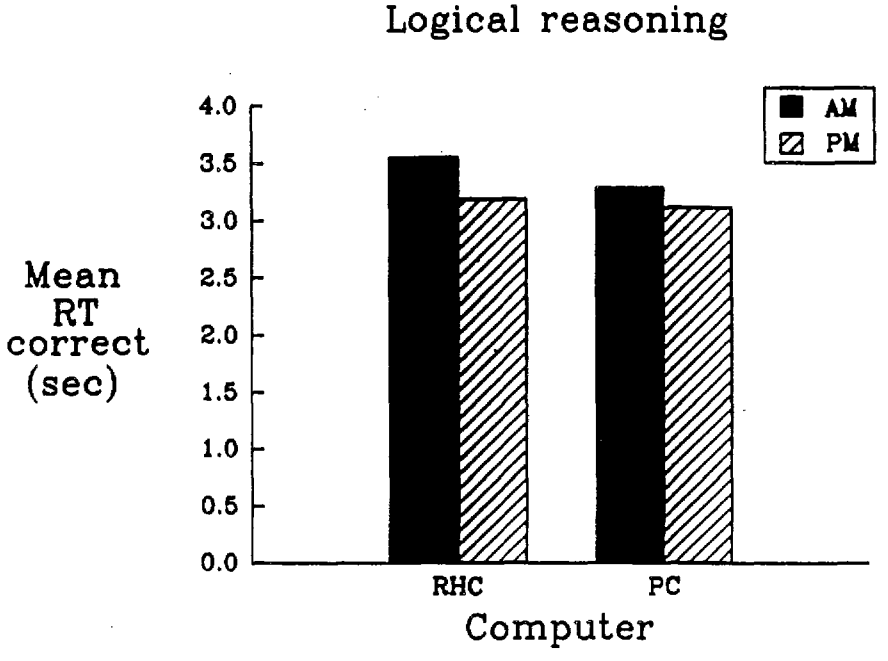

Figure 10. Session by computer interaction for the mean reaction time for correct responses on the logical reasoning task.

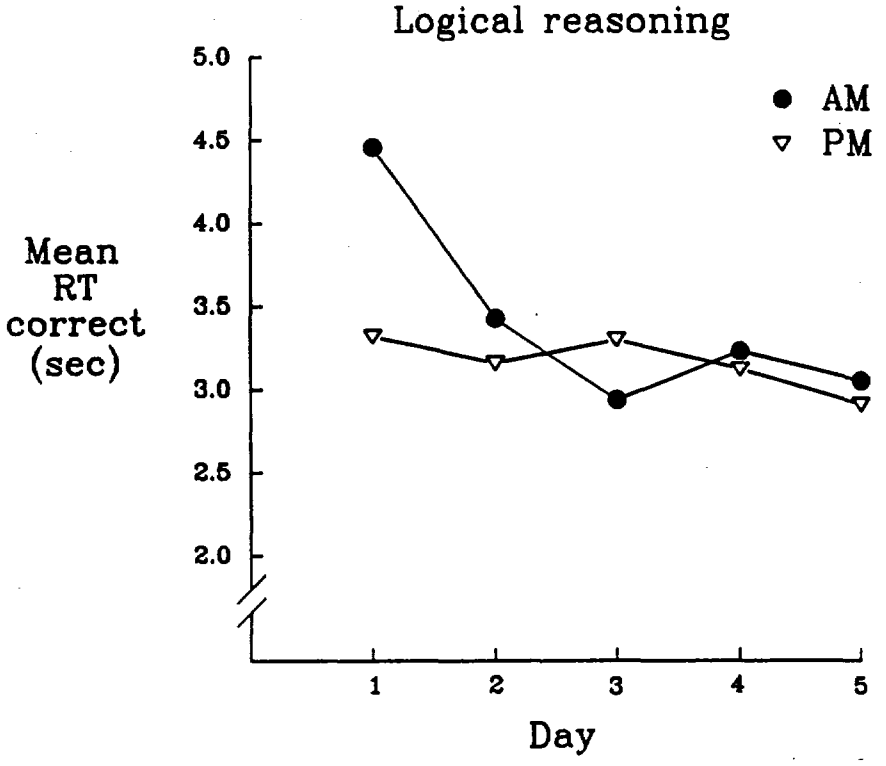

Figure 11. Day by session interaction for the mean reaction time for correct responses on the logical reasoning task.

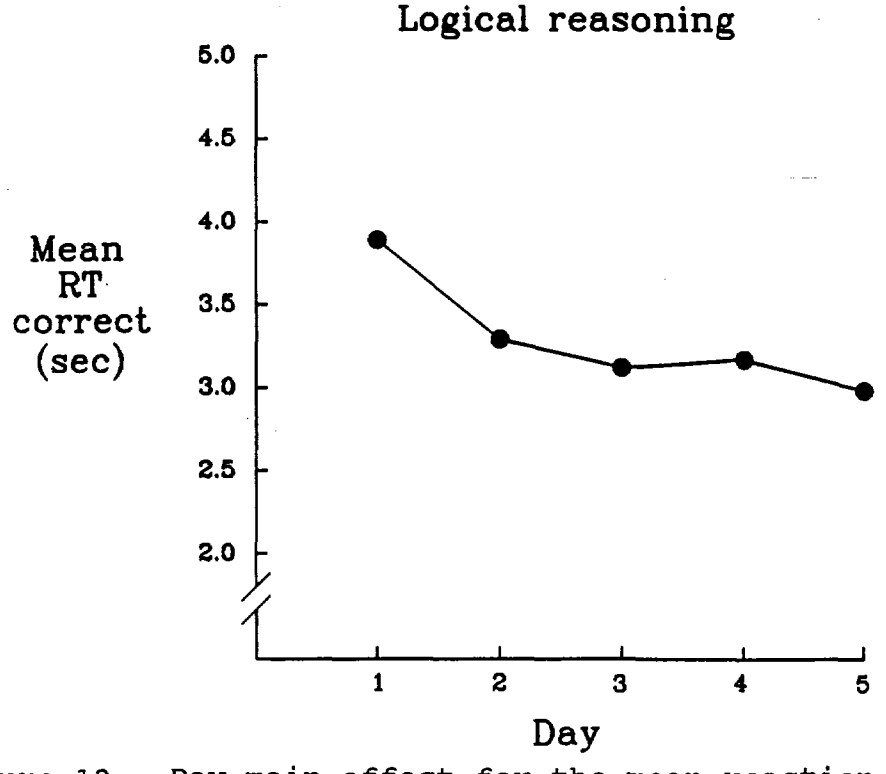

Figure 12. Day main effect for the mean reaction time for correct responses on the logical reasoning task.

effects for session ($F(1,23)=20.12$, $p=0.0002$) and computer also ($F(1,23)=13.23$, $p=0.0014$) were statistically significant.

Simple effects analysis for the session by computer interaction revealed a computer simple effect for the morning sessions ($F(1,23)=17.41$, $p=0.0004$) due to the RTs for the hand-held (3.55 s) being significantly longer than those for the desktop (3.29 s). There were also significant session simple effects for both the hand-held ($F(1,23)=17.70$, $p=0.0003$) and the desktop ($F(1,23)=16.06$, $p=0.0006$). For the hand-held, RTs for the morning session (3.55 s) were longer than the afternoon (3.19 s) session. For the desktop, RTs for the morning session (3.29 s) also were longer than the afternoon session (3.13 s).

Simple effects analysis for the day by session interaction (see Figure 11) revealed session simple effects on Monday ($F(1,23)=32.96$, $p<0.0001$), Tuesday ($F(1,23)=5.91$, $p=0.0233$), Wednesday ($F(1,23)=28.81$, $p<0.0001$), and Friday ($F(1,23)=6.04$, $p=0.0220$). On Monday, RTs were reduced from the morning session (4.46 s) to the afternoon session (3.32 s). On Tuesday, RTs again were longer in the morning (3.43 s) than in the afternoon (3.16 s). However, on Wednesday, RTs were shorter in the morning (2.94 s) than in the afternoon (3.30 s). By Friday, the pattern was restored to longer RTs in the morning (3.05 s) than in the afternoon (2.91 s).

The day simple effects also were significant for both the morning ($F(1.59,36.64)=22.08$, $p<0.0001$) and afternoon ($F(2.79,64.27)= 6.33$, $p=0.0010$) sessions. RTs were longer on Monday morning (4.46 s) relative to Tuesday (3.43 s), Wednesday (2.94 s), Thursday (3.23 s), and Friday (3.05 s) morning sessions. Tuesday morning (3.43 s) RTs also were longer than Wednesday (2.94 s) and Friday (3.05 s) morning sessions. Finally, Thursday morning RTs (3.23 s) were longer than Wednesday (2.94 s) and Friday (3.05 s) morning sessions. For the afternoon sessions, RTs on Wednesday (3.30 s) were longer than Tuesday (3.16 s) or Thursday (3.12 s). Furthermore, RTs on Friday afternoon (2.91 s) were shorter than Monday (3.32 s), Tuesday (3.16 s), Wednesday (3.30 s), and Thursday (3.12 s) afternoon sessions.

Contrasts for the day main effect (see Figure 12) indicated that mean RT for correct responses was significantly longer on Monday (3.89 s) than on Tuesday (3.29 s), Wednesday (3.12 s), Thursday (3.17 s), or Friday (2.98 s). Likewise, RTs on Tuesday (3.29 s) were longer than on Wednesday (3.12 s) and Friday (2.98 s). Finally, RTs on Thursday (3.17 s) were longer than on Friday (2.98 s).

The session main effect resulted from a reduction in mean RT for all the morning sessions (3.42 s) relative to the

afternoon mean RT (3.16 s). The computer main effect was due to longer RTs on the hand-held computer (3.37 s) than on the desktop computer (3.21 s).

Throughput. The logical reasoning throughput analysis was quite simple; the only statistically significant finding was a day by session interaction ($F(1.28,29.37)=10.50$, $p=0.0016$). These data are shown in Figure 13.

Simple effects analysis for the interaction yielded significant session simple effects on Monday ($F(1,23)=50.88$, $p<0.0001$), Tuesday ($F(1,23)=6.54$, $p=0.0176$), and Wednesday ($F(1,23)=4.89$, $p=0.0372$). On Monday, throughput was lower in the morning (15.60) than in the afternoon (20.30). On Tuesday again throughput was lower in the morning (21.83) than the afternoon (23.02). The pattern reversed on Wednesday where throughput in the morning was 23.93 correct responses/min, but dropped to 20.08 correct responses/min in the afternoon.

There also was a significant day simple effect for the morning sessions ($F(1.20,27.56)=7.35$, $p=0.0084$). Contrasts showed significantly lower throughput on Monday morning (15.60) relative to Tuesday (21.83), Wednesday (23.93), Thursday (20.39), and Friday (21.80) morning sessions. Throughput on Tuesday morning (21.83) also was lower than Wednesday (23.93) morning. Finally, throughput on Thursday (20.39) morning was lower than Wednesday (23.93) and Friday (21.80) mornings.

Serial addition/subtraction

All subjects completed all sessions for the serial addition/subtraction task. Thus, analyses were based on data from all 24 subjects.

Transformed percent correct. ANOVA for the transformed percent correct measure revealed a three-way interaction between day, session, and computer ($F(4,92)=4.13$, $p=0.0040$). There also were significant main effects for day ($F(4,92)=4.75$, $p=0.0016$) and session ($F(1,23)=6.56$, $p=0.0174$). The three-way interaction is depicted in Figure 14 while the day main effect is depicted in Figure 15.

Simple effects analysis for the day by session by computer interaction detected simple two-way interactions between session and computer on Tuesday ($F(1,23)=11.56$, $p=0.0025$), and between day and session for the hand-held computer ($F(2.57,59.16)=3.49$, $p=0.0268$).

The session by computer simple interaction on Tuesday resulted from a computer simple effect for the afternoon session on Tuesday ($F(1,23)=4.91$, $p=0.0369$) and a session simple effect

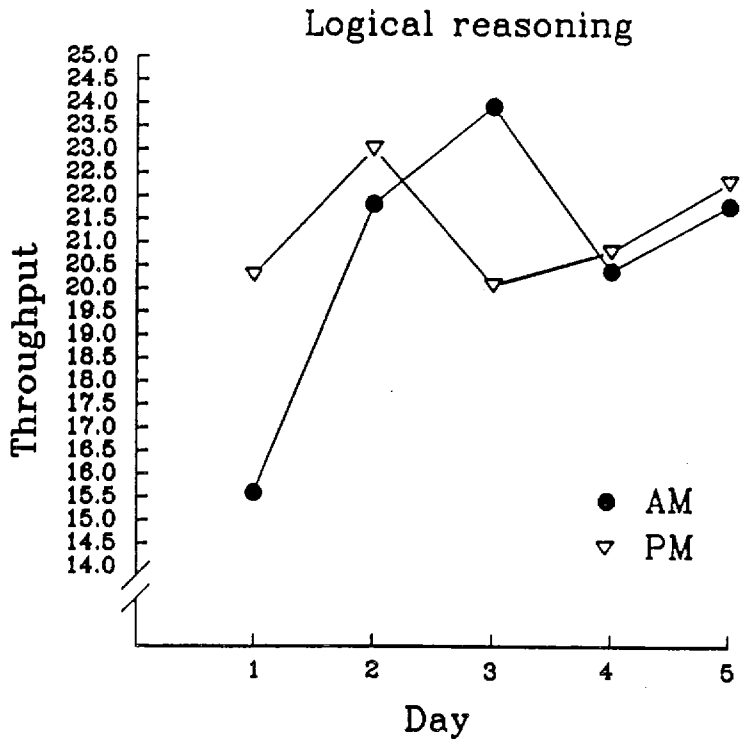

Figure 13. Day by session interaction for throughput on the logical reasoning task.

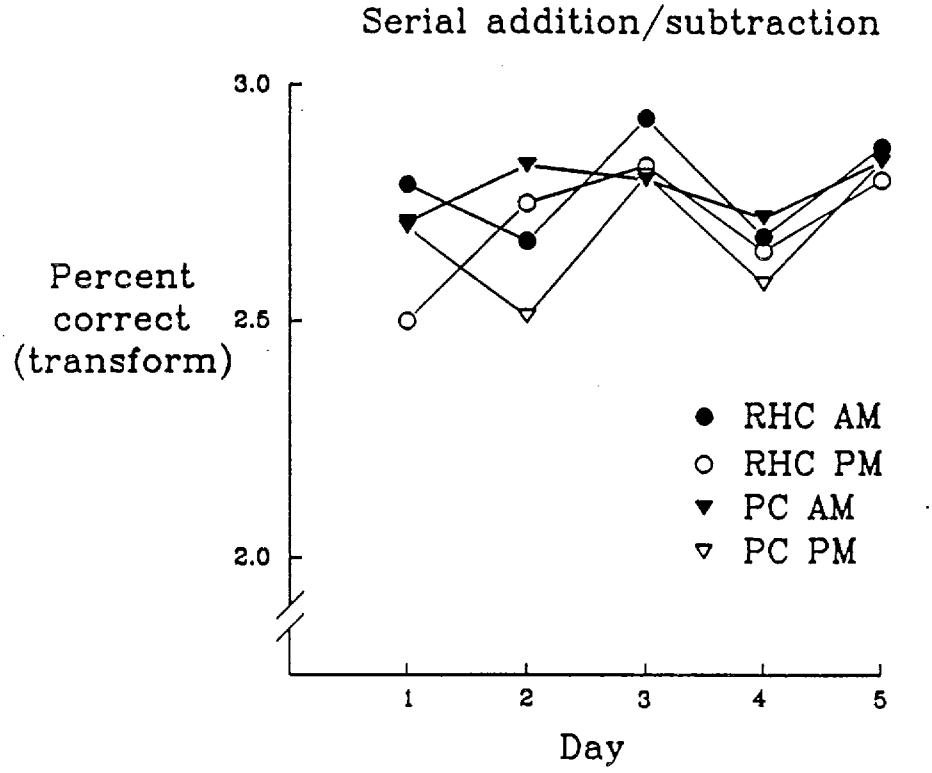

Figure 14. Day by session by computer interaction for transformed percent correct on the serial addition/subtraction task.

on Tuesday for the desktop computer ($F(1,23)=7.49$, $p=0.0117$). The computer simple effect for the Tuesday afternoon session reflected greater accuracy on the hand-held computer (2.75) than on the desktop computer (2.51). The session simple effect on Tuesday for the desktop was accounted for by a reduction in accuracy from the morning session (2.83) to the afternoon session (2.51).

The day by session simple interaction for the hand-held computer was accounted for by a session simple effect on Monday for the hand-held computer ($F(1,23)=6.47$, $p=0.0182$) and a day simple effect for afternoon sessions on the hand-held ($F(3.21,73.80)=3.65$, $p=0.0143$). The session simple effect on Monday for the hand-held computer resulted from a decrease in accuracy from the morning session (2.79) to the afternoon session (2.50).

Contrasts for the day simple effect across afternoon sessions on the hand-held computer indicated that accuracy increased significantly on Wednesday afternoon (2.83) and Friday afternoon (2.80) relative to Monday afternoon (2.50). In addition, accuracy on the hand-held decreased on Thursday afternoon (2.65) relative to Wednesday afternoon. None of the other contrasts were significant (Appendix C).

Contrasts for the day main effect (see Figure 15) indicated that, regardless of session or computer, accuracy increased from Monday (2.68) to Wednesday (2.84). Accuracy dropped significantly on Thursday (2.66) relative to Wednesday's performance, but was significantly higher on Friday (2.84) relative to Monday's performance. Accuracy on Friday was significantly better than on Thursday. Accuracy on Tuesday (2.69) was lower than on Wednesday and Friday. None of the other contrasts were significant (Appendix C).

The session main effect indicated that accuracy decreased from morning sessions to afternoon sessions. Collapsing across day and computer, accuracy dropped from a morning session average of 2.79 to an afternoon session average of 2.70.

RT for correct responses. ANOVA for the mean RT for correct responses revealed two-way interactions between day and computer ($F(2.56,58.93)=3.84$, $p=0.0185$) and between day and session ($F(2.57,59.04)=4.14$, $p=0.0135$). In addition, there was a main effect for day ($F(2.29,70.33)=9.87$, $p=0.0001$). Figure 16 depicts the day by computer interaction, Figure 17 depicts the day by session interaction, and Figure 18 depicts the day main effect.

Simple effects analysis for the day by computer interaction detected a computer simple effect on Monday ($F(1,23)=5.81$, $p=0.0243$) and day simple effects for both the hand-held

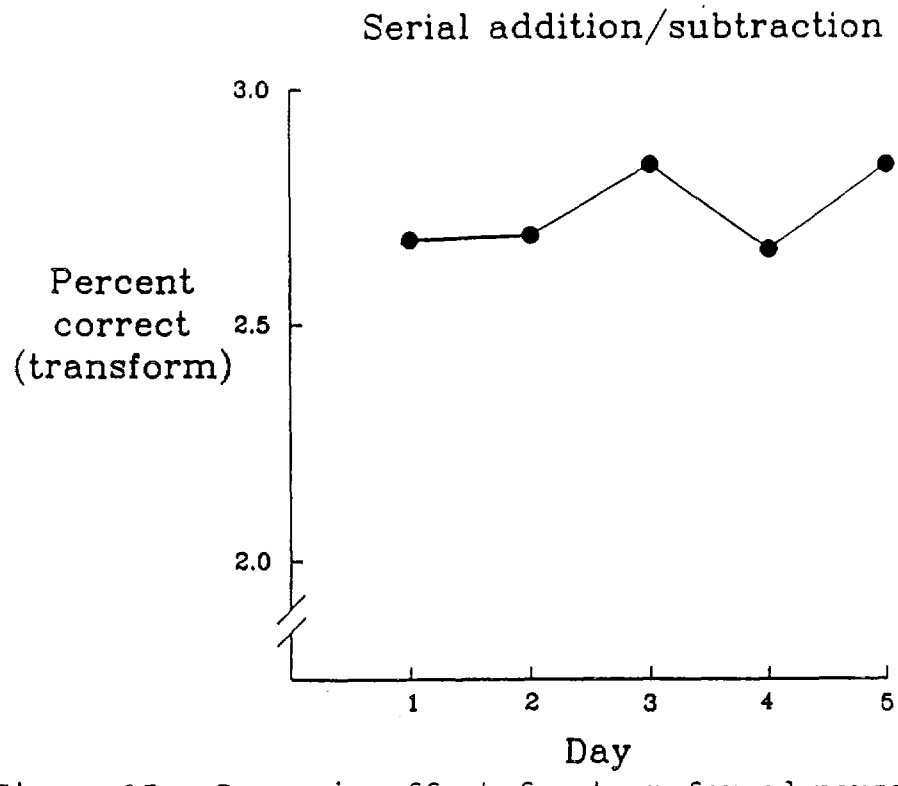

Figure 15. Day main effect for transformed percent correct on the serial addition/subtraction task.

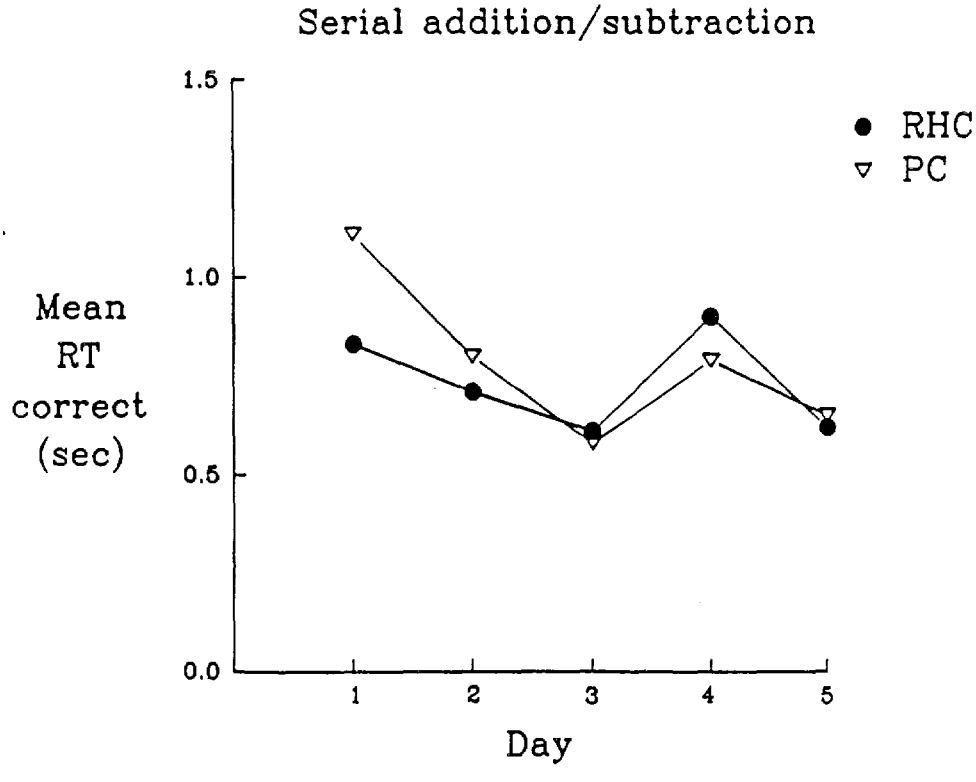

Figure 16. Day by computer interaction for the mean reaction time for correct responses on the serial addition/subtraction task.

($F(2.30,52.92)=4.76$, $p=0.0096$) and the desktop ($F(2.16,49.65)=10.02$, $p=0.0002$). The computer simple effect on Monday resulted from longer RTs for correct responses on the desktop (1.11 s) relative to the hand-held (0.83 s).

Contrasts for the day simple effect for the hand-held indicated that RTs for correct responses were significantly longer on Monday (0.83 s) than on Tuesday (0.71 s), Wednesday (0.61 s), and Friday (0.62 s). On Thursday, RTs for correct responses were longer (0.90 s) than either Wednesday or Friday. None of the other contrasts were significant (Appendix C).

Contrasts for the day simple effect for the desktop indicated that RTs for correct responses on Monday (1.11 s) were significantly longer than on Tuesday (0.80 s), Wednesday (0.58 s), Thursday (0.79 s), or Friday (0.65 s). RTs for correct responses on Wednesday were shorter than on either Tuesday or Thursday. Additionally, RTs on Thursday were significantly longer than on Friday. None of the other contrasts were significant (Appendix C).

Simple effects analysis for the day by session interaction (Figure 17) detected session simple effects on Tuesday ($F(1,23)=10.35$, $p=0.0038$) and on Thursday ($F(1,23)=4.43$, $p=0.0464$). On Tuesday, this was due to a decrease in RTs for correct responses from the morning session (0.84 s) to the afternoon session (0.67 s). On Thursday, the simple effect resulted from an increase in RTs from the morning session (0.74 s) to the afternoon session (0.95 s). In addition to the session simple effects, there were day simple effects for both the morning sessions ($F(2.16, 49.63)=7.70$, $p=0.0009$) and the afternoon sessions ($F(1.99,45.87)=8.10$, $p=0.0010$).

Contrasts for the day simple effect across morning sessions indicated that mean RTs for correct responses were significantly longer at the Monday morning session (0.94 s) than at the Wednesday (0.59 s), Thursday (0.74 s), or Friday (0.66 s) morning sessions. RTs on Tuesday morning (0.84 s) also were longer than on Wednesday or Friday morning, while RTs on Thursday morning increased significantly relative to Wednesday morning.

Contrasts for the day simple effect across afternoon sessions indicated that mean RTs for correct responses decreased significantly from Monday afternoon (1.00 s) through Tuesday (0.67 s) and Wednesday (0.61 s) afternoons, to Friday (0.60 s) afternoon. RTs on Thursday afternoon (0.95 s) were significantly longer than on Tuesday, Wednesday, or Friday. None of the other contrasts were significant (Appendix C).

Contrasts for the day main effect (Figure 18) revealed essentially the same pattern of results. Mean RTs for correct

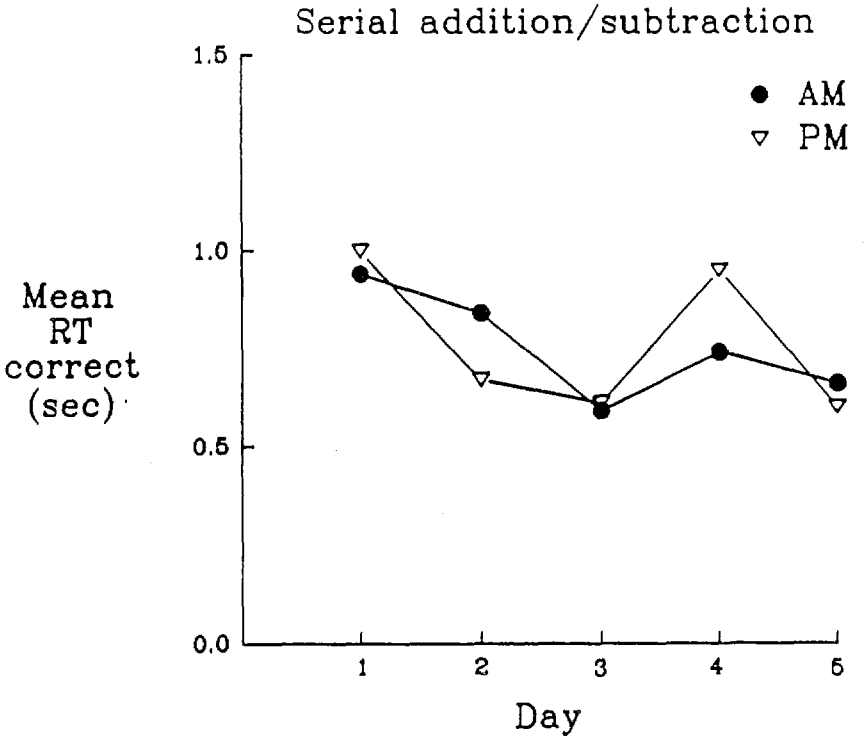

Figure 17. Day by session interaction for the mean reaction time for correct responses on the serial addition/subtraction task.

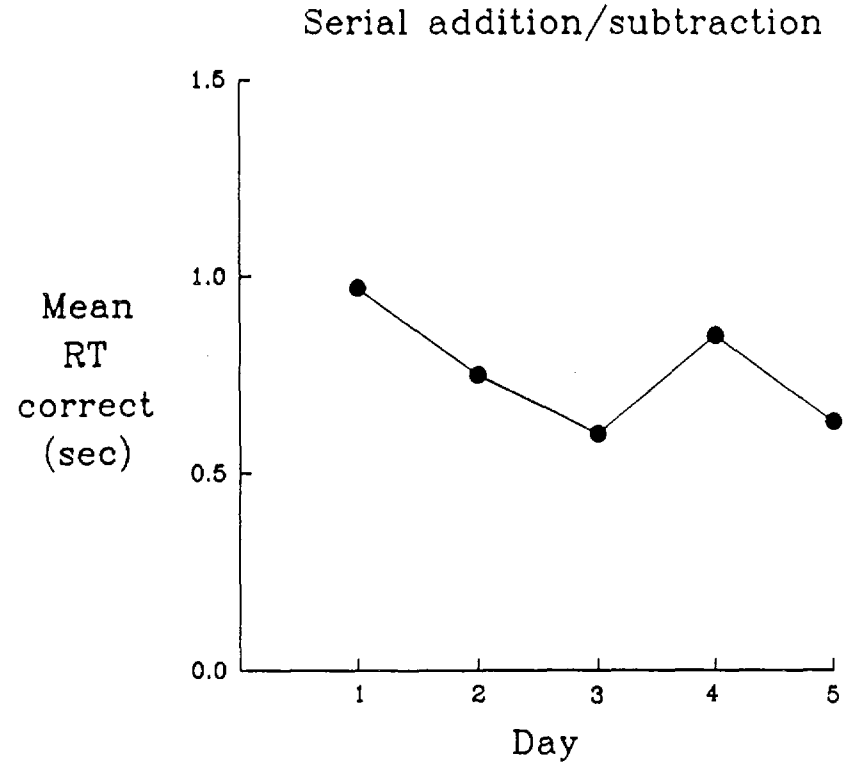

Figure 18. Day main effect for the mean reaction time for correct responses on the serial addition/subtraction task.

responses on Monday (0.97 s), disregarding session and computer, were longer than on Tuesday (0.75 s), Wednesday (0.60 s), or Friday (0.63 s). RTs on Tuesday also were longer than on Wednesday or Friday. RTs on Thursday were higher relative to both Wednesday and Friday. None of the other contrasts were significant (Appendix C).

Throughput. ANOVA for the throughput measure revealed a significant day main effect ($F(2.02,46.49)=10.18$, $p=0.0002$) which is depicted in Figure 19. None of the other effects were significant.

Contrasts for the day main effect indicated that, regardless of session or computer, the number of correct responses/min was significantly lower on Monday (108.15 correct responses/min) than on Tuesday (144.03 correct responses/min), Wednesday (191.23 correct responses/min), Thursday (139.25 correct responses/min), or Friday (175.78 correct responses/min). On Tuesday, throughput was lower than on Wednesday or Friday; and again on Thursday, throughput was lower than on Wednesday or Friday.

Digit recall

One subject's digit recall data were lost due to equipment malfunction. Thus, analyses were performed on the remaining 23 subjects' data.

Transformed percent correct. Analysis of variance for the transformed percent correct measure on the digit recall task revealed significant interactions between day and session ($F(4,88)=4.21$, $p=0.0036$), between day and computer ($F(4,88)=5.06$, $p=0.0010$), and between session and computer ($F(1,22)=7.38$, $p=0.0126$). These interactions are depicted in Figures 20 through 22, respectively. Analysis of variance also revealed a day main effect for transformed percent correct ($F(4,88)=10.39$, $p<0.0001$). The main effect is depicted in Figure 23.

Simple effects analysis for the day by session interaction indicated that accuracy increased from the morning session (1.72) to the afternoon session (2.03) on Monday ($F(1,22)=12.11$, $p=0.0021$). Performance did not vary significantly from morning to afternoon on subsequent days. In addition, there was a significant day simple effect at the morning sessions ($F(2.87, 63.23)=14.93$, $p<0.0001$).

Contrasts for the day at morning effect indicated that Monday morning accuracy (1.72) was significantly worse than accuracy at the Wednesday (2.12), Thursday (2.03), and Friday (2.22) morning sessions. Also, Tuesday morning accuracy (1.89) was significantly worse than accuracy at the Wednesday, Thursday, and Friday morning sessions. Finally, accuracy on Thursday

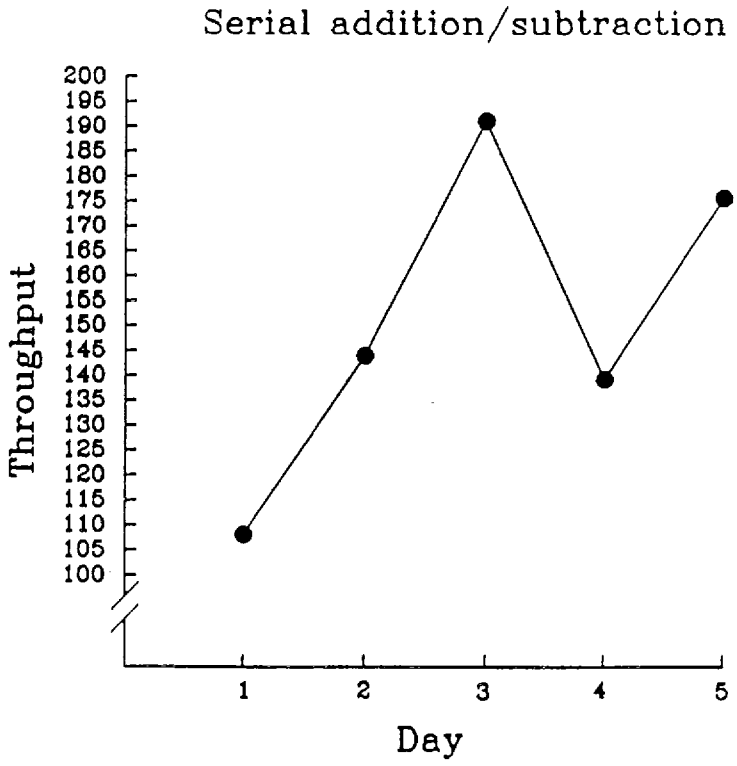

Figure 19. Day main effect for throughput on the serial addition/subtraction task.

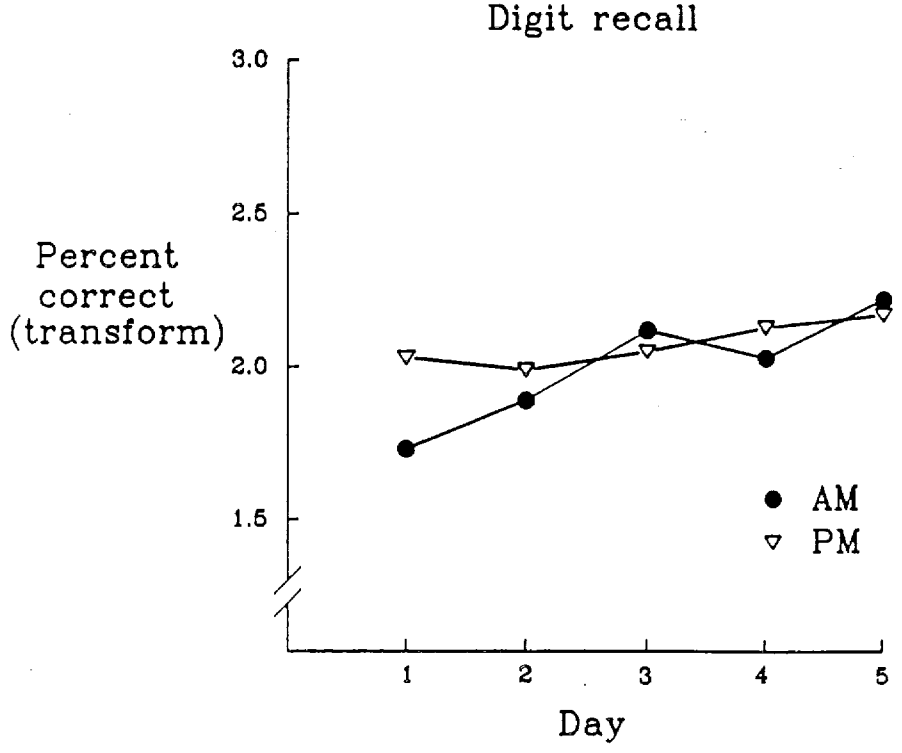

Figure 20. Day by session interaction for transformed percent correct on the digit recall.

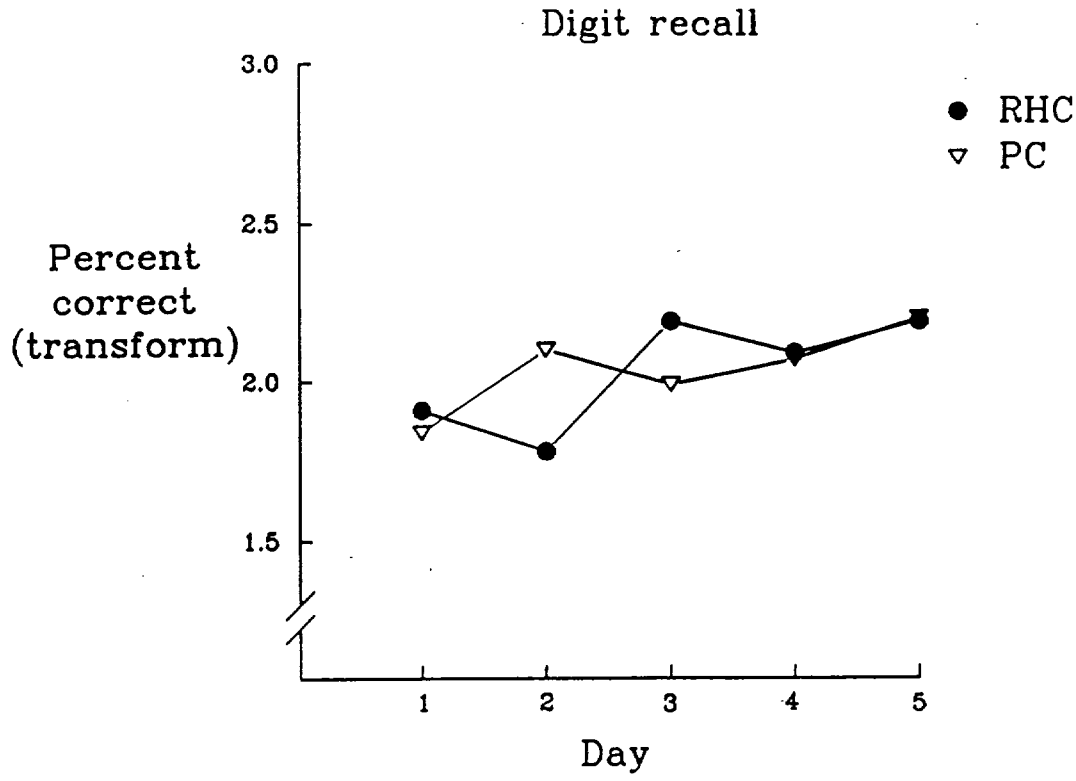

Figure 21. Day by computer interaction for transformed percent correct on the digit recall task.

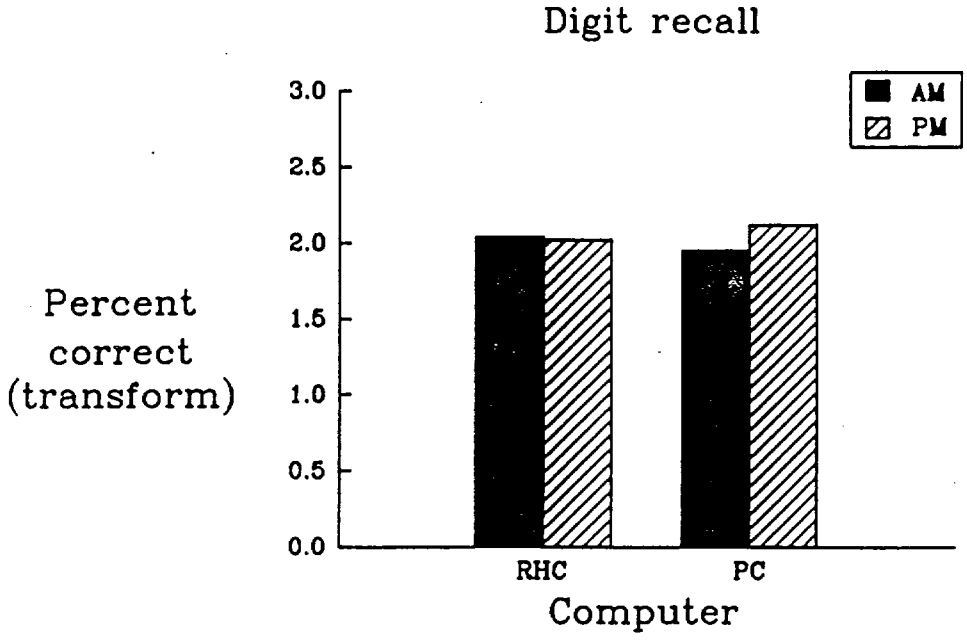

Figure 22. Session by computer interaction for transformed percent correct on the digit recall task.

morning was significantly lower than accuracy on Friday morning (see Appendix D).

Simple effects analysis for the day by computer interaction (Figure 21) revealed a computer simple effect on Tuesday ($F(1,22)=19.30$, $p=0.0002$) due to better performance on the desktop system (2.10) relative to the hand-held system (1.78). Also, there was a computer simple effect on Wednesday ($F(1,22)=5.75$, $p=0.0254$) resulting from a reversal of the pattern seen on Tuesday; accuracy was higher on the hand-held (2.18) relative to the desktop (1.99). Finally, there was a day simple effect for both the hand-held ($F(4,88)=11.19$, $p<0.0001$) and the desktop ($F(4,88)=4.75$, $p=0.0016$).

Contrasts for the day simple effect for the hand-held indicated that accuracy on the hand-held system on Monday (1.91) was significantly worse than accuracy on the hand-held system on Wednesday (2.18), Thursday (2.09), and Friday (2.18). Also, accuracy on the hand-held system on Tuesday (1.78) was worse than accuracy on Wednesday, Thursday, and Friday. No other contrasts were significant.

Contrasts for the day simple effect for the desktop indicated that accuracy on the desktop system on Monday (1.84) was significantly worse than accuracy on the desktop system on Tuesday (2.10) and Friday (2.20); and accuracy on the desktop on Wednesday (1.99) was worse than on Friday. No other contrasts reached significance.

Simple effects analysis for the session by computer interaction (Figure 22) revealed a session simple effect for the desktop only ($F(1,22)=15.56$, $p=0.0007$). Accuracy on the desktop was significantly better during the afternoon session (2.12) than during the morning session (1.95).

Contrasts for the main effect for day (Figure 23) indicated that, regardless of session or computer type, accuracy on Monday (1.87) was worse than accuracy on Wednesday (2.08), Thursday (2.08), or Friday (2.19). Also, accuracy on Tuesday (1.94) was worse than accuracy on Wednesday, Thursday, or Friday. Finally, Thursday accuracy was worse than Friday accuracy.

RT for correct responses. ANOVA for the RT for correct responses detected a three-way interaction between day, session, and computer ($F(4,88)=4.74$, $p=0.0017$) which is depicted in Figure 24. There were also two-way interactions between day and session ($F(4,88)=2.51$, $p=0.0476$), and between day and computer ($F(2.52,55.38)=5.48$, $p=0.0038$). See Figures 25 and 26. Furthermore, the main effects for day ($F(4,88)=4.43$, $p=0.0026$) and session ($F(1,22)=4.60$, $p=0.0432$) reached significance. The day main effect is depicted in Figure 27.

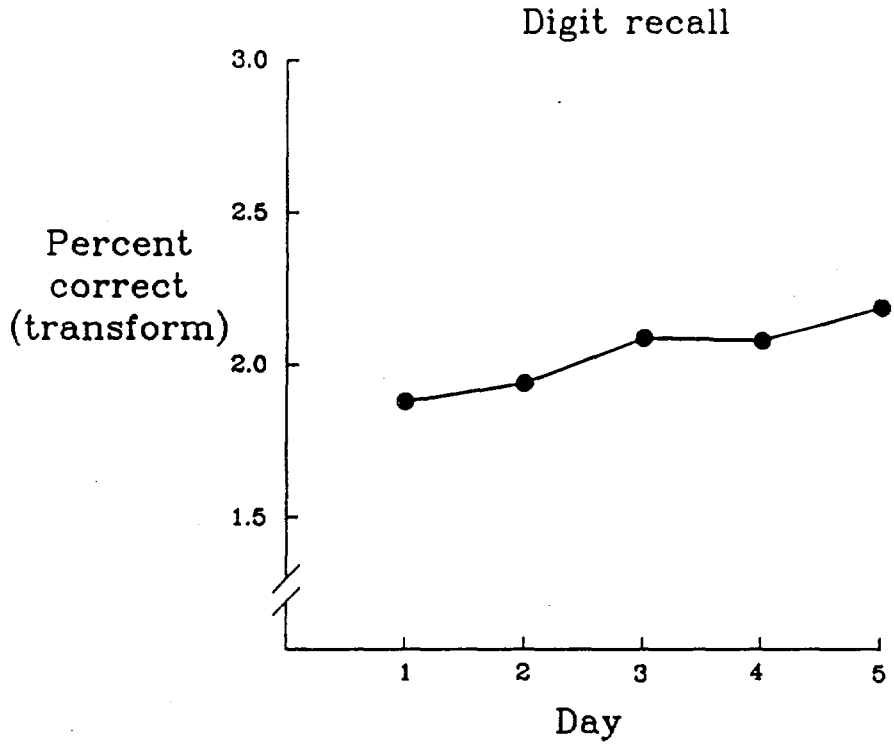

Figure 23. Day main effect for transformed percent correct on the digit recall task.

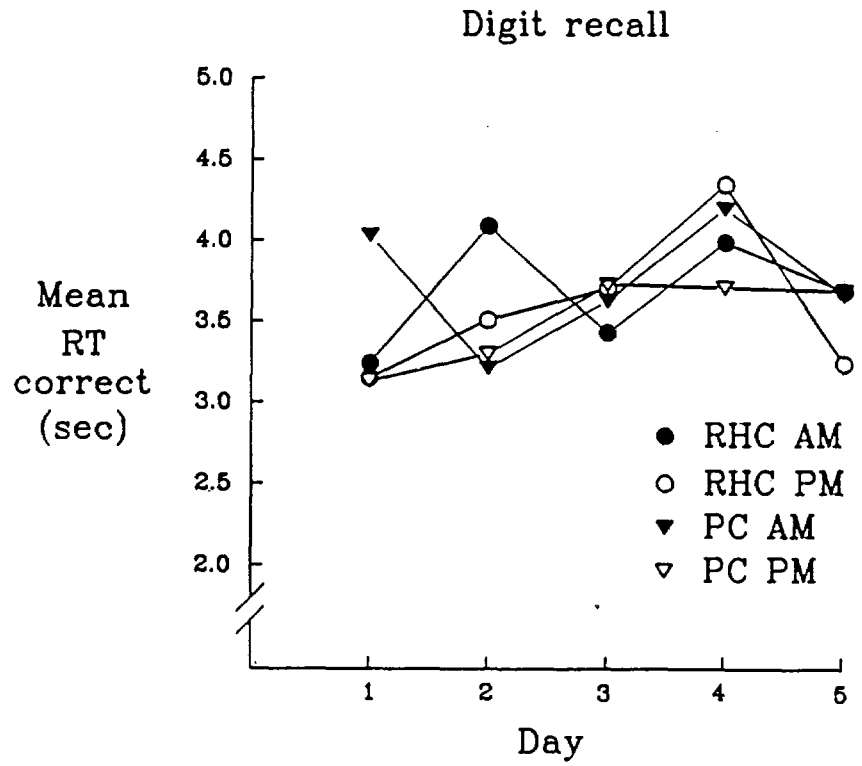

Figure 24. Day by session by computer interaction for the mean reaction time for correct responses on the digit recall task.

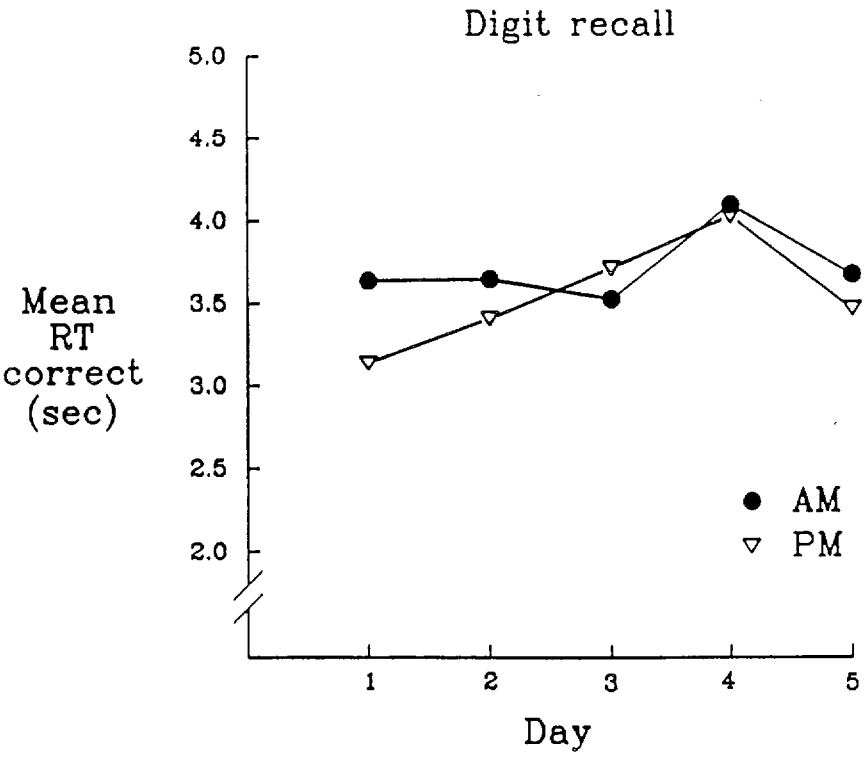

Figure 25. Day by session interaction for the mean reaction time for correct responses on the digit recall task.

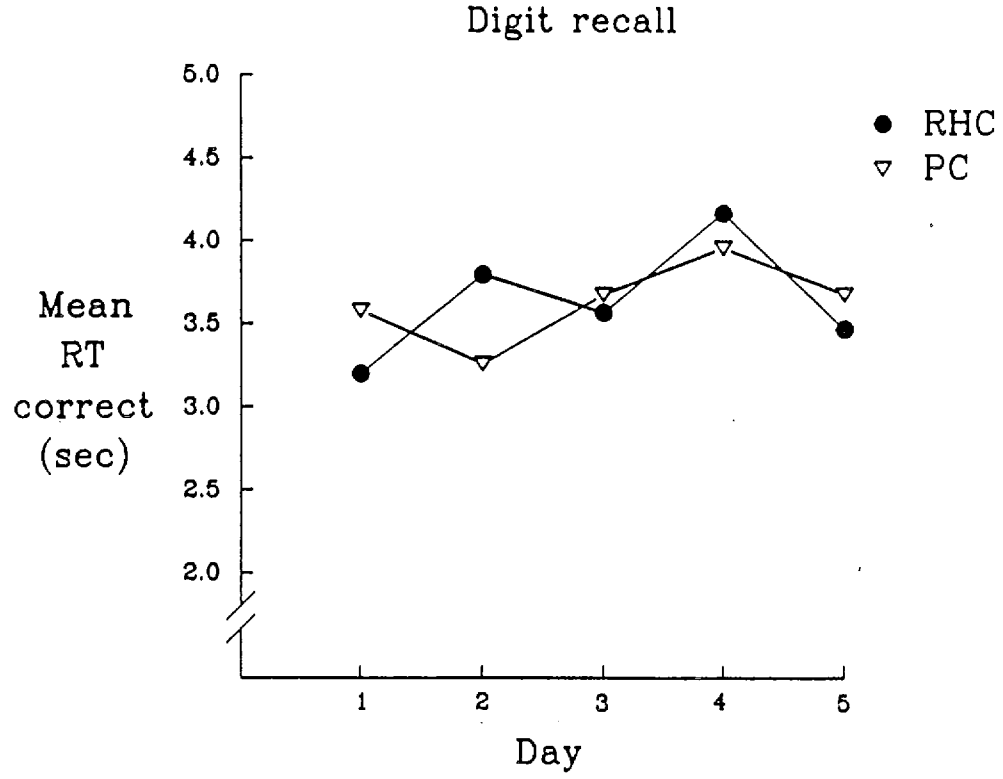

Figure 26. Day by computer interaction for the mean reaction time for correct responses on the digit recall task.

Simple effects analysis for the three-way interaction revealed simple two-way interactions between session and computer at Monday ($F(1,22)=5.31$, $p=0.0310$), at Tuesday ($F(1,22)=5.16$, $p=0.0333$), and at Thursday ($F(1,22)=5.02$, $p=0.0354$). There were simple two-way interactions between day and computer at the morning session ($F(2.43,53.57)=6.23$, $p=0.0021$) and at the afternoon session ($F(4,88)=3.59$, $p=0.0093$). Furthermore, there were significant day by session simple interactions for the hand-held computer ($F(2.52,55.55)=3.67$, $p=0.0232$) and for the desktop computer ($F(4,88)=3.62$, $p=0.0088$).

The session by computer simple interaction at Monday was due, in part, to a computer simple effect at the Monday morning session ($F(1,22)=4.90$, $p=0.0375$) where longer RTs were produced on the desktop (4.03 s) than on the hand-held (3.24 s). There also was a session simple effect on Monday for the desktop ($F(1,22)=9.65$, $p=0.0051$) indicating a reduction in response time from the morning session to the afternoon session (3.13 s).

The session by computer simple interaction at Tuesday resulted from a computer simple effect at the Tuesday morning session ($F(1,22)=24.12$, $p=0.0001$) and a session simple effect on Tuesday for the hand-held ($F(1,22)=4.61$, $p=0.0430$). However, in contrast to Monday's results, RTs on the hand-held (4.09 s) were longer than those on the desktop (3.21 s) at the Tuesday morning session. The session simple effect for the hand-held on Tuesday resulted from a reduction in response time from the morning session to the afternoon session (3.51 s).

The session by computer simple interaction on Thursday resulted from a computer simple effect only at the Thursday afternoon session ($F(1,22)=5.97$, $p=0.0230$). RTs for correct responses on the hand-held computer (4.35 s) were longer than those on the desktop (3.71 s) at this session.

The day by computer simple interaction at the morning session resulted from day simple effects across morning sessions for the hand-held ($F(2.79,61.46)=3.84$, $p=0.0157$) and the desktop ($F(2.86,62.83)=3.27$, $p=0.0289$). Also contributing to this simple interaction were the differences between computers at the Monday and Tuesday morning sessions mentioned above.

Contrasts for the day simple effect for hand-held computer morning sessions indicated RTs for the Monday morning session (3.24 s) were shorter than those for the Tuesday (4.09 s), Thursday (3.99 s), and Friday (3.69 s) morning sessions. Also, RTs at the Wednesday morning session (3.43 s) were significantly faster than those at the Tuesday morning and Thursday morning sessions. Contrasts for the day simple effect for desktop computer morning sessions indicated that mean RTs on Monday morning (4.03 s) were slower than mean RTs on Tuesday morning

(3.21 s). Also, on Thursday morning (4.20 s), RTs increased significantly over Tuesday and Wednesday morning (3.63 s) sessions. None of the other contrasts were significant.

The day by computer simple interaction at the afternoon session resulted from day simple effects across the afternoon sessions for both the hand-held ($F(4,88)=5.90$, $p=0.0003$) and the desktop ($F(4,88)=4.45$, $p=0.0026$). In addition, there were computer simple effects at both the Thursday afternoon session ($F(1,22)=5.97$, $p=0.0230$) and Friday afternoon session ($F(1,22)=6.03$, $p=0.0224$). As mentioned above, on Thursday afternoon RTs for correct responses on the hand-held computer were longer than on the desktop.On Friday afternoon, the pattern reversed such that RTs on the hand-held (3.24 s) were shorter than on the desktop (3.69 s).

Contrasts for the day simple effect for the hand-held computer afternoon sessions indicated that RTs increased significantly from Monday afternoon (3.15 s) to both Wednesday (3.71 s) and Thursday afternoon (4.35 s). RTs at the Thursday afternoon session also were significantly longer than RTs for the Tuesday afternoon session (3.51 s). By Friday, RTs had decreased to the point that the mean RT for the Friday afternoon session (3.24 s) was shorter than the mean RTs for the Wednesday and Thursday afternoon sessions (see Appendix D for contrasts).

Contrasts for the day simple effect for the desktop computer afternoon sessions indicated that RTs for correct responses increased significantly from 3.13 s on Monday afternoon to 3.73 s on Wednesday afternoon, and were still longer on Thursday afternoon (3.71 s) and Friday afternoon (3.69 s). Tuesday afternoon RTs (3.30 s) were significantly shorter than Wednesday and Thursday afternoon RTs. None of the other contrasts were significant (see Appendix D).

The day by session simple interaction for the hand-held computer was accounted for by session simple effects for the hand-held on Tuesday ($F(1,22)=4.61$, $p=0.0430$) and Friday ($F(1,22)=5.26$, $p=0.0318$). On Tuesday, mean RT for correct responses dropped from 4.09 s at the morning session to 3.51 s at the afternoon session. On Friday, mean RT for correct responses dropped from 3.69 s at the morning session to 3.24 s at the afternoon session. In addition, there were day simple effects across both morning and afternoon sessions for the hand-held which were discussed above.

The day by session simple interaction for the desktop resulted, in part, from a session simple effect on Monday for the desktop, and from day simple effects across both the morning and afternoon sessions. Again, contrasts for these effects were discussed above.

Simple effects analysis for the day by session interaction (Figure 25) revealed a session simple effect on Monday ($F(1,22)=8.15$, $p=0.0092$) and a day simple effect for the afternoon session ($F(4,88)=6.63$, $p=0.0001$). The Monday session simple effect was indicative of a reduction in mean RT from the morning session (3.64 s) to the afternoon session (3.14 s).

Contrasts for the day simple effect for afternoon sessions indicated a significant increase in mean RT for correct responses from Monday (3.14 s) to both Wednesday (3.72 s) and Thursday (4.03 s). Mean RT for the Tuesday afternoon session (3.41 s) also was shorter than the Thursday afternoon session. However, by Friday afternoon, mean RT had dropped significantly (3.46 s) relative to Thursday afternoon.

The day by computer interaction (Figure 26) resulted from a computer simple effect on Tuesday ($F(1,22)=26.48$, $p<0.0001$) and day simple effects for both the hand-held system ($F(2.73,59.96)=5.58$, $p=0.0026$) and the desktop system ($F(4,88)=3.57$, $p=0.0095$). The computer simple effect on Tuesday indicated significantly longer RTs for correct responses on the hand-held (3.80 s) relative to the desktop (3.26 s).

Contrasts for the day simple effect for the hand-held revealed a significant increase in RTs for correct responses on Tuesday (3.80 s), Wednesday (3.57 s), and Thursday (4.17 s) relative to Monday's performance (3.20 s). Thursday's RTs were also significantly longer than both Wednesday's and Friday's (3.46 s). None of the other contrasts were significant (see Appendix D).

Contrasts for the day simple effect for the desktop revealed a different pattern. Mean RTs for correct responses on Tuesday (3.26 s) were significantly shorter than on Wednesday (3.68 s), Thursday (3.96 s), or Friday (3.68 s). None of the other contrasts were significant.

Finally, contrasts for the day main effect (Figure 27) indicated that, regardless of the session or the computer, RTs for correct responses on Thursday were significantly longer (4.06 s) than on Monday (3.39 s), Tuesday (3.53 s), Wednesday (3.62 s), or Friday (3.57 s). None of the other contrasts were significant (Appendix D). The session main effect was accounted for by a reduction in RTs for correct responses from morning (3.72 s) to afternoon (3.55 s), regardless of day or computer.

Throughput. ANOVA for throughput (number of correct responses/min) revealed a three-way interaction (see Figure 28) between day, session, and computer ($F(4,88)=3.86$, $p=0.0062$). Also, the two-way interaction between day and computer ($F(2.59,57.06)=3.85$, $p=0.0181$), the main effect for day

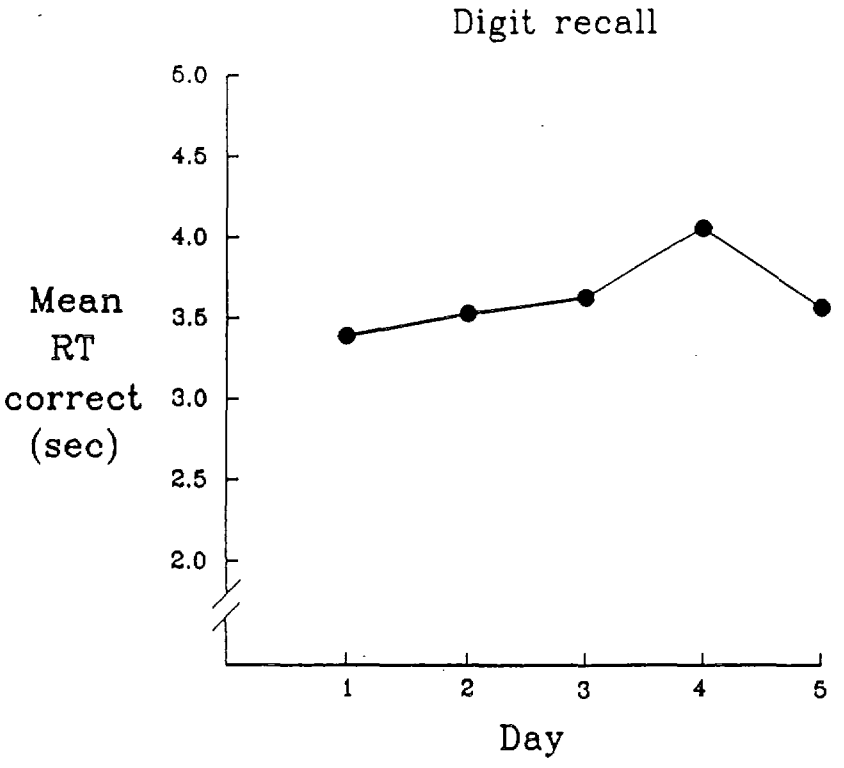

Figure 27. Day main effect for the mean reaction time for correct responses on the digit recall task.

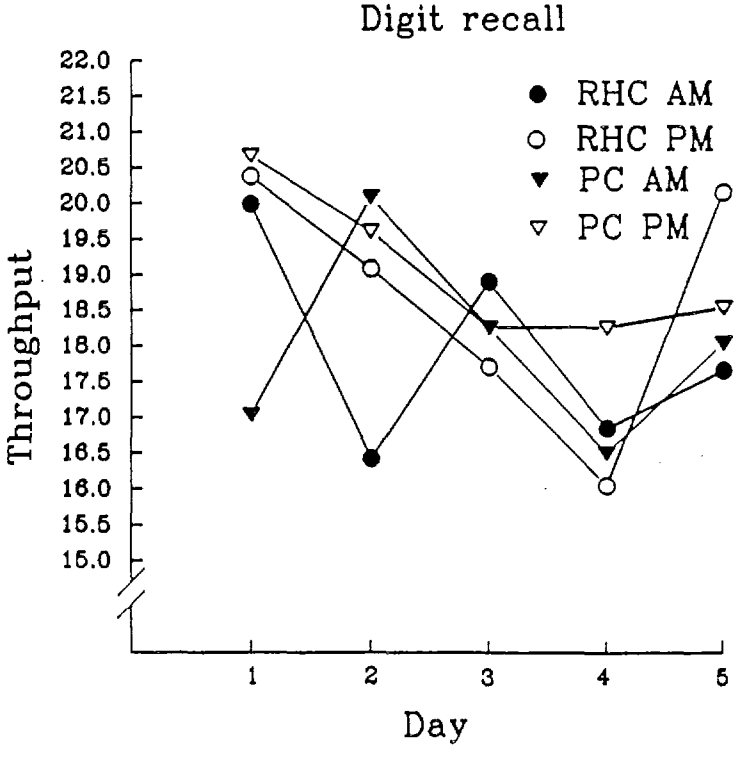

Figure 28. Day by session by computer interaction for the mean reaction time for correct responses on the digit recall task.

($F(2.84,62.56)=3.50$, $p=0.0225$), and the main effect for session ($F(1,22)=8.74$, $p=0.0073$) reached significance. Figure 29 depicts the two-way interaction while Figure 30 shows the day main effect.

Simple effects analysis for the three-way interaction revealed simple two-way interactions between session and computer on Monday ($F(1,22)=7.47$, $p=0.0122$) and Tuesday ($F(1,22)=4.79$, $p=0.0396$), between day and computer at the morning session ($F(4,88)=6.05$, $p=0.0002$), and between day and session for the hand-held computer ($F(4,88)=4.34$, $p=0.0030$).

The session by computer simple interaction on Monday was accounted for by a computer simple effect for the Monday morning session ($F(1,22)=5.49$, $p=0.0286$) and a session simple effect on Monday for the desktop computer ($F(1,22)=9.49$, $p=0.0055$). The number of correct responses/min at the Monday morning session was greater on the hand-held (19.99 correct responses/min) than on the desktop (17.03 correct responses/min). For the desktop system, throughput increased significantly from the Monday morning session to the Monday afternoon session (20.67 correct responses/min).

The session by computer simple interaction on Tuesday was accounted for by a computer simple effect for the Tuesday morning session ($F(1,22)=20.84$, $p=0.0002$) and a session simple effect on Tuesday for the hand-held computer ($F(1,22)=5.34$, $p=0.0306$). The number of correct responses/min at the Tuesday morning session was greater on the desktop (20.09 correct responses/min) than on the hand-held (16.42 correct responses/min). For the hand-held system, throughput increased significantly from the Tuesday morning session to the Tuesday afternoon session (19.09 correct responses/min).

The day by computer simple interaction for the morning sessions resulted, in part, from the computer simple effects at the Monday morning and Tuesday morning sessions described above. Furthermore, there were day simple effects across the morning sessions for both the hand-held ($F(4,88)=3.60$, $p=0.0092$) and the desktop ($F(4,88)=2.64$, $p=0.0390$).

Contrasts for the day simple effect across morning sessions for the hand-held indicated throughput decreased significantly from Monday morning (19.99 correct responses/min) to Tuesday morning (16.42 correct responses/min), and remained significantly lower on Thursday morning (16.85 correct responses/min) and Friday morning (17.66 correct responses/min) relative to the Monday morning session. Wednesday morning (18.91 correct responses/min) throughput on the hand-held was significantly higher than either Tuesday morning or Thursday morning. None of the other contrasts were significant (Appendix D).

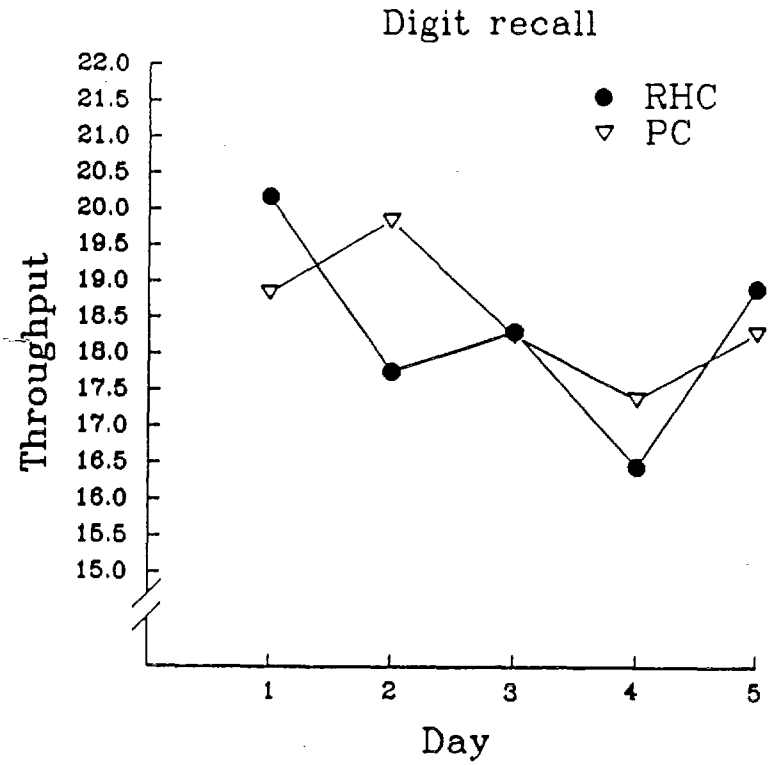

Figure 29. Day by computer interaction for the mean reaction time for correct responses on the digit recall task.

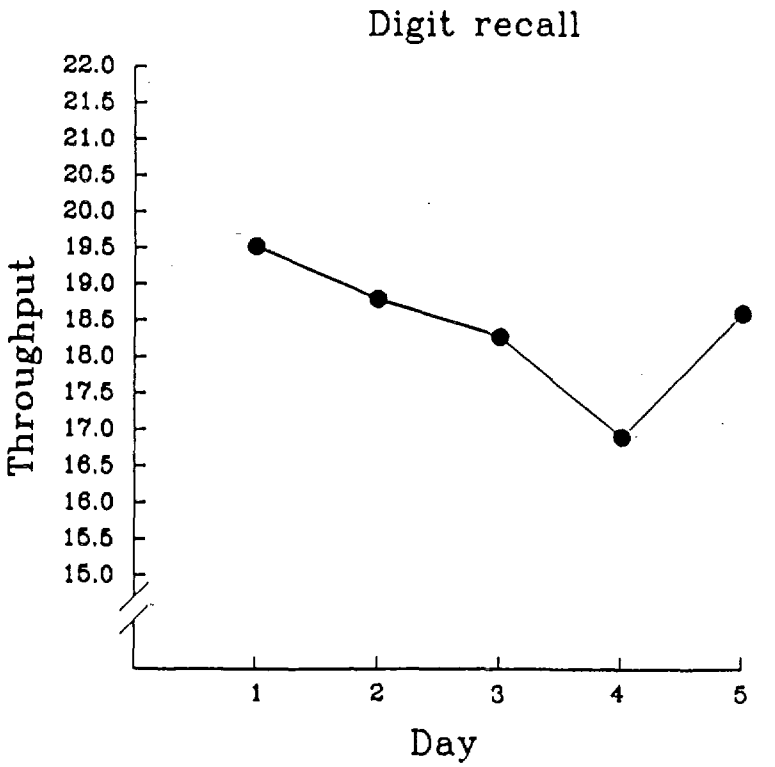

Figure 30. Day main effect for the mean reaction time for correct responses on the digit recall task.

Contrasts for the day simple effect across morning sessions for the desktop indicated throughput increased significantly from Monday morning (17.03 correct responses/min) to Tuesday morning (20.09 correct responses/min). By Thursday morning (16.50 correct responses/min) throughput on the desktop had dropped until it was significantly lower than either Tuesday morning or Wednesday morning (18.26 correct responses/min). None of the other contrasts were significant (Appendix D).

The day by session simple interaction for the hand-held computer resulted, in part, from a session simple effect on Tuesday for the hand-held and a day simple effect at the morning session for the hand-held, both of which were discussed previously. In addition, there was a session simple effect on Friday for the hand-held ($F(1,22)=7.62$, $p=0.0114$) which was due to an increase in throughput from the morning session (17.66 correct responses/min) to the afternoon session (20.16 correct responses/min); and there was a day simple effect on the hand-held computer at the afternoon session ($F(4,88)=5.15$, $p=0.0009$).

Contrasts for the day simple effect on the hand-held computer across afternoon sessions indicated throughput was highest at the Monday afternoon session (20.38 correct responses/min) and dropped significantly on the Wednesday afternoon (17.71 correct responses/min) and Thursday afternoon (16.05 correct responses/min) sessions. Thursday afternoon performance on the hand-held also was worse than Tuesday afternoon (19.09 correct responses/min). On Friday afternoon, throughput increased significantly (20.16 correct responses/min) over both Wednesday afternoon and Thursday afternoon. None of the other contrasts were significant (Appendix D).

Simple effects analysis for the day by computer interaction (Figure 29) revealed a computer simple effect on Tuesday ($F(1,22)=17.78$, $p=0.0004$), a day simple effect for the hand-held computer ($F(4,88)=4.42$, $p=0.0027$), and a day simple effect for the desktop computer ($F(4,88)=2.53$, $p=0.0459$). The computer simple effect on Tuesday was due to a larger throughput value for the desktop system (19.85 correct responses/min) than the hand-held system (17.76 correct responses/min).

Contrasts for the day simple effect for the hand-held indicated that throughput on Monday (20.18 correct responses/min) was higher than both Tuesday (17.76 correct responses/min) and Thursday (16.45 correct responses/min). On Thursday, throughput also was lower than Wednesday (18.31 correct responses/min) and Friday (18.91 correct responses/min). None of the other contrasts were significant (Appendix D).

Contrasts for the day simple effect for the desktop showed a different pattern of results. For the desktop, throughput was

significantly higher on Tuesday (19.85 correct responses/min) than on Wednesday (18.26 correct responses/min) or Thursday (17.38 correct responses/min). None of the other contrasts were significant (Appendix D).

Contrasts for the day main effect from the ANOVA indicated that, disregarding session and computer, throughput was significantly lower on Thursday than on any of the other days (Figure 30). None of the other contrasts were significant (Appendix D). The session main effect was accounted for by an increase in throughput from the morning sessions (17.98 correct responses/min) to the afternoon sessions (18.88 correct responses/min).

Four-choice RT

One subject's data for the four-choice RT task were lost due to equipment malfunction. Thus, analyses were performed on the remaining 23 subjects' data.

Transformed percent correct. ANOVA for the transformed percent correct measure revealed a two-way interaction between day and session ($F(2.81,61.73)=2.80$, $p=0.0505$) and a main effect for day ($F(2.30,50.51)=4.86$, $p=0.0089$). These effects are depicted in Figures 31 and 32, respectively.

Simple effects analysis for the day by session interaction detected significant session simple effects for Wednesday ($F(1,22)=18.49$, $p=0.0003$) and Thursday ($F(1,22)=6.18$, $p=0.0210$). The analysis also detected day simple effects for the morning ($F(2.25, 49.41)=3.05$, $p=0.0508$) and afternoon ($F(2.58,56.77)=5.86$, $p=0.0024$) sessions.

The session simple effect on Wednesday resulted from an increase in accuracy from the morning session (2.91) to the afternoon session (3.03). The session simple effect on Thursday again was due to an increase in accuracy from morning (2.96) to afternoon (3.03).

Contrasts for the day simple effect for the morning sessions indicated that accuracy on Monday morning (2.80) was lower than Tuesday morning (2.94), Thursday morning (2.96), and Friday morning (2.96). None of the other contrasts were significant (Appendix E).

Contrasts for the day simple effect for the afternoon sessions indicated that accuracy on Monday afternoon (2.87) was lower than Wednesday afternoon (3.03) and Thursday afternoon (3.03). Accuracy on Tuesday afternoon (2.91) also was lower than Wednesday and Thursday afternoons. On Friday afternoon (2.92),

however, accuracy dropped significantly relative to Wednesday and Thursday. None of the other contrasts were significant (Appendix E).

Finally, contrasts for the day main effect (Figure 32) indicated that, regardless of session or computer, accuracy on Monday (2.83) was significantly lower than Tuesday (2.93), Wednesday (2.97), and Thursday (2.99). Accuracy on Thursday also was higher than on Tuesday and Friday (2.94). None of the other contrasts were significant (Appendix E).

RT for correct responses. ANOVA for the mean RT for correct responses revealed two-way interactions between day and computer ($F(1.69,37.19)=4.24$, $p=0.0274$) and between day and session ($F(1.79,39.46)=27.04$, $p<0.0001$). These interactions are depicted in Figures 33 and 34, respectively. There were also significant main effects for day ($F(1.56,34.36)=41.24$, $p<0.0001$), session ($F(1,22)=10.10$, $p=0.0043$), and computer ($F(1,22)=7.02$, $p=0.0146$). Figure 35 depicts the day main effect.

Simple effects analysis for the day by computer interaction detected computer simple effects for Tuesday ($F(1,22)=54.40$, $p<0.0001$) and Wednesday ($F(1,22)=8.78$, $p=0.0072$). On Tuesday, RTs for correct responses were shorter on the desktop system (0.45 s) than on the hand-held system (0.51 s). On Wednesday, RTs for correct responses again were shorter on the desktop (0.47 s) than on the hand-held (0.51 s). While this tendency continued for the rest of the week, the differences were not significant. Also there were simple effects for day on both the hand-held ($F(2.10,46.10)=27.59$, $p<0.0001$) and the desktop ($F(1.39,30.53)=28.42$, $p<0.0001$).

Contrasts for the day simple effect on the hand-held indicated that RTs for correct responses on Monday (0.60 s) were significantly longer than Tuesday (0.51 s), Wednesday (0.51 s), Thursday (0.51 s), and Friday (0.48 s). Furthermore, Friday RTs on the hand-held were significantly faster than Tuesday, Wednesday, and Thursday. None of the other contrasts were significant (Appendix E).

Contrasts for the day simple effect on the desktop indicated that, again, RTs for correct responses were significantly longer on Monday (0.60 s) than on Tuesday (0.45 s), Wednesday (0.47 s), Thursday (0.49 s), or Friday (0.46 s). On Tuesday, RTs were shorter than on Wednesday or Thursday. In addition, RTs on Thursday were significantly longer than Wednesday and Friday. None of the other contrasts were significant (Appendix E).

Simple effects analysis for the day by session interaction (Figure 34) detected significant session simple effects on Monday ($F(1,22)=33.13$, $p<0.0001$), Tuesday ($F(1,22)=8.70$, $p=0.0074$), and

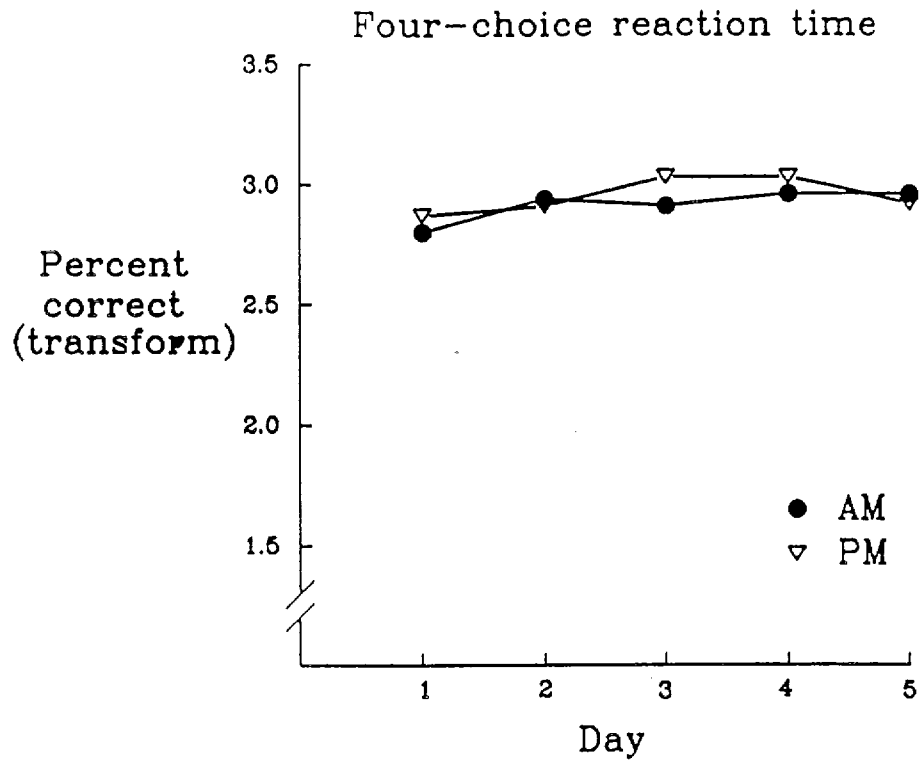

Figure 31. Day by session interaction for transformed percent correct on the four-choice reaction time task.

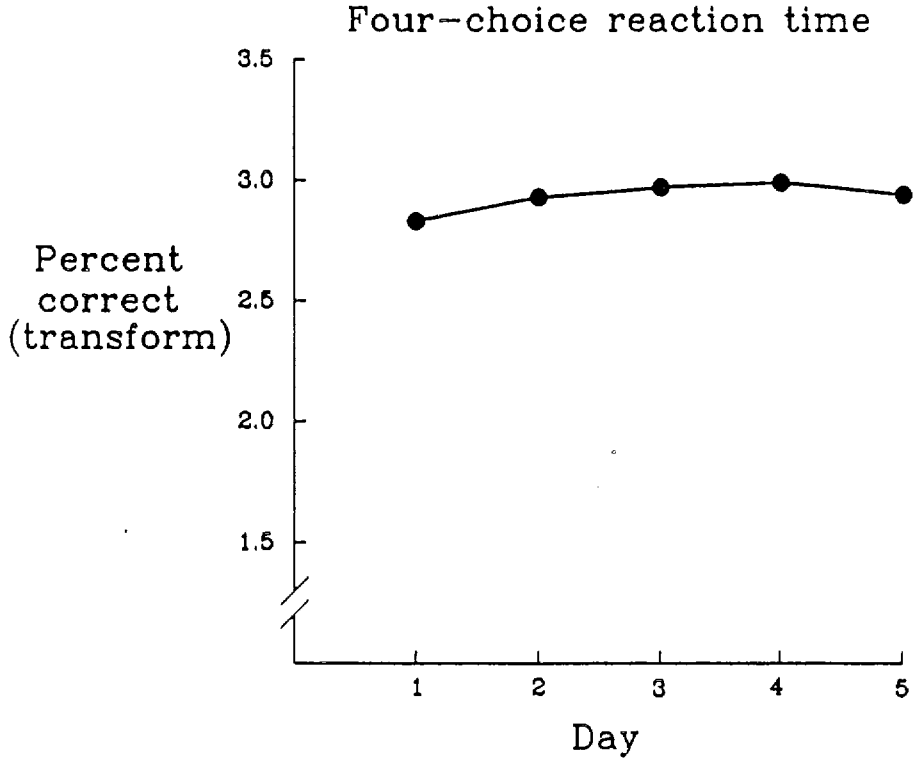

Figure 32. Day main effect for transformed percent correct on the four-choice reaction time task.

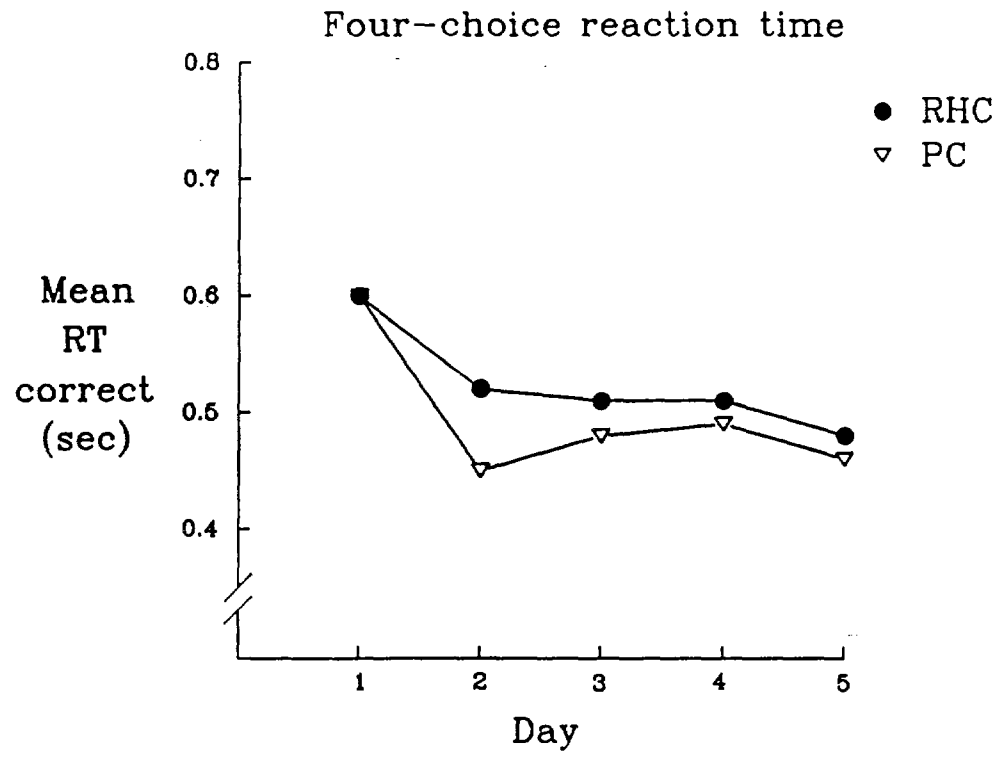

Figure 33. Day by computer interaction for the mean reaction time for correct responses on the four-choice reaction time task.

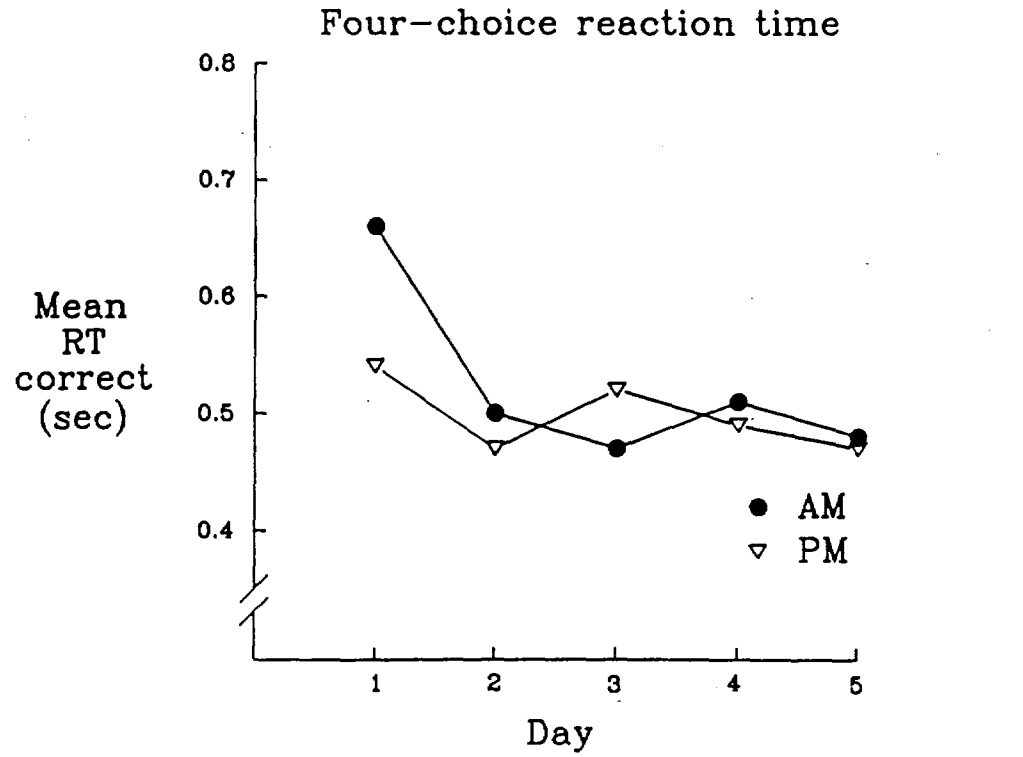

Figure 34. Day by session interaction for the mean reaction time for correct responses on the four-choice reaction time task.

Wednesday ($F(1,22)=18.26$, $p=0.0003$). On Monday and Tuesday these effects were due to a decrease in RTs for correct responses from the morning session (Monday=0.66 s, Tuesday=0.50 s) to the afternoon session (Monday=0.54 s, Tuesday=0.47 s). On Wednesday, however, the morning session RTs were shorter (0.46 s) than the afternoon RTs (0.52 s). Also, there were day simple effects across both the morning sessions ($F(1.45,31.84)= 47.43$, $p<0.0001$) and the afternoon sessions ($F(2.66,58.61)= 15.98$, $p<0.0001$).

Contrasts for the day simple effect across morning sessions indicated significantly longer RTs for correct responses on Monday (0.66 s) relative to Tuesday (0.50 s), Wednesday (0.46 s), Thursday (0.50 s), and Friday (0.47 s). Furthermore, RTs on Tuesday morning were longer than RTs on Wednesday and Friday mornings; and Thursday morning RTs exhibited the same pattern. None of the other contrasts were significant (Appendix E).

Contrasts for the day simple effect across afternoon sessions indicated RTs for correct responses on Monday (0.54 s) were significantly longer than RTs on Tuesday (0.47 s), Thursday (0.49 s), and Friday (0.47 s). Wednesday afternoon RTs (0.52 s) were longer than on Tuesday, Thursday, or Friday afternoons. Finally, Thursday afternoon RTs were longer than Tuesday and Friday afternoon RTs. None of the other contrasts were significant (Appendix E).

Contrasts for the day main effect (Figure 35) suggested that, regardless of session and computer, RTs for correct responses were longer on Monday (0.60 s) than on Tuesday (0.48 s), Wednesday (0.49 s), Thursday (0.50 s), and Friday (0.47 s). In addition, RTs on Tuesday were shorter than RTs on Thursday, and RTs on Friday were shorter than RTs on Wednesday and Thursday. The computer main effect was due to shorter RTs for correct responses on the desktop (0.50 s) than on the hand-held (0.52 s). The session main effect resulted from an overall reduction in RTs from the morning session (0.52 s) to the afternoon session (0.50 s).

Throughput. ANOVA for the throughput measure revealed a three-way interaction between day, session, and computer ($F(2.72,59.90)=3.46$, $p=0.0252$); and two-way interactions between day and computer ($F(2.67,58.74)=10.32$, $p<0.0001$) and between day and session ($F(2.51,55.27)=30.91$, $p<0.0001$). In addition, main effects were observed for day ($F(2.49,54.85)=48.01$, $p<0.0001$), session ($F(1,22)=5.76$, $p=0.0253$), and computer ($F(1,22)=18.32$, $p=0.0003$). The three-way interaction is depicted in Figure 36, the two-way interactions are depicted in Figures 37 and 38, and the day main effect is depicted in Figure 39.

Simple effects analysis for the day by session by computer interaction detected simple two-way interactions between session

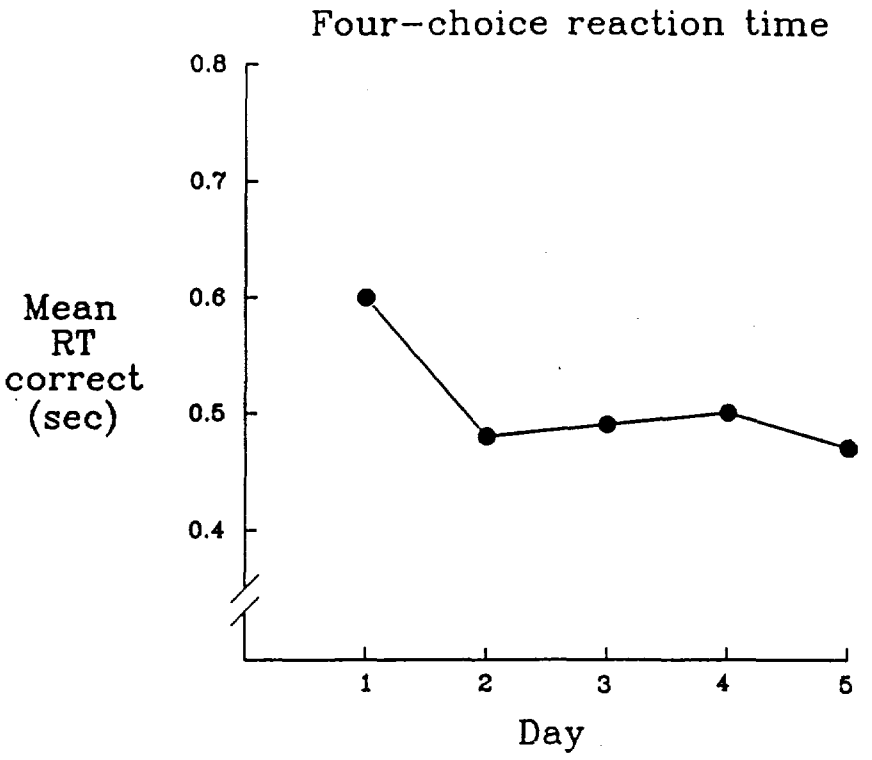

Figure 35. Day main effect for the mean reaction time for correct responses on the four-choice reaction time task.

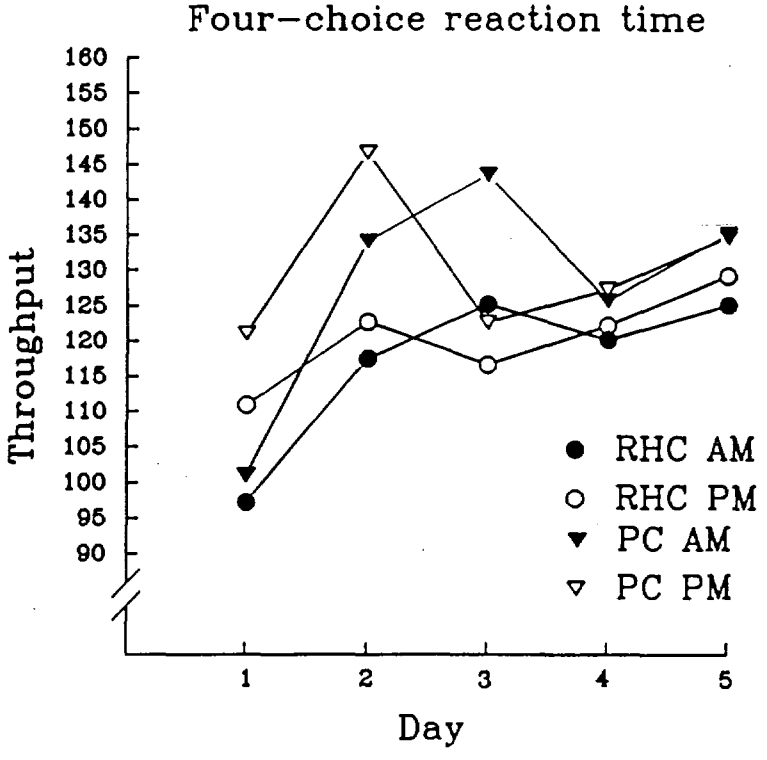

Figure 36. Day by session by computer interaction for throughput on the four-choice reaction time task.

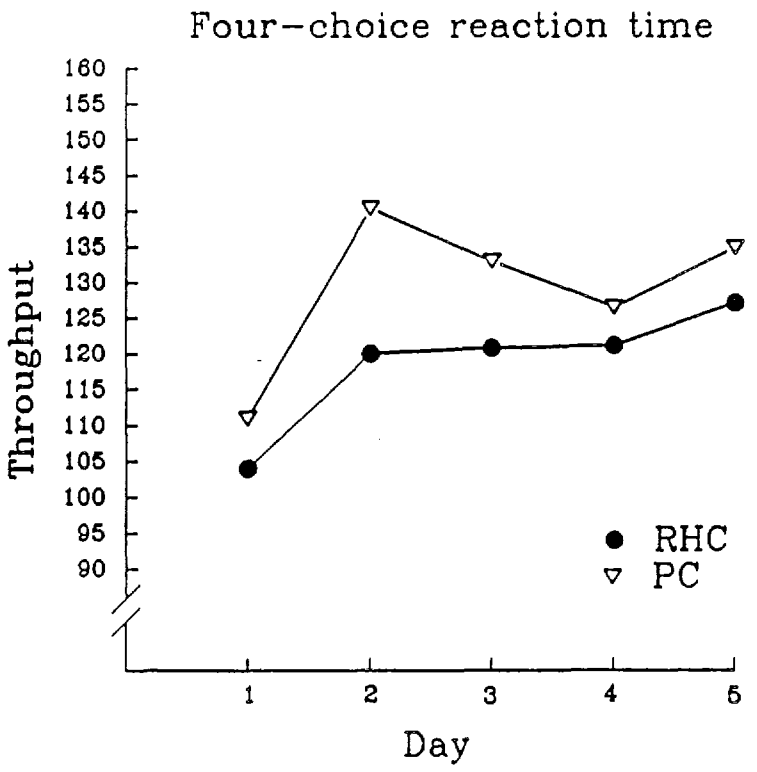

Figure 37. Day by computer interaction for throughput on the four-choice reaction time task.

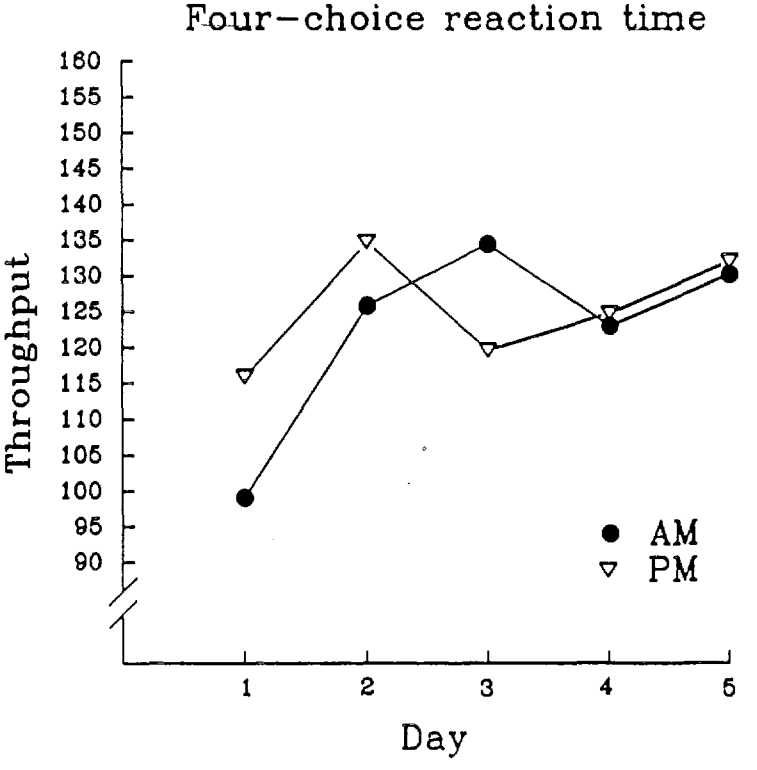

Figure 38. Day by session interaction for throughput on the four-choice reaction time task.

and computer on Wednesday ($F(1,22)=14.10$, $p=0.0011$), between day and computer at both the morning session ($F(2.45,53.99)=4.19$, $p=0.0144$) and the afternoon session ($F(2.90,63.73)=9.65$, $p<0.0001$), and between day and session on both the hand-held ($F(3.31,72.78)=12.63$, $p<0.0001$) and the desktop ($F(4,88)=18.06$, $p<0.0001$).

The session by computer simple interaction on Wednesday resulted from computer simple effects at both the Wednesday morning session ($F(1,22)=18.76$, $p=0.0003$) and the Wednesday afternoon session ($F(1,22)=4.35$, $p=0.0488$). In addition, there were session simple effects on Wednesday for both the hand-held ($F(1,22)=10.85$, $p=0.0033$) and the desktop ($F(1,22)=31.68$, $p<0.0001$). On Wednesday morning, the number of correct responses/min was greater on the desktop (143.55 correct responses/min) than on the hand-held (125.16 correct responses/min). The same was true on Wednesday afternoon: 122.59 correct responses/min on the desktop versus 116.58 correct responses/min on the hand-held. The session simple effects on Wednesday for both the hand-held and the desktop resulted from a reduction in throughput from the morning session to the afternoon session.

The day by computer simple interaction across morning sessions was accounted for by computer simple effects at the Tuesday morning ($F(1,22)=27.56$, $p<0.0001$), Wednesday morning (see above), and Friday morning ($F(1,22)=8.12$, $p=0.0093$) sessions. In each case, throughput was greater on the desktop than on the hand-held. In addition to the computer simple effects, there were day simple effects across morning sessions for both the hand-held ($F(4,88)=45.58$, $p<0.0001$) and the desktop ($F(2.47,54.24)=33.19$, $p<0.0001$).

Contrasts for the day simple effect for morning sessions on the hand-held computer indicated throughput on Monday morning (97.21 correct responses/min) was significantly lower than on Tuesday morning (117.47 correct responses/min), Wednesday morning (125.16 correct responses/min), Thursday morning (120.16 correct responses/min), or Friday morning (125.11 correct responses/min). Throughput on Tuesday morning also was significantly lower than Wednesday morning or Friday morning. While throughput on Thursday morning decreased significantly relative to Wednesday morning, it returned to essentially the same level by Friday morning. None of the other contrasts were significant (Appendix E).

Contrasts for the day simple effect for the desktop computer morning sessions indicated throughput on the Monday morning session (101.02 correct responses/min) was significantly lower than on Tuesday morning (134.12 correct responses/min), Wednesday morning (143.55 correct responses/min), Thursday morning (125.73

correct responses/min), or Friday morning (135.18 correct responses/min). Throughput reached its highest level on Wednesday morning, significantly exceeding Tuesday, Thursday, and Friday morning. On Thursday morning throughput dropped such that it was significantly lower than either Tuesday or Friday morning. None of the other contrasts were significant.

The day by computer simple interaction across afternoon sessions was accounted for, in part, by computer simple effects on Monday ($F(1,22)=7.18$, $p=0.0137$), Tuesday ($F(1,22)=45.13$, $p<0.0001$), and Wednesday (see above) afternoon. In each case, throughput was higher on the desktop than on the hand-held. In addition, day simple effects were detected for the afternoon sessions on both the hand-held ($F(4,88)=11.91$, $p<0.0001$) and the desktop ($F(4,88)=20.23$, $p<0.0001$).

Contrasts for the day simple effect across afternoon sessions on the hand-held indicated throughput for the Monday afternoon session (110.86 correct responses/min) was significantly lower than Tuesday afternoon (122.69 correct responses/min), Wednesday afternoon (116.58 correct responses/min), Thursday afternoon (122.19 correct responses/min), or Friday afternoon (129.21 correct responses/min) sessions. Throughput on Tuesday afternoon also was lower than on Friday afternoon. Wednesday afternoon throughput was significantly lower than Thursday afternoon. By Friday afternoon, throughput had increased significantly relative to both Wednesday and Thursday. None of the other contrasts were significant (Appendix E).

Contrasts for the day simple effect across afternoon sessions for the desktop indicated that throughput for the Monday afternoon session (121.03 correct responses/min) was significantly lower than on Tuesday afternoon (146.72 correct responses/min) or Friday afternoon (134.72 correct responses/min) sessions. On Tuesday afternoon, throughput was significantly higher than on Wednesday afternoon (122.59 correct responses/min), Thursday afternoon (127.29 correct responses/min), or Friday afternoon. By Friday afternoon, throughput had increased until in was significantly higher than either Wednesday afternoon or Thursday afternoon. None of the other contrasts were significant (Appendix E).

The day by session simple interaction on the hand-held computer resulted from session simple effects for the hand-held on Monday ($F(1,22)=36.92$, $p<0.0001$), Wednesday (see above), and Friday ($F(1,22)=8.86$, $p=0.0070$). Throughput for the Monday morning session (97.21 correct responses/min) was lower than the Monday afternoon session (110.86 correct responses/min). On Wednesday, throughput for the morning session (125.16 correct responses/min) was higher than the afternoon session (116.58

correct responses/min). By Friday, the morning session (125.11 correct responses/min) again was lower than the afternoon session (129.21 correct responses/min). In addition, there were day simple effects for both morning and afternoon sessions on the hand-held computer which were described above.

The day by session simple interaction for the desktop computer was accounted for by session simple effects for the desktop on Monday ($F(1,22)=12.12$, $p=0.0021$), Tuesday ($F(1,22)=22.98$, $p=0.0001$), and Wednesday (see above). On Monday and Tuesday, throughput increased from morning to afternoon while, on Wednesday, throughput decreased from morning to afternoon. In addition, there were day simple effects for the desktop across both morning and afternoon sessions which were described above.

Simple effects analysis for the day by computer interaction (Figure 37) revealed computer simple effects on Tuesday ($F(1,22)=50.46$, $p<0.0001$), Wednesday ($F(1,22)=14.26$, $p=0.0010$), Thursday ($F(1,22)=5.39$, $p=0.0299$), and Friday ($F(1,22)=7.65$, $p=0.0113$). On each day, the number of correct responses/min was higher on the desktop than on the hand-held (see Figure 37). In addition, there were day simple effects for both the hand-held ($F(2.87,63.12)=33.75$, $p<0.0001$) and the desktop ($F(2.48,54.51)=37.68$, $p<0.0001$).

Contrasts for the day simple effect for the hand-held indicated throughput was significantly lower on Monday (104.03 correct responses/min) relative to Tuesday (120.08), Wednesday (120.87), Thursday (121.17), and Friday (127.16). Throughput on Friday was higher than Monday, Tuesday, Wednesday, and Thursday. None of the other contrasts were significant. Contrasts for the day simple effect for the desktop, again, indicated throughput increased from Monday (111.03 correct responses/min) through Tuesday (140.42), Wednesday (133.07), Thursday (126.51), and Friday (134.95). Throughput on the desktop peaked on Tuesday where the number of correct responses/min exceeded Wednesday, Thursday and Friday. Throughput on Thursday was lower than on Wednesday or Friday. None of the other contrasts were significant.

Simple effects analysis for the day by session interaction (Figure 38) revealed session simple effects on Monday ($F(1,22)=46.12$, $p<0.0001$), Tuesday ($F(1,22)=17.81$, $p=0.0004$), and Wednesday ($F(1,22)=28.69$, $p<0.0001$). On Monday and Tuesday, throughput increased from morning to afternoon (99.11 to 115.95 on Monday and 125.79 to 134.71 on Tuesday). Yet on Wednesday, throughput decreased from morning to afternoon (134.36 to 119.59). In addition, there were day simple effects for both the morning session ($F(2.78,61.23)=63.95$, $p<0.0001$) and the afternoon session ($F(4,88)=20.52$, $p<0.0001$).

Contrasts for the day simple effect across morning sessions indicated throughput was lower on Monday (99.11) than on Tuesday (125.79), Wednesday (134.36), Thursday (122.94), or Friday (130.15). Throughput on Tuesday was lower than on Wednesday. Finally, throughput on Thursday was lower than on Wednesday or Friday. None of the other contrasts were significant.

Contrasts for the day simple effect across the afternoon sessions indicated throughput was lower on Monday (115.95) than on Tuesday (134.71), Thursday (124.74), or Friday (131.96). Throughput peaked on Tuesday afternoon where the number of correct responses/min exceeded Wednesday (119.59) and Thursday. Throughput on Wednesday afternoon was lower than on Thursday or Friday afternoons, and throughput on Friday afternoon was higher than on Thursday. None of the other contrasts were significant.

The computer main effect indicated throughput was higher on the desktop (129.20 correct responses/min) than on the hand-held (118.66) regardless of day or session. The session main effect indicated afternoon performance (125.39) was slightly better than morning performance (122.47).

Contrasts for the day main effect (Figure 39) indicated that, regardless of session or computer type, throughput on Monday (107.53) was lower than on Tuesday (130.25), Wednesday (126.97), Thursday (123.84), or Friday (131.05). Tuesday performance was better than Wednesday or Thursday, and Thursday was worse than Wednesday. Finally, Friday performance was better than Wednesday and Thursday.

Six-letter search (MAST6)

One subject's data were lost due to equipment malfunction. In addition, another subject's RT and throughput data were eliminated from the analyses because he was an outlier. Thus, the analyses for transformed percent correct were based on data from 23 subjects while analyses for mean RT for correct responses and throughput were based on data from 22 subjects. The significance tables are listed in Appendix F.

Transformed percent correct. ANOVA revealed a significant day by session interaction for the transformed percent correct variable ($F(4,88)=3.00$, $p=0.0227$). These data are presented in Figure 40. The day main effect (Figure 41) also was significant ($F(4,88)=11.42$, $p<0.0001$).

Simple effects analysis for the day by session interaction revealed a significant session simple effect on Wednesday ($F(1,22)=9.40$, $p=0.0056$). Accuracy improved from the Wednesday morning session (2.66) to the Wednesday afternoon session (2.91).

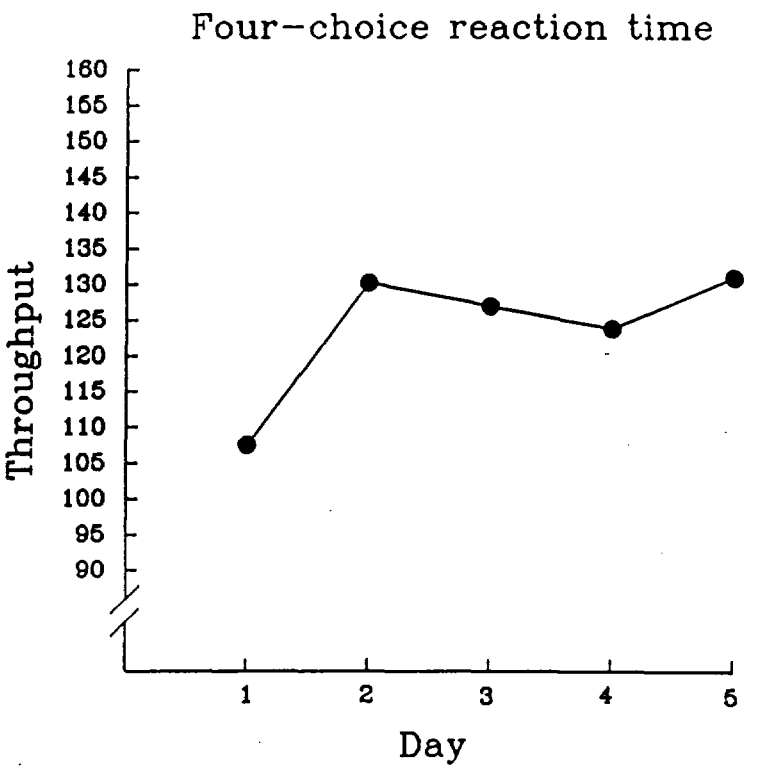

Figure 39. Day main effect for throughput on the four-choice reaction time task.

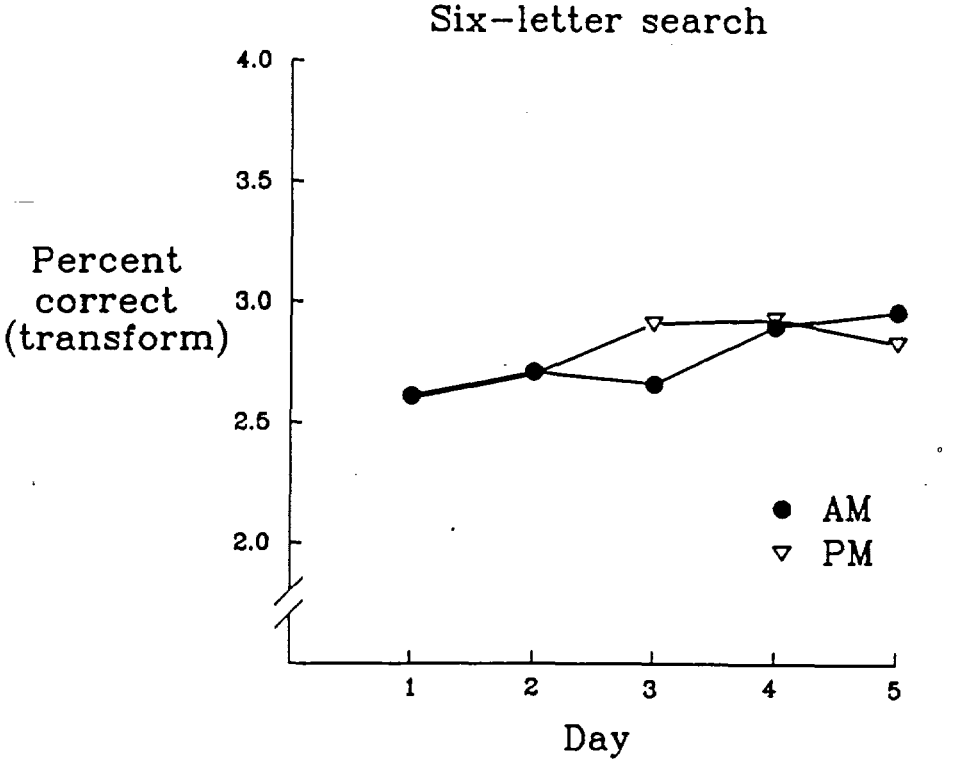

Figure 40. Day by session interaction for transformed percent correct on the six-letter search task.

Also, there were day simple effects for both the morning sessions ($F(4,88)=6.93$, $p=0.0001$) and the afternoon sessions ($F(4,88)=7.11$, $p=0.0001$).

Contrasts for the day simple effect for morning sessions showed that transformed percent correct increased on Thursday (2.90) and Friday (2.96) morning sessions relative to the Monday (2.61), Tuesday (2.71) and Wednesday (2.66) morning sessions. Contrasts for the day simple effect for afternoon sessions indicated that accuracy on Monday afternoon (2.60) was lower than on Wednesday (2.91), Thursday (2.93), and Friday (2.83) afternoons. Furthermore, on Tuesday (2.70) afternoon, accuracy also was lower than on Wednesday (2.91) and Thursday (2.93) afternoons.

Contrasts for the day main effect (Figure 41) showed accuracy was lower on Monday (2.61) relative to Tuesday (2.70), Wednesday (2.79), Thursday (2.92), and Friday (2.89) scores. Accuracy on Tuesday (2.70) was also lower than on Thursday (2.92) and Friday (2.89). Finally, accuracy on Wednesday was lower than on Thursday. None of the other contrasts were significant.

Mean RT for correct responses. There were three statistically significant interactions for the mean RT for correct responses: day by session by computer ($F(4,84)=2.95$, $p=0.0249$), day by session ($F(4,84)=5.16$, $p=0.0009$), and day by computer ($F(2.12,45.96)= 3.50$, $p=0.0345$). Data for the three-way interaction is graphed in Figure 42. The three-way interaction was accounted for by four significant simple two-way interactions.

In the first simple interaction, session by computer on Monday ($F(1,21)=4.99$, $p=0.0366$), the desktop computer morning session RTs for correct responses (11.18) were significantly higher than ($F(1,21)=13.63$, $p=0.0014$) those for the afternoon session (10.09).

The second simple two-way interaction, day by session for the hand-held ($F(4,84)=4.65$, $p=0.0019$), was accounted for, in part, by an increase in RTs from the morning session (9.01) to the afternoon session (9.99) on Wednesday ($F(1,21)=8.89$, $p=0.0071$). On Thursday, the pattern was reversed ($F(1,21)=4.85$, $p=0.0389$); morning RTs were longer (10.40) than afternoon (9.73). This pattern continued through Friday ($F(1,21)=5.70$, $p=0.0264$) where morning RTs (10.05) again were longer than afternoon RTs (9.22). The day simple effect for the hand-held morning sessions also was significant ($F(4,84)=4.17$, $p=0.0040$). Contrasts showed the mean RT on the Wednesday morning (9.01) was significantly shorter than Monday (10.19), Tuesday (9.98), Thursday (10.40), and Friday (10.05) morning sessions.

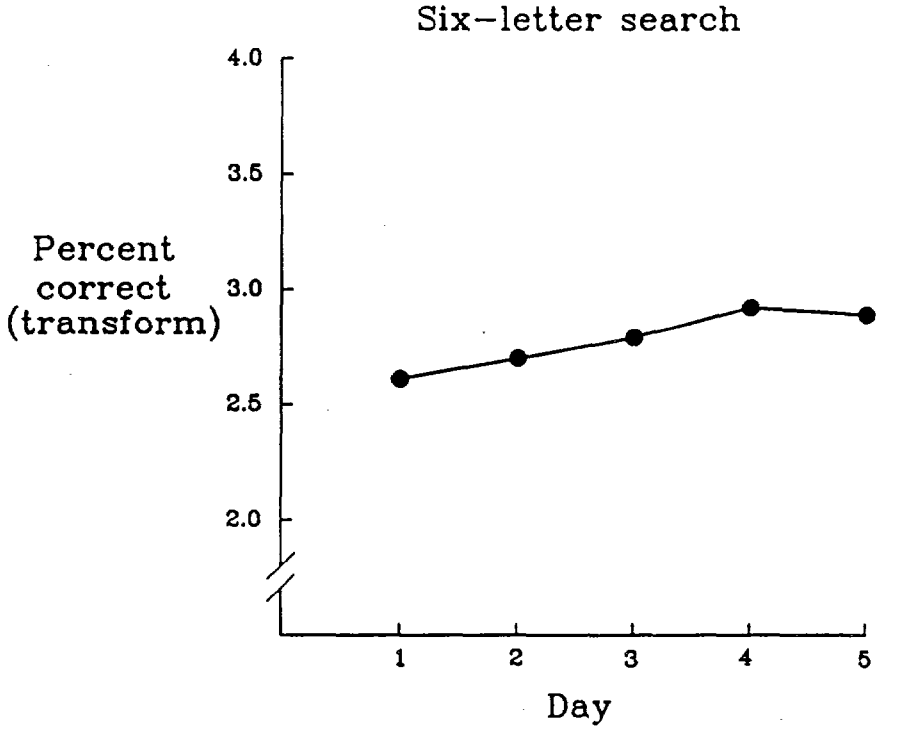

Figure 41. Day main effect for transformed percent correct on the six-letter search task.

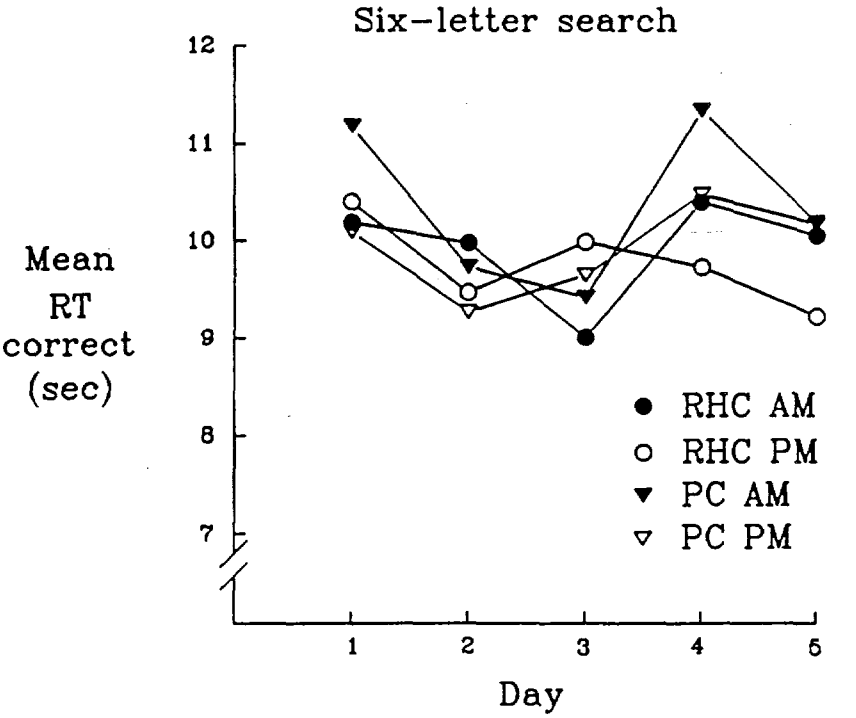

Figure 42. Day by session by computer interaction for the mean reaction time for correct responses on the six-letter search task.

The third significant simple two-way interaction, day by session for the desktop computer ($F(4,84)=3.25$, $p=0.0157$), resulted, in part, from statistically significant differences between the desktop computer morning and afternoon sessions on Monday (see above). In addition, RTs for the desktop computer morning session on Thursday (11.34 s) were significantly longer than the afternoon session (10.48 s) for the six-letter search task ($F(1,21)=10.08$, $p=0.0046$). There were also statistically significant reaction time differences between days at the desktop computer morning sessions ($F(2.84,59.74)=7.22$, $p=0.0004$) and the desktop computer afternoon sessions ($F(2.76,58.02)=3.46$, $p=0.0249$). For the desktop computer morning sessions, mean RTs on Monday (11.18 s) were significantly longer than on Tuesday (9.73 s) and Wednesday (9.42 s). Mean RTs increased from Wednesday morning to Thursday (11.34 s) and Friday (10.19 s) morning; and Thursday morning RTs were longer than Tuesday (9.73 s) or Friday (10.19 s). For the desktop computer afternoon sessions, the Tuesday mean RTs (9.27 s) were shorter than Monday (10.09 s), Thursday (10.48 s) and Friday (10.17 s).

The day by computer simple interaction for afternoon sessions was the last significant simple two-way interaction stemming from the three-way interaction ($F(4,84)=5.04$, $p=0.0011$). The analysis revealed computer simple effects on Thursday afternoon ($F(1,21)= 7.88$, $p=0.0106$) and Friday afternoon (9.22 vs 10.17) ($F(1,21)=18.00$, $p=0.0004$). On Thursday afternoon, shorter latencies were generated on the hand-held (9.73 s) than the desktop (10.48 s). Again on Friday the hand-held produced shorter RTs (9.22 s) than the desktop (10.17 s). In addition, the day simple effect for the desktop computer afternoon sessions was significant (see above).

The day by computer two-way interaction was statistically significant ($F(2.12,45.96)=3.50$, $p=0.0345$) as shown in Figure 43. The simple effect analysis revealed RTs for the desktop computer differed statistically among the days ($F(2.23,46.76)=6.74$, $p=0.0019$). Contrasts showed longer RTs on the desktop on Monday (10.63 s) than on Tuesday (9.50 s) and Wednesday (9.54 s). On Thursday, RTs increased significantly (10.91 s) relative to Tuesday (9.50 s) and Wednesday (9.54 s). By Friday, RTs had decreased slightly, but significantly, relative to Thursday (10.18 s), yet were still longer than Tuesday (9.50 s) or Wednesday (9.54 s).

The remaining significant two-way interaction, illustrated in Figure 44, was the day by session interaction ($F(4,84)=5.16$, $p=0.0009$). The simple effects analysis disclosed an increase in RT from the morning session (9.22 s) to the afternoon session (9.82 s) on Wednesday ($F(1,21)=6.95$, $p=0.0155$). On Thursday, RTs decreased from the morning (10.87 s) to afternoon (10.10 s) session ($F(1,21)=10.36$, $p=0.0041$). Furthermore, there was a day

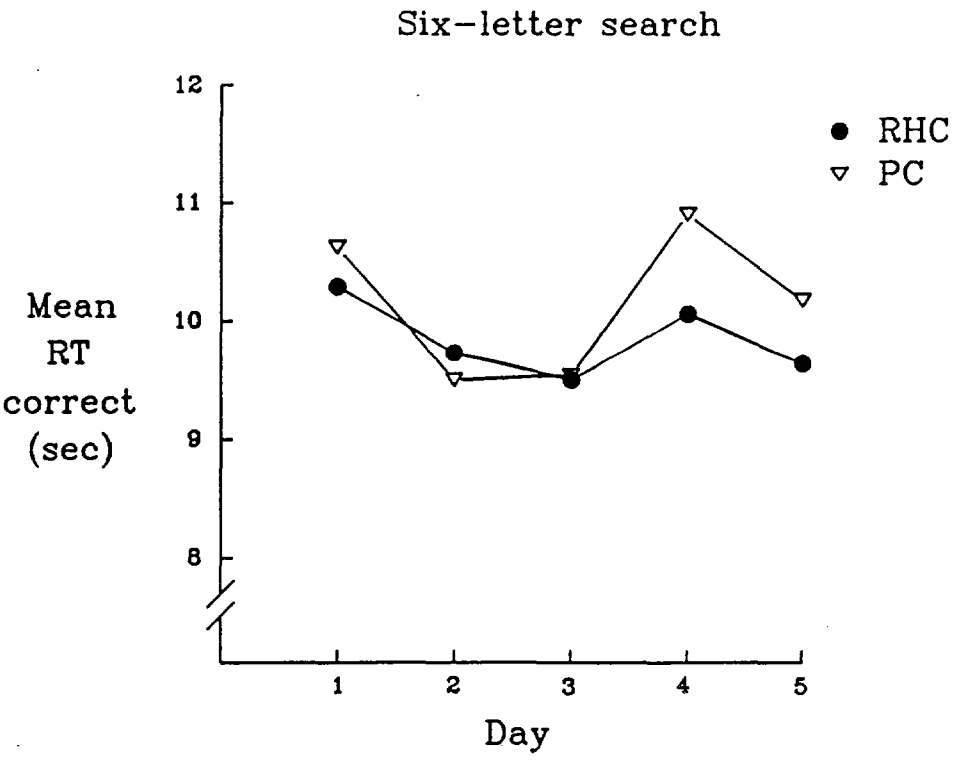

Figure 43. Day by computer interaction for the mean reaction time for correct responses on the six-letter search task.

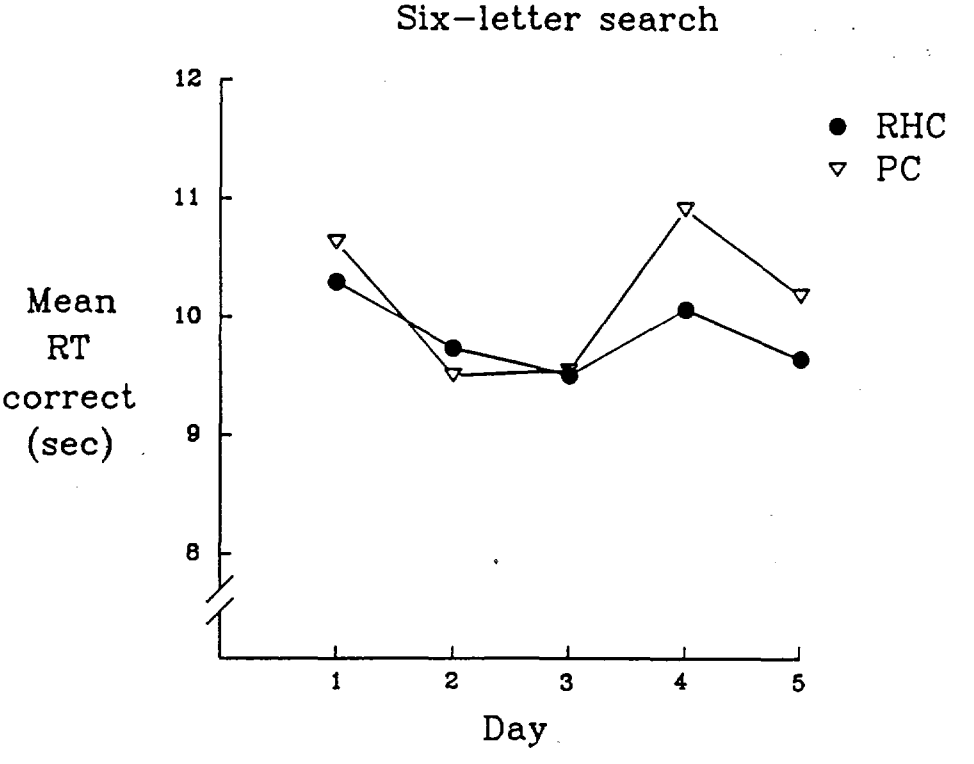

Figure 44. Day by session interaction for the mean reaction time for correct responses on the six-letter search task.

simple effect for the morning sessions ($F(2.73,57.32)=8.41$, $p=0.0002$). Contrasts indicated a reduction of morning RTs from Monday (10.68 s) to Tuesday (9.86 s) and Wednesday (9.22 s). Wednesday morning's RTs (9.22 s) were shorter than Thursday morning's (10.87 s) and Friday morning's (10.12 s). Finally, RTs on Thursday morning (10.87 s) were longer than on Tuesday (9.86 s) or Friday (10.12 s) mornings.

The day ($F(2.22,46.55)=5.40$, $p=0.0062$) and session ($F(1,21)=4.96$, $p=0.0369$) main effects also were statistically significant for the six-letter search task (see Figure 45 for the day main effect). Contrasts for the day main effect showed differences between Monday (10.46) versus Tuesday (9.62) and Wednesday (9.52), and Thursday (10.49) versus Tuesday (9.62), Wednesday (9.52), and Friday (9.91). The significant session main showed the morning session reaction time (10.15) was significantly slower than the afternoon reaction time (9.85).

Throughput. ANOVA for the six-letter search task throughput data revealed a statistically significant day by session interaction ($F(2.03,42.69)=3.29$, $p=0.0460$). The day by computer interaction was also significant ($F(2.58,54.23)=5.19$, $p=0.0047$). Finally, the day main effect was significant ($F(1.88,39.42)=3.35$, $p=0.0433$). These data are illustrated in Figures 46 through 48, respectively.

The day by session interaction was accounted for by three significant simple effects. First, there was a significant day simple effect for the morning sessions ($F(2.41,50.53)=7.11$, $p=0.0010$). Contrasts revealed that throughput increased significantly from Monday morning (6.14) to both Tuesday (6.63) and Wednesday (7.01) mornings. On Thursday morning (5.85), throughput dropped relative to Tuesday (6.63) and Wednesday (7.01) mornings. However, by Friday morning (6.24) throughput had increased relative to Thursday, but was still significantly lower than Wednesday morning (7.01). Second, there was a significant session simple effect on Wednesday ($F(1,21)=9.24$, $p=0.0062$) where throughput dropped from the morning session (7.01) to the afternoon session (6.46). And third, there was a significant session simple effect on Thursday ($F(1,21)=7.62$, $p=0.0117$) where throughput increased from the morning session (5.85) to the afternoon session (6.23).

The day by computer interaction (Figure 47) was accounted for by three significant simple effects. First, there was a significant day simple effect for the desktop computer ($F(1.92,40.41)=5.67$, $p=0.0073$). Contrasts indicated that throughput scores on the desktop were significantly higher on Tuesday (6.86) than they were on Monday (6.34), Thursday (5.77) or Friday (6.18). Throughput on Wednesday (6.82) was significantly higher than on Thursday (5.77) and Friday (6.18),

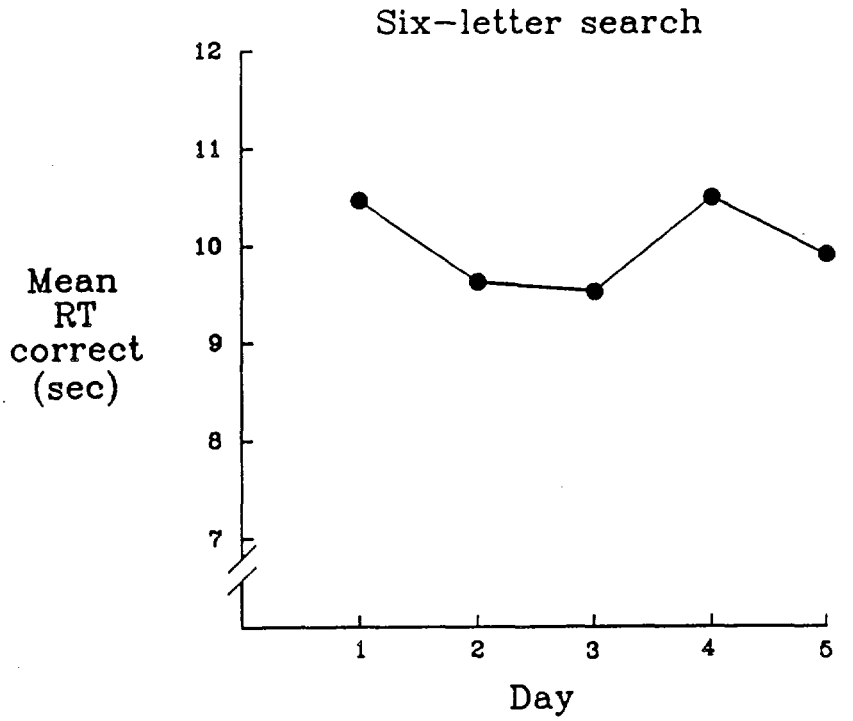

Figure 45. Day main effect for the mean reaction time for correct responses on the six-letter search task.

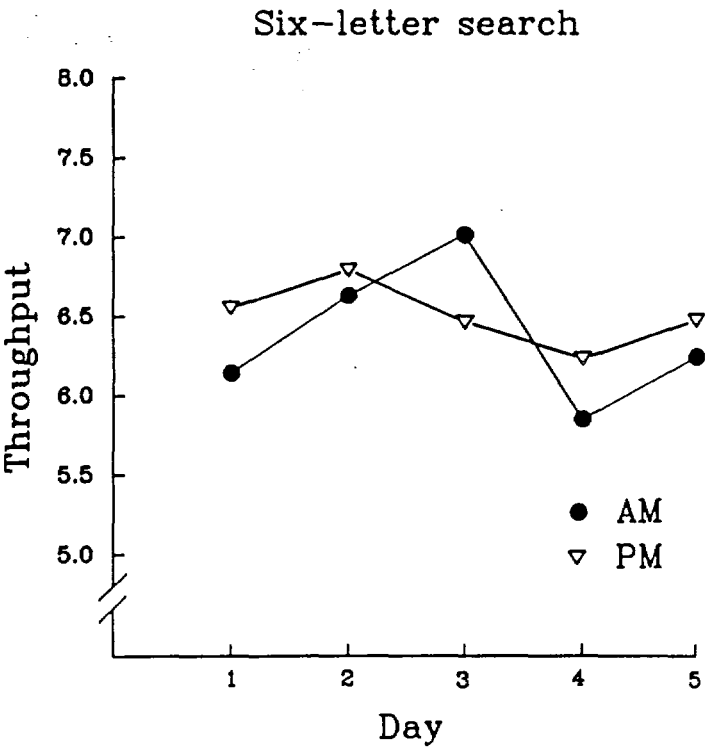

Figure 46. Day by session interaction for throughput on the six-letter search task.

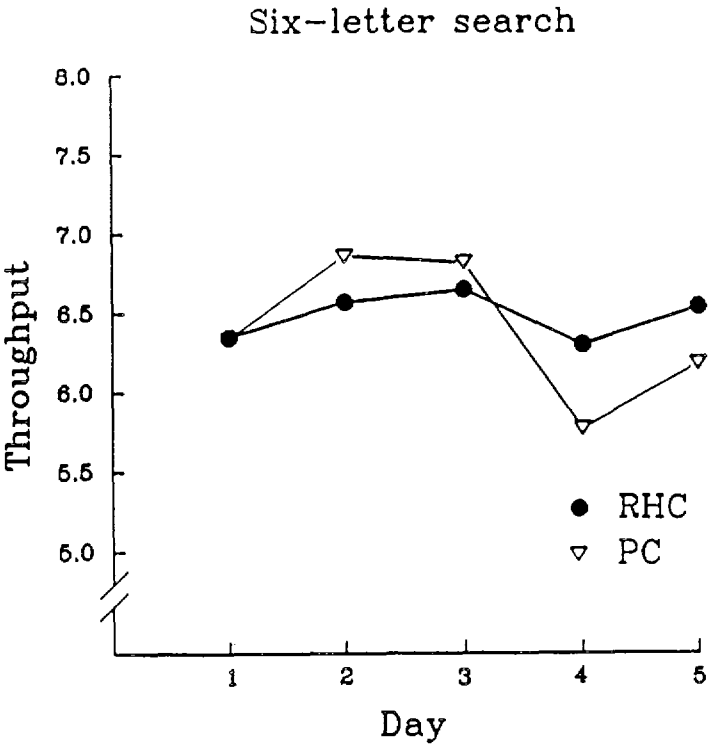

Figure 47. Day by computer interaction for throughput on the six-letter search task.

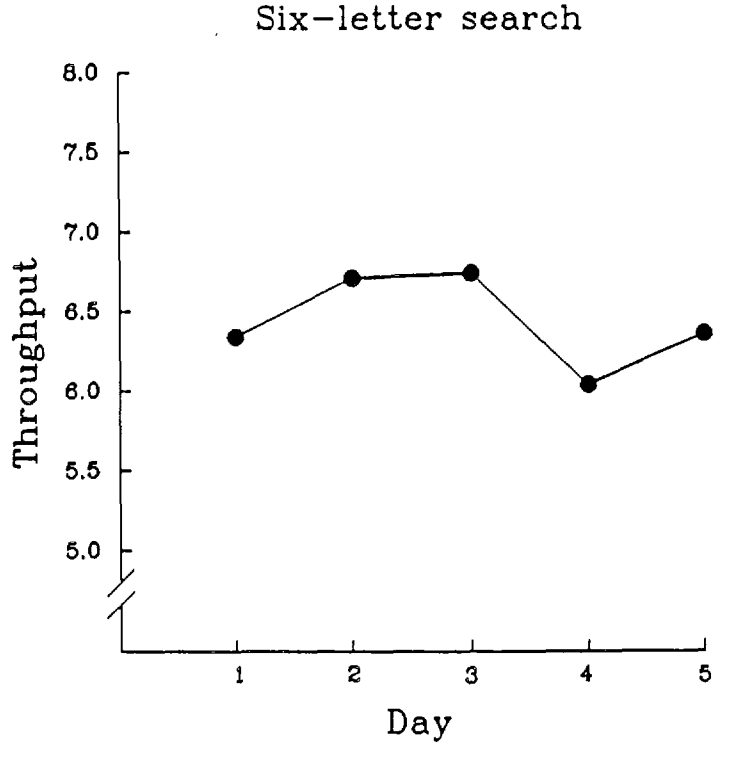

Figure 48. Day main effect for throughput on the six-letter search task.

while Thursday's throughput scores (5.77) were lower than Friday's (6.18). Second, there was a significant computer simple effect on Thursday ($F(1,21)=23.07$, $p=0.0001$) due to higher throughput on the hand-held (6.30) than the desktop (5.77). And third, there was a significant computer simple effect on Friday ($F(1,21)=12.69$, $p=0.0018$) where throughput again was higher on the hand-held (6.54) than the desktop (6.18).

Contrasts for the day main effect (Figure 48) indicated that throughput increased significantly from Monday (6.34) to Tuesday (6.71). Throughput dropped on Thursday (6.04) relative to Tuesday (6.71) and Wednesday (6.74), and was also lower than on Friday (6.36). None of the other contrasts were significant.

Discussion and conclusions

Considering that the primary objective of the study was the determination of the comparability of data collected on the two devices, discussion will focus predominantly on those effects which involved differences between computers. Yet, effects involving day and session determine the stability of subject performance on the various tasks and the sensitivity of the tasks to time-of-day and weekly variation. Therefore, a brief discussion of these effects will be presented.

Sensitivity. Interactions between day and session were observed on each of the six tasks for at least one measure. On only one task, serial addition/subtraction, did percent correct not show sensitivity to time-of-day and weekly variation. Mean RT for correct responses was always sensitive to such temporally-related variability in performance. Yet, the patterns of such variability were not the same for every task or every measure. Tasks which contained a significant memory component (pattern comparison, digit recall, and six-letter search) typically showed improvement in accuracy across morning sessions with performance becoming worse toward the end of the week. This end-of-week decline in performance also was apparent for reaction time. Accuracy and RT on the logical reasoning task tended to improve linearly across days. For the four-choice RT task, accuracy tended to reach asymptote by midweek while RT decreased initially, then increased at midweek. Differences between sessions on Wednesday possibly were due to motivational or strategy-selection changes resulting from the removal of feedback following the Wednesday morning session. The drop in performance observed on Thursday sessions likely resulted from this removal of feedback also.

Interactions between day, session, and computer were observed on five of the six tasks for at least one of the dependent measures. Only the logical reasoning task failed to produce a three-way interaction. Typically, the dependent

variable involved in the three-way interaction was either throughput or the mean RT for correct responses. Assessing the differences in performance on the two devices is complicated by the existence of these three-way interactions.

Computer differences. For the pattern comparison task, the three-way interaction was a result of higher throughput scores on the desktop computer than the hand-held computer every afternoon except Thursday. There were no computer differences at morning sessions. Furthermore, the hand-held computer showed changes across days at the morning sessions while the desktop computer showed changes across days at the afternoon sessions. Computer differences on the pattern comparison task were fairly consistent.

The lower throughput values and longer RTs on the hand-held computer relative to the desktop likely were due to differences in visibilities of the two displays. The hand-held computer's LCD has a lower contrast value than the desktop computer's CRT display. This results from the LCD's use of reflectance rather than luminance to produce the image (see Table 1). The lower contrast of the hand-held computer's LCD display apparently decreased the subject's ability to process pattern information quickly. However, once information was extracted, accurate decisions could be made. This conclusion is supported by the lack of consistent computer differences for the percent correct measure. Also, note that differences between devices were typically observed earlier rather than later in the week. This suggests that subjects, with continued practice, managed to compensate for any deleterious effects the lower contrast of the liquid crystal display had on performance.

The logical reasoning task exhibited the fewest number of computer-related effects. Only the mean RTs for correct responses showed any computer differences. As with the pattern comparison task, RTs were longer on the hand-held computer than on the desktop. These differences exhibited themselves primarily at the morning sessions. Again, this possibly was due to differences in the contrasts of the two displays.

Of the five tasks which produced a three-way interaction, the percent correct measure was involved only on the serial addition/subtraction task. Here the interaction was due, in part, to decreasing accuracy from morning to afternoon during only the first part of the week for both computers. Also, accuracy increased across only afternoon sessions for the hand-held computer, but not the desktop. The only other measure to show sensitivity to computer differences was the mean RT for correct responses. RTs were longer on the desktop computer than on the hand-held, but only on the first day of testing.

Table 1.

Luminance and contrast values
for hand-held and desktop computer displays.

Hand-held computer Liquid crystal display (Dark target)
Target luminance (L_t) = 5.0 footlamberts Background luminance (L_b) = 9.5 footlamberts Contrast = $(L_b - L_t)/L_b$ = 0.47
Desktop computer Cathode-ray-tube display (Bright target)
Target luminance (L_t) = 16.2 footlamberts Background luminance (L_b) = 4.4 footlamberts Contrast = $(L_t - L_b)/(L_b)$ = 2.68

Results on the digit recall task indicated a large amount of variability in performance. While differences between the two devices existed, they were not consistent. Accuracy was greater on the desktop computer on Tuesday, but was greater on the hand-held the following day. The mean RT for correct responses showed computer differences on Monday and Tuesday mornings, but these also were in opposite directions. Further, there were computer differences on Thursday and Friday afternoon sessions which again were in opposite directions. Similar computer differences were observed for the throughput measure on Monday and Tuesday morning sessions. So, while differences between the two devices were observed, it is difficult to conclude that they resulted from the different hardware characteristics of the two devices.

Computer differences also were observed on the four-choice RT task. The day by computer interaction for the mean RT for correct responses primarily resulted from computer differences on Tuesday and Wednesday where RTs on the desktop computer were shorter than those on the hand-held. Apparently, performance improved more rapidly on the desktop computer, but this initial advantage did not continue later in the week. The throughput measure was involved in a three-way interaction. In addition to the computer differences on Tuesday and Wednesday which were observed also for the mean RT for correct responses, greater throughput values were seen for the desktop computer than the hand-held on Monday afternoon and on Friday morning. Overall,

the computer differences for the four-choice RT task were consistent; faster correct responses always were recorded on the desktop than the hand-held computer. While it is possible these differences were due to the decreased visibility associated with the LCD display, the magnitude of the difference must be taken into account. Both devices use the 18.2 Hz interrupt timer to measure subject response times. This interrupt frequency provides an average timing resolution of 54.9 ms. The difference in average RT between the two devices was only 32 ms which is well within the resolution of the response timing routine.

The six-letter search task produced computer differences also. Analysis of the mean RT for correct responses revealed a three-way interaction. This resulted from relatively longer RTs on the desktop computer than the hand-held only at the Thursday and Friday afternoon sessions and the lack of a significant change across days for the afternoon sessions on the hand-held computer. While RTs on both computers tended to rise at midweek (following removal of feedback), there was greater subsequent improvement on the hand-held computer at afternoon sessions.

The throughput measure behaved in a similar manner. While there was no three-way interaction for this variable, the day by computer interaction was significant. Computer differences were observed on Thursday and Friday resulting from relatively lower throughput for the desktop computer than the hand-held. Also, there were significant changes across days only on the desktop computer.

These findings on the six-letter search task were of particular interest, first of all, because the difference between computers exhibits itself later in the week rather than earlier unlike the other tasks. Also, the longer RTs were observed on the desktop computer rather than the hand-held. Both of these findings were inconsistent with a display contrast difference explanation. This inconsistency can be explained when the angular subtense of the two displays is taken into account. After computing an average viewing distance on both devices for a subset of five subjects, the angular subtense of the distance between the target array and the search array was computed for both hand-held and desktop computers. The interarray distance had an angular subtense of 3.83° on the hand-held computer while it had an angular subtense of 6.91° on the desktop computer. This difference in the interarray distance is a result of the different aspect ratios of the two displays. The aspect ratio refers to the ratio of the width of a screen image to its height.

In conclusion, there were tasks in which the type of device used to present stimuli and record data influenced the results obtained. Differences between the two devices in terms of their display characteristics seem to account for the influences.

These findings do not diminish the utility of the ruggedized, field-portable computer for cognitive data collection in operational settings. However, keep in mind that while the differences observed were statistically significant, the magnitude of the differences generally was not large.

They do, however, suggest that caution must be exercised when attempting to combine results of studies involving the use of desktop computers with those from studies involving the use of hand-held computers. If, for example, differences in outcome were found when investigating the same intervention in both a laboratory study using a desktop computer and a field study using a hand-held computer, it would be difficult to attribute these differences to an interaction between the influences of the intervention and the field environment without taking the different hardware characteristics of the two devices into account. One way to avoid this difficulty would be to use the ruggedized, hand-held computer in both laboratory and field environments.

Future applications of the ruggedized, hand-held computer will benefit from the recent development of new performance assessment software which uses software-controlled response timing routines with millisecond resolution to eliminate the need for peripheral timing devices. Additional modifications will be required to eliminate the differences in aspect ratios of the different displays, but graphics-based text generation would provide a possible solution. Currently, efforts are being directed toward such development.

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APPENDIX A

Pattern comparison			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Wed	5.26	1,23	0.0314
Tue vs Wed	7.50	1,23	0.0117
Wed vs Fri	6.02	1,23	0.0221
Mon vs Thu @ AM	4.54	1,23	0.0441
Tue vs Wed @ AM	7.28	1,23	0.0128
Tue vs Thu @ AM	4.85	1,23	0.0380
Wed vs Fri @ AM	5.55	1,23	0.0273
Tue vs Fri @ PM	8.23	1,23	0.0087
Wed vs Fri @ PM	12.10	1,23	0.0020
Thu vs Fri @ PM	10.05	1,23	0.0043
Tue vs Wed @ Hand-held	11.69	1,23	0.0023
Wed vs Thu @ Hand-held	7.39	1,23	0.0123
Mon vs Tue @ Desktop	7.36	1,23	0.0124
Mon vs Wed @ Desktop	5.28	1,23	0.0311
Mon vs Thu @ Desktop	18.10	1,23	0.0003
Thu vs Fri @ Desktop	7.21	1,23	0.0132

Pattern comparison			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Tue	16.22	1,23	0.0005
Mon vs Wed	15.15	1,23	0.0007
Tue vs Thu	6.52	1,23	0.0178
Wed vs Thu	15.97	1,23	0.0006
Thu vs Fri	5.76	1,23	0.0249
Mon vs Tue @ AM	12.75	1,23	0.0016
Mon vs Wed @ AM	20.06	1,23	0.0002
Mon vs Thu @ AM	5.53	1,23	0.0276
Mon vs Fri @ AM	6.07	1,23	0.0217
Tue vs Wed @ AM	4.62	1,23	0.0424
Wed vs Thu @ AM	11.17	1,23	0.0028
Mon vs Tue @ PM	8.14	1,23	0.0090
Tue vs Thu @ PM	8.07	1,23	0.0092
Wed vs Thu @ PM	10.79	1,23	0.0032
Thu vs Fri @ PM	7.50	1,23	0.0117

APPENDIX A (Continued)

Pattern comparison			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Tue	8.90	1,23	0.0067
Mon vs Wed	7.93	1,23	0.0098
Tue vs Thu	5.17	1,23	0.0327
Wed vs Thu	11.33	1,23	0.0027
Thu vs Fri	4.53	1,23	0.0443
Mon vs Tue @ AM @ Hand-held	7.20	1,23	0.0133
Mon vs Wed @ AM @ Hand-held	11.72	1,23	0.0023
Tue vs Wed @ AM @ Hand-held	4.52	1,23	0.0444
Tue vs Thu @ AM @ Hand-held	7.09	1,23	0.0139
Wed vs Thu @ AM @ Hand-held	15.73	1,23	0.0006
Wed vs Fri @ AM @ Hand-held	4.37	1,23	0.0479
Mon vs Tue @ PM @ Desktop	4.38	1,23	0.0476
Mon vs Wed @ PM @ Desktop	5.75	1,23	0.0250
Tue vs Thu @ PM @ Desktop	5.34	1,23	0.0301
Wed vs Thu @ PM @ Desktop	9.94	1,23	0.0045

APPENDIX B

Logical reasoning			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Tue	19.21	1,23	0.0002
Mon vs Wed	24.27	1,23	0.0001
Mon vs Thu	35.09	1,23	0.0000
Mon vs Fri	46.41	1,23	0.0000
Tue vs Wed	4.28	1,23	0.0501
Tue vs Thu	4.93	1,23	0.0365
Tue vs Fri	7.23	1,23	0.0131
Mon vs Tue @ AM	23.33	1,23	0.0001
Mon vs Wed @ AM	24.34	1,23	0.0001
Mon vs Thu @ AM	38.23	1,23	0.0000
Mon vs Fri @ AM	27.47	1,23	0.0000
Mon vs Wed @ PM	7.78	1,23	0.0104
Mon vs Thu @ PM	14.32	1,23	0.0010
Mon vs Fri @ PM	34.65	1,23	0.0000
Tue vs Thu @ PM	4.55	1,23	0.0438
Tue vs Fri @ PM	9.11	1,23	0.0061

Logical reasoning			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Tue	16.27	1,23	0.0005
Mon vs Wed	26.01	1,23	0.0000
Mon vs Thu	16.67	1,23	0.0005
Mon vs Fri	23.51	1,23	0.0001
Tue vs Wed	8.37	1,23	0.0082
Tue vs Fri	7.55	1,23	0.0115
Thu vs Fri	12.84	1,23	0.0016
Mon vs Tue @ AM	23.10	1,23	0.0001
Mon vs Wed @ AM	36.08	1,23	0.0000
Mon vs Thu @ AM	22.23	1,23	0.0001
Mon vs Fri @ AM	24.39	1,23	0.0001
Tue vs Wed @ AM	22.81	1,23	0.0001
Tue vs Fri @ AM	5.92	1,23	0.0231
Wed vs Thu @ AM	9.74	1,23	0.0048
Thu vs Fri @ AM	6.08	1,23	0.0215
Mon vs Fri @ PM	11.97	1,23	0.0021
Tue vs Wed @ PM	4.29	1,23	0.0497
Tue vs Fri @ PM	6.88	1,23	0.0152
Wed vs Thu @ PM	4.30	1,23	0.0496
Wed vs Fri @ PM	22.21	1,23	0.0001
Thu vs Fri @ PM	14.58	1,23	0.0009

Logical reasoning			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Tue @ AM	7.07	1,23	0.0140
Mon vs Wed @ AM	18.93	1,23	0.0002
Mon vs Thu @ AM	53.57	1,23	0.0000
Mon vs Fri @ AM	60.13	1,23	0.0000
Tue vs Wed @ AM	15.08	1,23	0.0008
Wed @ Thu @ AM	4.25	1,23	0.0506
Thu vs Fri @ AM	8.46	1,23	0.0079

APPENDIX C

Serial addition/subtraction			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Wed	7.27	1,23	0.0129
Mon vs Fri	5.05	1,23	0.0345
Tue vs Wed	7.14	1,23	0.0136
Tue vs Fri	7.41	1,23	0.0121
Wed vs Thu	14.68	1,23	0.0009
Thu vs Fri	22.66	1,23	0.0001
Mon vs Wed @ PM @ Hand-held	13.68	1,23	0.0012
Mon vs Fri @ PM @ Hand-held	7.57	1,23	0.0114
Wed vs Thu @ PM @ Hand-held	6.18	1,23	0.0206
Thu vs Fri @ PM @ Desktop	14.33	1,23	0.0010

Serial addition/subtraction			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Tue	16.11	1,23	0.0005
Mon vs Wed	23.30	1,23	0.0001
Mon vs Fri	23.76	1,23	0.0001
Tue vs Wed	10.47	1,23	0.0037
Tue vs Fri	11.06	1,23	0.0029
Wed vs Thu	9.75	1,23	0.0048
Thu vs Fri	10.55	1,23	0.0035
Mon vs Wed @ AM	13.97	1,23	0.0011
Mon vs Thu @ AM	4.92	1,23	0.0367
Mon vs Fri @ AM	7.37	1,23	0.0124
Tue vs Wed @ AM	21.44	1,23	0.0001
Tue vs Fri @ AM	6.19	1,23	0.0205
Wed vs Thu @ AM	8.04	1,23	0.0094
Mon vs Tue @ PM	19.52	1,23	0.0002
Mon vs Wed @ PM	18.71	1,23	0.0003
Mon vs Fri @ PM	26.24	1,23	0.0000
Tue vs Thu @ PM	4.61	1,23	0.0426
Wed @ Thu @ PM	9.16	1,23	0.0060
Thu vs Fri @ PM	9.81	1,23	0.0047
Mon vs Tue @ Hand-held	4.68	1,23	0.0412
Mon vs Wed @ Hand-held	17.99	1,23	0.0003
Mon vs Fri @ Hand-held	7.25	1,23	0.0130
Wed vs Thu @ Hand-held	7.66	1,23	0.0110
Thu vs Fri @ Hand-held	7.99	1,23	0.0095
Mon vs Tue @ Desktop	8.36	1,23	0.0082
Mon vs Wed @ Desktop	18.13	1,23	0.0003
Mon vs Thu @ Desktop	7.66	1,23	0.0110
Mon vs Fri @ Desktop	13.69	1,23	0.0012
Tue vs Wed @ Desktop	10.63	1,23	0.0034
Wed vs Thu @ Desktop	9.52	1,23	0.0052
Thu vs Fri @ Desktop	5.68	1,23	0.0258

Serial addition/subtraction			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Tue	6.61	1,23	0.0171
Mon vs Wed	13.54	1,23	0.0012
Mon vs Thu	9.71	1,23	0.0049
Mon vs Fri	20.28	1,23	0.0002
Tue vs Wed	8.04	1,23	0.0094
Tue vs Fri	15.94	1,23	0.0006
Wed vs Thu	8.19	1,23	0.0088
Thu vs Fri	13.14	1,23	0.0014

APPENDIX D

Digit recall			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Wed	13.83	1,22	0.0012
Mon vs Thu	10.23	1,22	0.0042
Mon vs Fri	22.70	1,22	0.0001
Tue vs Wed	9.86	1,22	0.0048
Tue vs Thu	7.51	1,22	0.0120
Tue vs Fri	28.53	1,22	0.0000
Thu vs Fri	6.17	1,22	0.0211
Mon vs Wed @ AM	34.46	1,22	0.0000
Mon vs Thu @ AM	16.71	1,22	0.0005
Mon vs Fri @ AM	31.05	1,22	0.0000
Tue vs Wed @ AM	10.75	1,22	0.0034
Tue vs Thu @ AM	6.79	1,22	0.0161
Tue vs Fri @ AM	23.85	1,22	0.0001
Thu vs Fri @ AM	15.30	1,22	0.0007
Mon vs Wed @ Hand-held	9.11	1,22	0.0063
Mon vs Thu @ Hand-held	4.76	1,22	0.0400
Mon vs Fri @ Hand-held	9.26	1,22	0.0060
Tue vs Wed @ Hand-held	42.24	1,22	0.0000
Tue vs Thu @ Hand-held	29.21	1,22	0.0000
Tue vs Fri @ Hand-held	41.59	1,22	0.0000
Mon vs Tue @ Desktop	6.88	1,22	0.0155
Mon vs Fri @ Desktop	13.52	1,22	0.0013
Wed vs Fri @ Desktop	6.32	1,22	0.0198

Digit recall			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Thu	9.59	1,22	0.0053
Tue vs Thu	5.98	1,22	0.0230
Wed vs Thu	6.94	1,22	0.0152
Thu vs Fri	9.89	1,22	0.0047
Mon vs Wed @ PM	12.38	1,22	0.0019
Mon vs Thu @ PM	18.33	1,22	0.0003
Tue vs Thu @ PM	6.53	1,22	0.0181
Thu vs Fri @ PM	10.04	1,22	0.0044
Mon vs Tue @ Hand-held	7.28	1,22	0.0131
Mon vs Wed @ Hand-held	4.55	1,22	0.0442
Mon vs Thu @ Hand-held	10.69	1,22	0.0035
Wed vs Thu @ Hand-held	5.67	1,22	0.0264
Thu vs Fri @ Hand-held	12.44	1,22	0.0019
Tue vs Wed @ Desktop	6.30	1,22	0.0199
Tue vs Thu @ Desktop	10.58	1,22	0.0036
Tue vs Fri @ Desktop	6.06	1,22	0.0221
Mon vs Tue @ AM @ Hand-held	6.44	1,22	0.0187
Mon vs Thu @ AM @ Hand-held	5.19	1,22	0.0328
Mon vs Fri @ AM @ Hand-held	4.20	1,22	0.0525
Tue vs Wed @ AM @ Hand-held	12.65	1,22	0.0018
Wed vs Thu @ AM @ Hand-held	5.01	1,22	0.0356
Mon vs Tue @ AM @ Desktop	5.89	1,22	0.0239
Tue vs Thu @ AM @ Desktop	9.08	1,22	0.0064
Wed vs Thu @ AM @ Desktop	5.06	1,22	0.0348
Mon vs Wed @ PM @ Hand-held	7.80	1,22	0.0106
Mon vs Thu @ PM @ Hand-held	13.50	1,22	0.0013
Tue vs Thu @ PM @ Hand-held	4.90	1,22	0.0375
Wed vs Fri @ PM @ Hand-held	5.26	1,22	0.0318
Thu vs Fri @ PM @ Hand-held	13.21	1,22	0.0015
Mon vs Wed @ PM @ Desktop	10.72	1,22	0.0035
Mon vs Thu @ PM @ Desktop	13.04	1,22	0.0016
Mon vs Fri @ PM @ Desktop	7.77	1,22	0.0108
Tue vs Wed @ PM @ Desktop	4.71	1,22	0.0411
Tue vs Thu @ PM @ Desktop	4.76	1,22	0.0401

Digit recall			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Thu	13.05	1,22	0.0015
Tue vs Thu	4.82	1,22	0.0390
Wed vs Thu	5.87	1,22	0.0241
Thu vs Fri	17.08	1,22	0.0004
Mon vs Tue @ Hand-held	6.60	1,22	0.0175
Mon vs Thu @ Hand-held	14.17	1,22	0.0011
Wed vs Thu @ Hand-held	5.00	1,22	0.0358
Thu vs Fri @ Hand-held	20.32	1,22	0.0002
Tue vs Wed @ Desktop	4.68	1,22	0.0417
Tue vs Thu @ Desktop	8.92	1,22	0.0068
Mon vs Tue @ AM @ Hand-held	7.39	1,22	0.0125
Mon vs Thu @ AM @ Hand-held	7.18	1,22	0.0137
Mon vs Fri @ AM @ Hand-held	5.32	1,22	0.0309
Tue vs Wed @ AM @ Hand-held	6.52	1,22	0.0181
Wed vs Thu @ AM @ Hand-held	4.89	1,22	0.0378
Mon vs Tue @ AM @ Desktop	4.57	1,22	0.0440
Tue vs Thu @ AM @ Desktop	9.52	1,22	0.0054
Wed vs Thu @ am @ Desktop	5.23	1,22	0.0322
Mon vs Wed @ PM @ Hand-held	7.95	1,22	0.0100
Mon vs Thu @ PM @ Hand-held	16.54	1,22	0.0005
Tue vs Thu @ PM @ Hand-held	4.56	1,22	0.0442
Wed vs Fri @ PM @ Hand-held	5.94	1,22	0.0234
Thu vs Fri @ PM @ Hand-held	18.48	1,22	0.0003
Mon vs Wed @ PM @ Desktop	9.03	1,22	0.0065
Mon vs Thu @ PM @ Desktop	4.87	1,22	0.0381

APPENDIX E

4-choice serial reaction time			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Tue	4.52	1,22	0.0449
Mon vs Wed	6.50	1,22	0.0183
Mon vs Thu	11.71	1,22	0.0024
Tue vs Thu	4.63	1,22	0.0427
Thu vs Fri	4.27	1,22	0.0508
Mon vs Tue @ AM	4.67	1,22	0.0419
Mon vs Thu @ AM	5.32	1,22	0.0309
Mon vs Fri @ AM	4.64	1,22	0.0424
Mon vs Wed @ PM	10.11	1,22	0.0043
Mon vs Thu @ PM	10.46	1,22	0.0038
Tue vs Wed @ PM	6.06	1,22	0.0221
Tue vs Thu @ AM	6.05	1,22	0.0223
Wed vs Fri @ PM	15.36	1,22	0.0007
Thu vs Fri @ PM	13.67	1,22	0.0013

4-choice serial reaction time			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Tue	57.21	1,22	0.0000
Mon vs Wed	60.77	1,22	0.0000
Mon vs Thu	40.94	1,22	0.0000
Mon vs Fri	47.22	1,22	0.0000
Tue vs Thu	6.01	1,22	0.0227
Wed vs Fri	8.54	1,22	0.0079
Thu vs Fri	25.04	1,22	0.0001
Mon vs Tue @ AM	58.88	1,22	0.0000
Mon vs Wed @ AM	67.75	1,22	0.0000
Mon vs Thu @ AM	55.78	1,22	0.0000
Mon vs Fri @ AM	46.68	1,22	0.0000
Tue vs Wed @ AM	27.22	1,22	0.0000
Tue vs Fri @ AM	4.93	1,22	0.0370
Wed vs Thu @ AM	17.38	1,22	0.0004
Thu vs Fri @ AM	11.14	1,22	0.0030
Mon vs Tue @ PM	25.40	1,22	0.0000
Mon vs Thu @ PM	12.11	1,22	0.0021
Mon vs Fri @ PM	28.15	1,22	0.0000
Tue vs Wed @ PM	18.99	1,22	0.0003
Tue vs Thu @ PM	10.51	1,22	0.0037
Wed vs Thu @ PM	6.44	1,22	0.0188
Wed vs Fri @ PM	21.54	1,22	0.0001
Thu vs Fri @ PM	32.06	1,22	0.0000
Mon vs Tue @ Hand-held	27.42	1,22	0.0000
Mon vs Wed @ Hand-held	43.78	1,22	0.0000
Mon vs Thu @ Hand-held	36.52	1,22	0.0000
Mon vs Fri @ Hand-held	42.10	1,22	0.0000
Tue vs Fri @ Hand-held	10.66	1,22	0.0035
Wed vs Fri @ Hand-held	8.15	1,22	0.0092
Thu vs Fri @ Hand-held	13.17	1,22	0.0015
Mon vs Tue @ Desktop	43.00	1,22	0.0000
Mon vs Wed @ Desktop	32.33	1,22	0.0000
Mon vs Thu @ Desktop	22.16	1,22	0.0001
Mon vs Fri @ Desktop	27.71	1,22	0.0000
Tue vs Wed @ Desktop	13.73	1,22	0.0012
Tue vs Thu @ Desktop	30.37	1,22	0.0000
Wed vs Thu @ Desktop	6.11	1,22	0.0216
Thu vs Fri @ Desktop	19.64	1,22	0.0002

4-choice serial reaction time			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Tue	94.20	1,22	0.0000
Mon vs Wed	117.34	1,22	0.0000
Mon vs Thu	47.64	1,22	0.0000
Mon vs Fri	72.01	1,22	0.0000
Tue vs Wed	4.71	1,22	0.0411
Tue vs Thu	12.00	1,22	0.0022
Wed vs Thu	7.10	1,22	0.0142
Wed vs Fri	5.03	1,22	0.0354
Thu vs Fri	30.44	1,22	0.0000
Mon vs Tue @ AM	105.82	1,22	0.0000
Mon vs Wed @ AM	172.47	1,22	0.0000
Mon vs Thu @ AM	100.18	1,22	0.0000
Mon vs Fri @ AM	86.54	1,22	0.0000
Tue vs Wed @ AM	49.72	1,22	0.0000
Wed vs Thu @ AM	24.75	1,22	0.0001
Thu vs Fri @ AM	10.82	1,22	0.0033
Mon vs Tue @ PM	43.51	1,22	0.0000
Mon vs Thu @ PM	9.17	1,22	0.0062
Mon vs Fri @ PM	31.92	1,22	0.0000
Tue vs Wed @ PM	31.74	1,22	0.0000
Tue vs Thu @ PM	20.08	1,22	0.0002
Wed vs Thu @ PM	4.89	1,22	0.0377
Wed vs Fri @ PM	27.26	1,22	0.0000
Thu vs Fri @ PM	35.14	1,22	0.0000
Mon vs Tue @ Hand-held	41.30	1,22	0.0000
Mon vs Wed @ Hand-held	80.23	1,22	0.0000
Mon vs Thu @ Hand-held	50.84	1,22	0.0000
Mon vs Fri @ Hand-held	71.22	1,22	0.0000
Tue vs Fri @ Hand-held	9.90	1,22	0.0047
Wed vs Fri @ Hand-held	7.75	1,22	0.0108
Thu vs Fri @ Hand-held	15.45	1,22	0.0007
Mon vs Tue @ Desktop	80.21	1,22	0.0000
Mon vs Wed @ Desktop	60.33	1,22	0.0000
Mon vs Thu @ Desktop	25.54	1,22	0.0000
Mon vs Fri @ Desktop	41.50	1,22	0.0000
Tue vs Wed @ Desktop	19.21	1,22	0.0002
Tue vs Thu @ Desktop	30.94	1,22	0.0000
Tue vs Fri @ Desktop	5.68	1,22	0.0262
Wed vs Thu @ Desktop	11.90	1,22	0.0023
Thu vs Fri @ Desktop	21.81	1,22	0.0001
Mon vs Tue @ AM @ Desktop	46.18	1,22	0.0000
Mon vs Wed @ AM @ Desktop	70.96	1,22	0.0000
Mon vs Thu @ AM @ Desktop	35.85	1,22	0.0000
Mon vs Fri @ AM @ Desktop	36.25	1,22	0.0000

Contrasts (continued)	F	df	p
Tue vs Wed @ AM @ Desktop	16.84	1,22	0.0005
Tue vs Thu @ AM @ Desktop	8.99	1,22	0.0066
Wed vs Thu @ AM @ Desktop	23.15	1,22	0.0001
Wed vs Fri @ AM @ Desktop	5.25	1,22	0.0318
Thu vs Fri @ AM @ Desktop	9.06	1,22	0.0065
Mon vs Tue @ PM @ Desktop	42.55	1,22	0.0000
Mon vs Fri @ PM @ Desktop	11.25	1,22	0.0029
Tue vs Wed @ PM @ Desktop	80.57	1,22	0.0000
Tue vs Thu @ PM @ Desktop	35.14	1,22	0.0000
Tue vs Fri @ PM @ Desktop	19.26	1,22	0.0002
Wed vs Fri @ PM @ Desktop	19.77	1,22	0.0002
Thu vs Fri @ PM @ Desktop	11.16	1,22	0.0030
Mon vs Tue @ AM @ Hand-held	78.14	1,22	0.0000
Mon vs Wed @ AM @ Hand-held	126.43	1,22	0.0000
Mon vs Thu @ AM @ Hand-held	76.22	1,22	0.0000
Mon vs Fri @ AM @ Hand-held	85.17	1,22	0.0000
Tue vs Wed @ AM @ Hand-held	23.65	1,22	0.0001
Tue vs Fri @ AM @ Hand-held	7.60	1,22	0.0115
Wed vs Thu @ AM @ Hand-held	5.03	1,22	0.0354
Thu vs Fri @ AM @ Hand-held	5.74	1,22	0.0255
Mon vs Tue @ PM @ Hand-held	10.93	1,22	0.0032
Mon vs Wed @ PM @ Hand-held	5.02	1,22	0.0355
Mon vs Thu @ PM @ Hand-held	13.88	1,22	0.0012
Mon vs Fri @ PM @ Hand-held	37.95	1,22	0.0000
Tue vs Fri @ PM @ Hand-held	5.31	1,22	0.0310
Wed vs Thu @ PM @ Hand-held	4.28	1,22	0.0506
Wed vs Fri @ PM @ Hand-held	19.80	1,22	0.0002
Thu vs Fri @ PM @ Hand-held	12.65	1,22	0.0018

APPENDIX F

Six-letter search			
% Correct			
Contrasts	**F**	**df**	**p**
Mon vs Tue	6.46	1,22	0.0186
Mon vs Wed	9.69	1,22	0.0051
Mon vs Thu	20.66	1,22	0.0002
Mon vs Fri	24.75	1,22	0.0001
Tue vs Thu	14.04	1,22	0.0011
Tue vs Fri	13.71	1,22	0.0012
Wed vs Thu	5.03	1,22	0.0353
Mon vs Thu @ AM	12.18	1,22	0.0021
Mon vs Fri @ AM	17.26	1,22	0.0004
Tue vs Thu @ AM	4.42	1,22	0.0471
Tue vs Fri @ AM	9.04	1,22	0.0065
Wed vs Thu @ AM	6.17	1,22	0.0211
Wed vs Fri @ AM	10.68	1,22	0.0035
Mon vs Wed @ PM	14.77	1,22	0.0009
Mon vs Thu @ PM	11.35	1,22	0.0028
Mon vs Fri @ PM	8.82	1,22	0.0071
Tue vs Wed @ PM	6.97	1,22	0.0149
Tue vs Thu @ PM	13.74	1,22	0.0012

Six-letter search			
Reaction time for correct responses			
Contrasts	**F**	**df**	**p**
Mon vs Tue	17.39	1,21	0.0004
Mon vs Wed	6.17	1,21	0.0215
Tue vs Thu	15.67	1,21	0.0007
Wed vs Thu	13.13	1,21	0.0016
Thu vs Fri	15.31	1,21	0.0008
Mon vs Tue @ AM	18.80	1,21	0.0003
Mon vs Wed @ AM	13.57	1,21	0.0014
Tue vs Thu @ AM	11.58	1,21	0.0027
Wed vs Thu @ AM	26.30	1,21	0.0000
Wed vs Fri @ AM	7.12	1,21	0.0144
Thu vs Fri @ AM	11.91	1,21	0.0024
Mon vs Tue @ Desktop	15.72	1,21	0.0007
Mon vs Wed @ Desktop	6.23	1,21	0.0209
Tue vs Thu @ Desktop	23.98	1,21	0.0001
Tue vs Fri @ Desktop	5.31	1,21	0.0315
Wed vs Thu @ Desktop	16.31	1,21	0.0006
Wed vs Fri @ Desktop	5.54	1,21	0.0284
Thu vs Fri @ Desktop	22.22	1,21	0.0001
Mon vs Tue @ AM @ Desktop	10.94	1,21	0.0034
Mon vs Wed @ AM @ Desktop	11.33	1,21	0.0029
Tue vs Thu @ AM @ Desktop	13.33	1,21	0.0015
Wed vs Thu @ AM @ Desktop	25.85	1,21	0.0000
Wed vs Fri @ AM @ Desktop	4.49	1,21	0.0463
Thu vs Fri @ AM @ Desktop	21.71	1,21	0.0001
Mon vs Tue @ PM @ Desktop	5.57	1,21	0.0280
Tue vs Thu @ PM @ Desktop	12.16	1,21	0.0022
Tue vs Fri @ PM @ Desktop	16.28	1,21	0.0006
Mon vs Wed @ AM @ Hand-held	6.10	1,21	0.0222
Tue vs Wed @ AM @ Hand-held	5.17	1,21	0.0336
Wed vs Thu @ AM @ Hand-held	15.85	1,21	0.0007
Wed vs Fri @ AM @ Hand-held	5.21	1,21	0.0329

Six-letter search			
Throughput			
Contrasts	**F**	**df**	**p**
Mon vs Tue	6.51	1,21	0.0186
Tue vs Thu	13.22	1,21	0.0015
Wed vs Thu	12.07	1,21	0.0023
Thu vs Fri	16.68	1,21	0.0005
Mon vs Tue @ Desktop	23.93	1,21	0.0001
Tue vs Thu @ Desktop	19.90	1,21	0.0002
Tue vs Fri @ Desktop	8.57	1,21	0.0080
Wed vs Thu @ Desktop	12.62	1,21	0.0019
Wed vs Fri @ Desktop	6.23	1,21	0.0209
Thu vs Fri @ Desktop	28.22	1,21	0.0000
Mon vs Tue @ AM	13.68	1,21	0.0013
Mon vs Wed @ AM	9.85	1,21	0.0050
Tue vs Thu @ AM	9.01	1,21	0.0068
Wed vs Thu @ AM	20.08	1,21	0.0002
Wed vs Fri @ AM	7.86	1,21	0.0106
Thu vs Fri @ AM	11.60	1,21	0.0027