Journal of Gerontology: PSYCHOLOGICAL SCIENCES
2000, Vol. 55B, No. 6, P343–P353

Age-Related Effects of Blocked and Random Practice Schedules on Learning a New Technology

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Computer technology is pervasive in today's society. Issues of training must be investigated to ensure that older individuals are capable of interacting with such technology. In the present research a simulated automatic teller machine (ATM) served as a prototypical technology for which issues of training and transfer could be investigated. The focus of the study was on the potential benefits of a random practice schedule (wherein trial types are intermixed) relative to a blocked practice schedule (wherein trial types are grouped together). Both younger and older adults benefited from random practice for the acquisition of the ability to perform transactions on an ATM. Moreover, random practice was beneficial for both age groups in the transfer of learning to novel tasks on a novel ATM. These data have general implications for theories of training and specific implications for the development of training protocols for older adults and new technologies.

THE requirement to learn to use new technologies is becoming pervasive in the lives of adults, young and old. For example, computer systems of various forms are prevalent in nearly every aspect of our lives, including videocassette recorders, computerized library catalogs, electronic banking, information kiosks, multifunction answering machines, ad infinitum.

A recent report by Rogers, Meyer, Walker, and Fisk (1998) revealed that older individuals are faced with this wide range of new technologies on a daily basis. A task facing the field of gerontology is to develop training tools to improve the accessibility of technology for older individuals. The cognitive and perceptual capabilities of a particular user group might necessitate age-specific training protocols (e.g., Mead & Fisk, 1998). Moreover, studying training benefits for different user populations within the context of a technology system offers a proving ground for general theories of training and transfer.

The context in which information is acquired has proved to be an important variable influencing learning. For example, the order in which training materials are presented to the learner, referred to as the practice schedule, influences how well information is learned. A massed practice schedule involves repeated presentations of a task with little or no delay between the presentations, whereas a distributed practice schedule provides a delay between each presentation of the task (i.e., spacing). For training programs comprising more than one task, the practice schedule is referred to as a blocked or random practice schedule based on task order, rather than on task spacing. A blocked practice schedule is analogous to a massed practice schedule, where the learner practices the first task repeatedly, then the second, and so on. A random practice schedule is analogous to a distributed practice schedule, where the learner practices the tasks in a pseudo-random order such that each task is not practiced consecutively. The spacing between task repetitions in a distributed schedule is filled by other tasks in a random practice schedule.

Practice schedules have been shown to affect the acquisition and transfer of training materials (Shea & Morgan, 1979). The basic finding is that blocked practice may yield better performance initially, but random practice is more beneficial when transfer to another task is required or when learning must be retained across intervals of time. Practice schedule effects were initially observed for learning lists of words (Hintzman, 1976; Underwood, 1961) and for movement control tasks (for a review see Adams, 1987). These patterns from the verbal and movement control learning literature have also been observed in the cognitive problem-solving domain of learning logical reasoning (e.g., Carlson & Yaure, 1990).

Battig (1979) attributed the effects of practice schedules to the contextual interference effect (see also Shea & Morgan, 1979). A blocked practice schedule has low contextual interference, and a random practice schedule has high contextual interference. Battig studied word list learning and posited that items in a list were subjected to a varying amount of interference from other items in the list. If the amount of interference was low, very little processing was required to remember the items; thus, they were learned relatively quickly but at a shallow level. If the amount of interference was high, more processing was required to remember them. This processing was more difficult, led to deeper learning, and ultimately to better transfer.

Carlson and Yaure (1990) demonstrated that there were other ways of procuring the benefits of random practice. When participants had to make same/different judgments for upper and lower case letters or verify the answer to an addition problem between trials of a blocked practice schedule, they performed as well on transfer tasks as participants who had a random practice schedule. These two tasks were chosen because they were sufficient to remove the original task procedure from working memory. Two other tasks that did not tax working memory did not affect transfer. Carlson and Yaure (1990) suggested that it is the continuous reloading of procedures into working memory in a random practice schedule that facilitates transfer. Reloading refers to the reactivation of items in memory needed to perform the task. They theorized that this reloading is one locus of the contextual interference effect.

The study of individual differences also provides some information about the way practice schedules affect learning. Mumford, Costanza, Baughman, Threlfall, and Fleishman (1994) provided evidence for the idea that distributed practice provides deep level processing, thereby allowing an individual to bring cognitive abilities to bear in the formation of well-organized knowledge structures. In their study, participants either massed or distributed their practice for controlling a simulated milk pasteurizing plant, a highly visual task. Participants who had high spatial visualization abilities did better with distributed practice, whereas low spatial ability participants did better with massed practice.

The explanation for Mumford and associates' (1994) results was that spatial abilities facilitate the development of knowledge structures. Distributed practice allows a deeper level of processing than massed practice; thus, participants with higher levels of ability were better able to develop knowledge structures using distributed practice. Mumford and colleagues also reported that performance was worse for high-ability participants who received massed practice, and low-ability participants who received distributed practice. These data suggest the importance of matching practice schedules to abilities.

An individual difference variable that might relate to benefits of a random practice schedule is working memory. The theoretical explanation for benefits of random practice is that this type of practice schedule requires the learner to reload the task procedure into working memory on every trial (Carlson & Yaure, 1990). What happens if working memory capacity is reduced or diminished? The benefits of random practice may be reduced if an individual has difficulty loading information into working memory or is more susceptible to interference from competing information in working memory. This idea is particularly germane to understanding benefits of random practice schedules for older adults. One of the most well-documented cognitive changes that accompanies old age is a decline in working memory (Salthouse, 1990). In addition, there is some suggestion that older individuals have difficulty in task switching (e.g., Salthouse, Fristoe, McGuthry, & Hambrick, 1998) or inhibiting information that is no longer relevant (Hasher & Zacks, 1988). Processing needed to benefit from random practice schedules can tax these cognitive abilities that show age-related declines. Thus, older adults may benefit less from random practice than do younger adults.

Few experiments have studied practice schedule effects for older adults. A study by Del Rey (1982) found that blocked practice yielded better acquisition for elderly women on a movement control task. However, if the participants maintained a high level of physical activity in their lives, they were able to benefit from a random practice schedule, whereas low activity-level participants did not benefit significantly from a random practice schedule. Thus, the random practice schedule effects were moderated by individual differences in levels of physical activity, which may be related to cognitive abilities such as working memory (Hawkins, Kramer, & Capaldi, 1992).

Kausler, Wiley, and Phillips (1990) also assessed the effects of practice schedules for older adults. In their study, participants were asked to perform a set of 16 simple motor tasks with a massed or distributed practice schedule, then asked to recall the tasks they had performed. Although younger adults recalled more tasks than the older adults, distributed practice facilitated recall better than massed practice for both age groups.

The Kausler and associates (1990) and Del Rey (1982) studies provide limited evidence that random practice can facilitate the performance and recall of movement control tasks by older adults. However, it is not clear if practice schedules affect older adults for more cognitively demanding tasks. It is possible that the greater working memory requirements for such tasks would expose differential effects of practice schedules for older and younger adults.

Overview of Experiment

This research focused on two primary questions. The first was whether a random practice schedule would be beneficial for individuals learning to use a novel technology, as it has been shown to benefit movement control, list learning, and cognitive problem solving. The second question was whether older adults would be able to benefit from a random practice schedule, given the working memory declines that typically accompany aging. It was conceivable that older adults would benefit more from blocked practice, which would allow them to learn the task components without having to repeatedly load the appropriate procedures into working memory. However, blocked practice typically yields more shallow learning, and thus performance benefits might not carry over to a transfer condition. Thus, the overall purpose of the experiment was to determine which type of practice schedule was best for novice ATM users, as well as if there was an Age by Practice Schedule interaction.

The effects of blocked and random practice schedules for older and younger adults were assessed using a simulation of an automatic teller machine (ATM). Using an ATM is a relatively complex task, particularly for those older adults for whom the system characteristics are unfamiliar. The system is hierarchically structured, is dynamic and interactive, and task success is dependent on completing multiple steps. However, ATM performance does benefit from training (Adams & Thieben, 1991; Mead & Fisk, 1998; Rogers, Fisk, Mead, Walker, & Cabrera, 1996). ATM use represents a real world task with which many older adults may have difficulty (Hatta & Iiyama, 1991), yet in which they show interest. Older adults have expressed willingness to learn to use ATMs if training were provided (Rogers, Cabrera, Walker, Gilbert, & Fisk, 1996).

The goal of the experiment was to determine the relative benefits of a blocked versus a random practice schedule for younger and older adults learning to use a simulated ATM. All participants received some initial instructions on how to use the ATM simulator because older adults were unable to perform the task correctly without instruction (Rogers, Fisk, et al., 1996). In the acquisition phase, participants practiced performing transactions on the ATM simulator using one of the two schedules. In the transfer phase, participants performed novel transactions in a random practice schedule. A random practice schedule was used to help ensure that the effects of the practice schedules during acquisition were made apparent at transfer by presenting the task set in its most difficult form. It was also considered more representative of the way an ATM would be used outside the laboratory (i.e., in the "real world").

The practice schedule effects for young adults reported by Carlson and his colleagues (Carlson & Shin, 1996; Carlson & Yaure, 1990) were expected to generalize to the present experiment. That is, the blocked practice schedule should yield better performance during acquisition, but the random practice schedule should yield better transfer performance.

For the older adults, there were two possibilities. First, their pattern of practice schedule effects could mimic the young adults. Both Del Rey (1982) and Kausler and colleagues (1990) demonstrated that older adults have the potential to benefit from a random practice schedule. However, the high contextual interference (random) schedule for the ATM simulator tasks might provide too much interference, overloading the working memory capacity of older adults. Thus, there was also the possibility that older adults would perform best with a blocked practice schedule both during acquisition and during transfer.

Table 1. Demographic, Ability, and Computer Use Data (Means and Standard Deviations)

Variable	Blocked Practice	Random Practice
Younger adults		
Age	18.7 (.80)	20.1 (2.93)
Education[a]	3.9 (.67)	3.9 (.37)
Health[b]	4.7 (1.34)	5.6 (.50)
Vocabulary[c]	20.6 (6.19)	18.5 (6.37)
Digit symbol substitution[d]	66.5 (12.03)	67.3 (9.25)
Alphabet span[e]	38.6 (10.90)	38.6 (14.21)
Reading comprehension[f]	33.25 (4.53)	32.3 (4.06)
Computer experience[g]	4.05 (1.36)	4.60 (1.23)
Computer use[h]	5.95 (1.50)	5.65 (1.39)
Older adults		
Age	69.4 (5.74)	69.4 (5.76)
Education[a]	5.1 (1.85)	4.8 (1.47)
Health[b]	5.0 (.79)	5.0 (.89)
Vocabulary[c]	31.4 (10.48)	28.0 (10.09)
Digit symbol substitution[d]	49.1 (10.39)	48.4 (8.86)
Alphabet span[e]	26.2 (9.91)	25.4 (10.82)
Reading comprehension[f]	22.4 (8.34)	21.4 (10.39)
Computer experience[g]	2.06 (1.44)	2.53 (1.54)
Computer use[h]	2.15 (1.79)	3.05 (2.93)

[a]1 = No high school, 5 = college graduate, 8 = doctoral degree.
[b]1 = poor, 6 = excellent.
[c]Ekstrom et al. (1976); score is number correct.
[d]Wechsler (1981); score is number correct.
[e]Craik (1986); score is absolute span (see LaPointe & Engle, 1990).
[f]Brown, Fishco, & Hanna (1993); score is number correct.
[g]"I have experience using computers"; Scale was 1 (strong disagreement) to 6 (strong agreement).
[h]How often used computers; Scale was 1 (never) to 4 (once per month) to 8 (once per day).

Methods

Participants

Participants were 40 younger adults, ranging in age from 18 to 25, and 40 older adults, ranging in age from 60 to 80 (see Table 1). One half of each age group was randomly assigned to each of the two experimental conditions (described below). Younger participants received course credit for their participation. Older participants were recruited from the community and received \$65 for their participation. All participants were screened before testing to ensure that they had never used an ATM. All participants had corrected or uncorrected vision of at least 20/40 for both near and far vision. They were also screened by questionnaire for medications affecting attention (based on Giambra & Quilter, 1988).

All participants were administered the following ability tests: the Extended Range Vocabulary Test (Ekstrom, French, Harman, & Dermen, 1976), the Digit Symbol Substitution Test (Wechsler, 1981), the Alphabet Span Test (Craik, 1986), and the Nelson-Denny Reading Test (Brown, Fishco, & Hanna, 1993). These tests were administered to ensure that the experimental groups were comparable. The demographic and ability data are presented in Table 1. The younger adults had higher scores than the older adults for digit symbol substitution $t(78) = 8.06$, $p < .001$; alphabet span, $t(78) = 5.00$, $p < .001$; and reading comprehension $t(78) = 6.71$, $p < .001$. The older adults had higher vocabulary scores than the younger adults, $t(78) = -5.32$, $p < .001$. Independent samples *t* tests within each age group revealed no significant differences in the older adult sample across the experimental conditions for age, education, health ratings, or ability test scores (all *p*s $> .30$). For the younger adult sample, the random practice group reported significantly higher health ratings than the blocked practice group, $t(39) = -2.81$, $p < .01$, but age, education, and ability test scores were not significantly different (all *p*s $> .05$).

Participants' general computer experience was also assessed (see Table 1). An analysis of variance (ANOVA) showed that self-reported computer experience was higher for younger adults than older adults, $F(1,71) = 39.61$, $MSE = 1.94$, $p < .001$, but no effect of practice schedule condition ($p = .12$) or an age by practice schedule interaction ($p = .89$). Frequency of computer use was also higher for younger adults than older adults, $F(1,71) = 51.37$, $MSE = 3.99$, $p < .001$, but did not differ for practice schedule condition ($p = .50$) nor did the age effect interact with practice schedule condition ($p = .18$).

Apparatus

A computer-simulated automatic teller machine (ATM1) was designed to emulate the ATM of a particular bank, having all of the standard features and options of the majority of ATMs (Figure 1). Five different types of transactions could be performed on the simulator: fast cash, withdrawal, deposit, transfer, and account information. All of these transactions are available on ATMs currently in use. A sec-

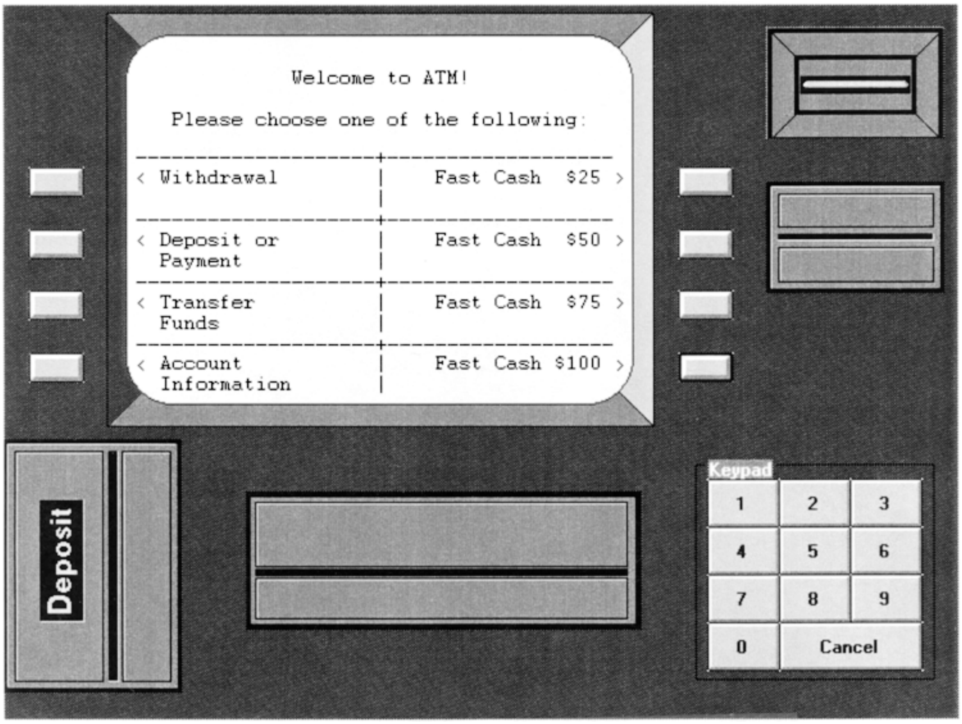

Figure 1. Illustration of the first screen of automatic teller machine simulator version 1 (ATM1). This simulator was modeled after an existing ATM. The background screen was gray and the menu options text was green.

ond ATM simulator (ATM2) was designed to test transfer of learning (Figure 2). ATM2 contained the same features as ATM1, but the surface layout of the features was different. In addition to the surface changes, ATM2 offered additional options that were not available on ATM1, including the option to buy tickets for a concert, check the gold exchange, and buy lottery tickets.

The simulated ATMs required the use of a computer mouse to perform the transactions. The position of the mouse on the computer screen appeared as a hand with the index finger extended. Participants had to move the mouse so that the finger was pointing to the command button or number on the keypad that they wanted to push and then click the mouse. Mouse training was provided to ensure that everyone was familiar with using a computer mouse before they used the mouse for the simulated ATM. Participants performed a minimum of 480 mouse actions (more if mistakes were made) during the mouse training. These actions involved entering number sequences on a number pad identical to the one in the ATM simulator, and clicking on a series of buttons that appeared at random locations on the screen.

A single transaction on the ATM simulator consisted of the following events. Participants were presented with a text window displaying the transaction to be completed. They clicked on the text window to dismiss it and prompt the appearance of their card at the slot. They were able to display the text window at any time by pressing the H (help) key on the keyboard. Participants clicked on the card to insert it, then entered their personal identification number (PIN; always 1 2 3 4) on the keypad. They then completed the transaction by clicking on the appropriate buttons and objects, such as cash and receipts. Upon completion of the task, participants pressed the F (finished) key to indicate they were finished. This brought up a text window with their next transaction.

Initial Instruction

Participants were first shown how to use the simulator. They were also provided with a general description of how ATMs work (Rogers, Fisk, et al., 1996). Participants read the description, then were given step-by-step instructions for performing each component of the transactions. A standard protocol was used to give the initial instructions. The experimenter explained the procedure for completing each task component, such as entering the PIN, and observed the participants as they carried it out. Participants went through three different transactions: fast cash, withdrawal, and deposit. These three transactions were chosen because they include all of the components of the five transactions available on the ATM1 simulator (such as menu item selection, using the deposit window, account selection, and taking cash, receipt, and card). Participants were allowed to ask any questions they had about the instructions, and were told that they could take as much time as they wanted to perform the transactions. All participants successfully completed the three transactions.

Procedure

Participants were randomly assigned to one of two practice-schedule groups: blocked practice or random practice.

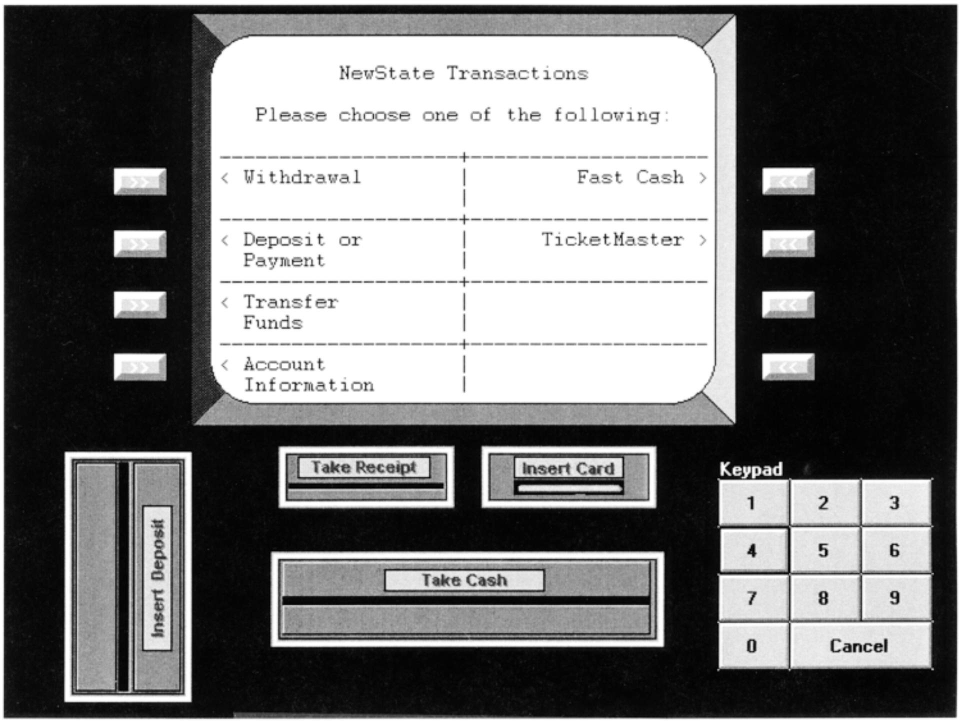

Figure 2. Illustration of the first screen of automatic teller machine simulator version 2 (ATM2). This simulator differed from ATM1 in several ways: different menu structure, options that were not available on ATM1, different surface layout, and the background screen was blue with yellow menu options text.

In the blocked practice schedule, participants performed five consecutive transactions of the same type in one set (see Table 2). For example, a person might be presented with five fast cash transactions in one set, then five withdrawal transactions in the next set, and so on. In the random practice schedule, participants performed five different transactions in a set (i.e., fast cash, withdrawal, transfer, deposit, and account information). The order of transactions was counterbalanced across participants using a partial Latin square.

The experiment was divided into three phases: acquisition, near transfer, and far transfer. The acquisition phase consisted of 10 sets of 5 transactions each, resulting in a total of 50 transactions (as illustrated in Table 2). The acquisition transactions were performed on ATM1. Each transfer phase consisted of one set of five transactions. Sample transactions for each phase are presented in Table 3. The transactions were presented in a random practice schedule for transfer for all participants. Due to the limited number of transactions in the transfer conditions, all participants received them in the same order. Transfer transactions were performed on ATM2. The near transfer set comprised transactions that participants had already been exposed to during acquisition. The far transfer set consisted of novel transactions.

Participants completed the experiment in two sessions, one on each of two consecutive days. The first session comprised the vision test, consent form, medication form, abilities tests, and the mouse tutor. The second session consisted of the acquisition and transfer phases. (Initially there were three sessions, with the last 25 acquisition trials and the transfer phases being completed on the third day. However, it was noted that participants were completing session 2 very quickly, so sessions 2 and 3 were combined. Two participants from each condition were run on the three-session schedule.)

Results

Accuracy performance was measured using a multiple component correct variable. A transaction was considered correct if the participant met all of the following conditions:

Table 2. Sample Order of Transactions for Blocked and Random Practice Schedules During Acquisition

	Transaction Set									
Schedule	1	2	3	4	5	6	7	8	9	10
Blocked	FFFFF	WWWWW	DDDDD	TTTTT	AAAAA	FFFFF	WWWWW	DDDDD	TTTTT	AAAAA
Random	FWDTA	WDTAF	DTAFW	TAFWD	AFWDT	FWDTA	WDTAF	DTAFW	TAFWD	AFWDT

Notes: F = fast cash; W = withdrawal; D = deposit; T = transfer; A = account information; order was counterbalanced across participants using a partial Latin square.

Table 3. Sample Transactions

Experiment Phase	Simulator	Sample Transaction
Acquisition[a]	ATM1	Withdraw $25 using Fast Cash
		Withdraw $100 from checking
		Transfer $300 to savings from checking
		Deposit $200 cash into line of credit
		Get balance on checking
Near transfer	ATM2	Withdraw $25 using Fast Cash
		Withdraw $100 from checking
		Transfer $300 to savings from checking
		Deposit $200 cash into line of credit
		Get balance on checking
Far transfer	ATM2	Get price per ounce on gold exchange
		Buy 3 Frank Sinatra tickets with credit card
		Pay $200 on electric bill with cash
		Buy a Lotto ticket with savings
		Pay $100 cable TV bill with credit card

[a]There were 50 total transactions during acquisition.

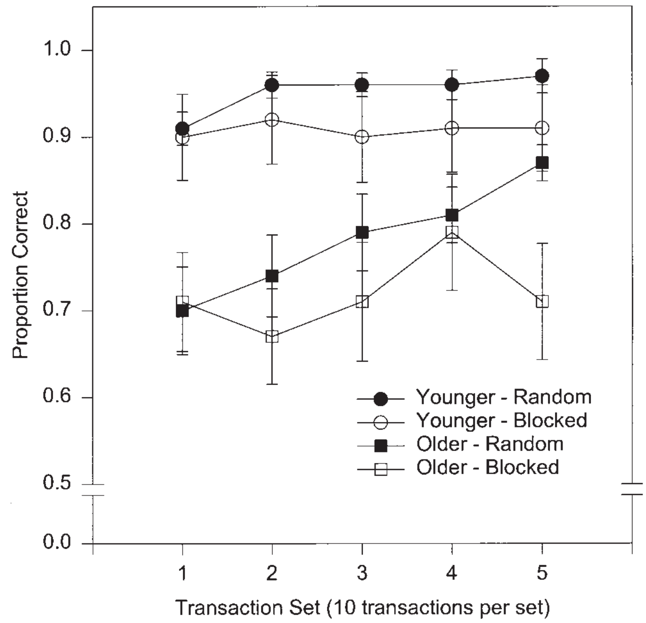

Figure 3. Mean proportion of correct transactions (with standard error bars) for older and younger adults in the blocked and random practice schedule conditions across the transaction sets of the acquisition phase.

(a) chose the appropriate menu item on each screen to perform the assigned transaction, referred to as menu navigation; (b) took their card; (c) took their receipt; and (d) took their cash when appropriate. Each of these four components was also used as a separate dependent variable, in addition to the overall correct variable. Latency for correct trials was also assessed. The latency period began when the text window displaying the task was dismissed, and ended when the participants pressed the F key to indicate they were finished. Time during which the computer was processing or the help window was displayed was excluded.

Acquisition Accuracy

The accuracy data for the acquisition phase are shown in Figure 3. The 50 acquisition transactions were divided into 5 sets of 10 transactions. Because we counterbalanced order across participants, each point in the graph represents an equal distribution of transaction types across practice schedules and age groups. A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 5 (transaction set) ANOVA was conducted using proportion correct as the dependent variable. The younger adults performed significantly better than the older adults, $F(1,76) = 20.54$, $MSE = .159$, $p < .001$. There was a significant main effect of Set, indicating improvement over Practice, $F(4,304) = 4.15$, $MSE = .001$, $p < .003$. There was also a significant Set by Age interaction, $F(4,304) = 2.51$, $MSE = .001$, $p < .042$. Follow-up ANOVAs revealed that performance improvement over transactions sets was significant for the older adults, $F(4,152) = 3.51$, $MSE = .023$, $p < .009$, but only marginally significant for the younger adults ($p = .06$). The interaction of Practice Schedule by Set was marginally significant, $F(4,304) = 2.30$, $MSE = .013$, $p = .059$. Follow-up ANOVAs for each schedule revealed that the blocked practice group showed no improvement over acquisition ($p = .42$), whereas the random practice group improved significantly, $F(4,152) = 7.22$, $MSE = .010$, $p < .001$.

One aspect to note about the data concerns the initial levels of performance. The younger adults averaged 90% correct for the first set of acquisition, and the older adults averaged 70% correct. These high levels of initial performance may have been due to the initial instructions provided to the participants and may have minimized somewhat the benefits of the practice schedules.

Performance for the final practice set provided an index of the cumulative benefits of the two practice schedules. At Set 5 the younger adults were performing significantly more transactions correctly than the older adults, $F(1,76) = 11.53$, $MSE = .039$, $p < .001$, and there was also a main effect of Practice Schedule, $F(1,76) = 5.65$, $MSE = .039$, $p < .02$, such that the random practice schedule group was performing significantly better than the blocked practice group. The Age by Practice Schedule interaction was not significant ($p = .27$). These data suggest that random practice on the ATM was more effective than blocked practice for both age groups.

Component Analyses

To further elucidate the acquisition benefits for the random practice schedule, analyses were conducted for the four component variables that composed the overall correct variable. A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 5 (transaction set) ANOVA was conducted using proportion correct for each component dependent variable, except as noted below for the "took cash" component. These data are presented in Table 4.

Menu navigation.—The menu navigation variable represented whether the participant made the correct menu selections for a transaction. A similar pattern of effects over acquisition was observed as for the overall correct variable. Significant main effects of Age, $F(1,76) = 50.66$, $MSE = .052$, $p < .001$, and Set, $F(4,304) = 6.71$, $MSE = .011$, $p <$

Table 4. Acquisition Accuracy Data for the Component Analyses (Means and Standard Deviations)

Variable	Transaction Set 1	2	3	4	5
Younger adults					
Menu navigation					
Blocked	.96 (.06)	.98 (.07)	.96 (.09)	.97 (.07)	.96 (.06)
Random	.91 (.09)	.96 (.07)	.96 (.06)	.96 (.08)	.97 (.07)
Took card					
Blocked	.94 (.22)	.95 (.22)	.95 (.22)	.95 (.22)	.95 (.22)
Random	1.00 (.00)	1.00 (.00)	1.00 (.00)	1.00 (.02)	1.00 (.02)
Took receipt					
Blocked	1.00 (.02)	1.00 (.02)	.99 (.04)	.99 (.05)	1.00 (.01)
Random	.99 (.03)	1.00 (.00)	.99 (.03)	1.00 (.00)	1.00 (.02)
Older adults					
Menu navigation					
Blocked	.74 (.24)	.74 (.20)	.77 (.24)	.86 (.16)	.80 (.18)
Random	.73 (.21)	.78 (.17)	.82 (.17)	.85 (.14)	.89 (.10)
Took card					
Blocked	.96 (.11)	.93 (.19)	.91 (.26)	.90 (.29)	.90 (.31)
Random	.96 (.12)	.95 (.18)	.97 (.12)	.97 (.08)	.98 (.06)
Took receipt					
Blocked	1.00 (.02)	.97 (.07)	.95 (.16)	.94 (.22)	.94 (.22)
Random	.92 (.11)	.96 (.11)	.96 (.06)	.97 (.06)	.98 (.05)

.001, were qualified by the Age by Set interaction, $F(4,304) = 3.54$, $MSE = .011$, $p < .008$. The older adults showed significant improvement over the transaction sets, whereas the younger adults showed only marginally significant improvement. An ANOVA for Set 5 showed a similar pattern, with younger adults performing better than older adults, $F(1,76) = 23.34$, $MSE = .013$, $p < .001$, and participants in the random practice groups making more correct menu selections than those in the blocked practice groups, $F(1,76) = 4.29$, $MSE = .013$, $p < .04$. There was a marginally significant interaction of Age and Practice Schedule, $F(1,76) = 2.81$, $MSE = .013$, $p = .098$. Follow-up analyses showed that the random practice group was significantly better than the blocked practice group for the older adults, $F(1,38) = 4.25$, $MSE = .021$, $p < .046$, but the difference was not significant for the younger adults ($p = .639$). The results for menu navigation follow the same general pattern as the results for the correct variable, suggesting that navigating in the menu hierarchy is at least partly the locus of the practice schedule effects in this task.

Took card.—Another component of the overall correct variable was whether participants remembered to take their card following completion of each transaction. The ANOVA revealed only a significant Age by Set by Practice Schedule interaction, $F(4,304) = 2.53$, $MSE = .004$, $p < .041$. For the younger adults, the random practice group's performance was stable across practice. On the contrary, for the older adults, the random practice group's performance increased across practice.

Took receipt.—The receipt component represents whether participants remembered to take their receipt at the end of the transaction. The ANOVA yielded a main effect of Age, $F(1,76) = 5.31$, $MSE = .026$, $p < .024$, with younger adults more likely to remember to take their receipt than the older adults. There was also a significant Set by Practice Schedule interaction, $F(4,304) = 3.29$, $MSE = .004$, $p < .012$, and a marginally significant Age by Set by Practice Schedule interaction, $F(4,304) = 2.30$, $MSE = .004$, $p < .059$. Remembering to take the receipt was stable across practice for both younger adult practice schedule groups. For the older adults, the blocked practice group's performance declined, whereas the random practice group's performance improved.

Took cash.—The remaining component of the overall correct variable was the cash variable. Because only two of the five transactions required cash to be taken, these data were analyzed by dividing acquisition into the first and last 25 transactions. A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 2 (transaction half) ANOVA revealed that the only significant effect for the cash variable was a main effect of Age. The younger adults ($M = .99$, $SD = .025$) took their cash significantly more often than the older adults, ($M = .93$, $SD = .153$, $F(1,72) = 7.85$, $MSE = .022$, $p < .007$. No differences for the practice schedule groups were significant (all p's $> .33$).

The analyses of the component variables show that the benefits of random practice were evident for menu navigation as well as for the consistent components of remembering to take one's card and receipt (which were the same for every transaction). The benefits of random practice for the component measures were more evident for the older adults, perhaps due to the high performance levels observed for both groups of young adults. However, random practice benefits were observed for the young adults in the more stringent, overall correct measure.

Acquisition Latency

The mean length of time required to correctly complete each set of transactions is displayed in seconds in Figure 4. A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 5 (transaction set) ANOVA was done using latency as the dependent variable. Some data were missing for the latency analyses because latencies were for correct trials only. If a participant did not get any of the transactions correct for a set of trials, they would be missing latency data for that set. Main effects were found for Set, $F(4,288) = 23.23$, $MSE = 2.9E + 9$, $p < .001$, and Age, $F(1,72) = 110.97$, $MSE = 1.3E + 9$, $p < .001$. All participant response times decreased over the acquisition sets, and the younger adults were faster overall than the older adults. A Set by Age interaction was found, $F(4,288) = 7.51$, $MSE = 2.9E + 9$, $p < .001$, where the older adults' response times decreased more than the younger adults'. A Set by Practice Schedule interaction was also found, $F(4,288) = 2,48$, $MSE = 2.9E + 9$, $p < .044$. The random practice groups' response times decreased more than the blocked practice groups'.

Latency data for the final set of practice (Set 5) were analyzed to assess differences in performance at the end of practice. The younger adults were performing significantly

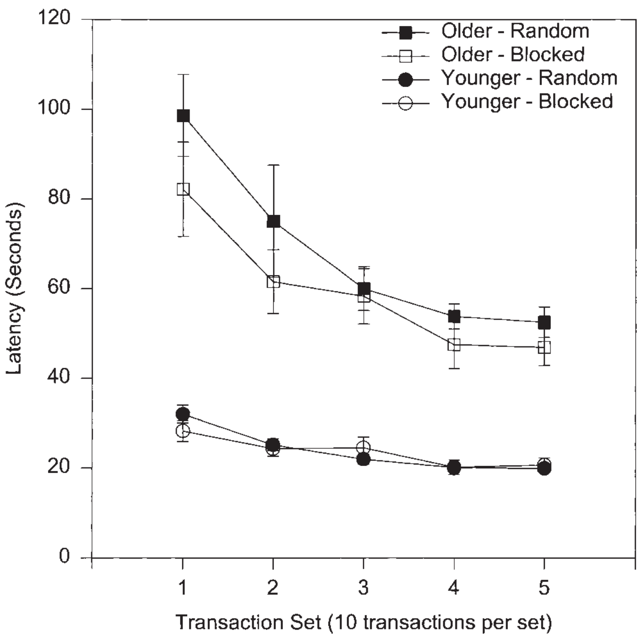

Figure 4. Mean latencies (with standard error bars) for older and younger adults in the blocked and random practice schedule conditions across the transaction sets of the acquisition phase.

faster than the older adults, $F(1,76) = 114.48$, $MSE = 1.72E + 10$, $p < .001$). However, the effect of practice schedule was not significant ($p = .38$), nor was the Age by Practice Schedule interaction ($p = .26$). Thus, both the blocked and random practice groups were responding at similar rates at the end of practice. As such, the accuracy benefits observed for the random practice groups cannot be attributed to a speed/accuracy tradeoff.

Transfer Accuracy

All participants performed five transactions on ATM1 during the near transfer phase, and five transactions on ATM2 in the far transfer phase of the experiment. Near transfer consisted of transactions that had been performed during the acquisition phase, and far transfer consisted of novel transactions. A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 2 (near or far transfer) ANOVA was computed with proportion of correct transactions as the dependent variable (see Table 5). Younger adults were more accurate than older adults, $F(1,76) = 19.76$, $MSE = 8.92E\text{-}02$, $p < .001$, and performance was more accurate for the near transfer condition relative to the far transfer condition, $F(1,76) = 8.72$, $MSE = 2.93E\text{-}02$, $p < .004$. The transfer condition effect interacted with age, $F(1,76) = 5.76$, $MSE = 2.93E\text{-}02$, $p < .019$. Follow-up analyses revealed that the difference between near and far transfer performance was significant only for the older adults, $t(39) = 3.83$, $p < .001$.

A primary question of interest for the transfer data was whether there was a significant difference in performance for participants who had been trained with the random practice schedule groups relative to the blocked practice schedule. The main effect of practice schedule was significant,

Table 5. Transfer Data for Overall Accuracy, Component Accuracy, and Latencies (Means and Standard Deviations)

Variable	Near Transfer	Far Transfer
Younger adults		
Overall		
Blocked	.81 (.24)	.76 (.29)
Random	.88 (.12)	.90 (.19)
Menu navigation		
Blocked	.86 (.15)	.80 (.23)
Random	.88 (.12)	.90 (.19)
Took card		
Blocked	.95 (.22)	.96 (.18)
Random	1.00 (0)	1.00 (0)
Took receipt		
Blocked	1.00 (0)	.94 (.13)
Random	1.00 (0)	.98 (.06)
Latency		
Blocked	23.59 (2.75)	44.51 (8.36)
Random	24.27 (4.47)	46.59 (10.72)
Older adults		
Overall		
Blocked	.66 (.28)	.51 (.30)
Random	.74 (.21)	.60 (.26)
Menu navigation		
Blocked	.75 (.22)	.56 (.26)
Random	.75 (.20)	.61 (.26)
Took card		
Blocked	.93 (.22)	.90 (.31)
Random	.99 (.04)	.95 (.14)
Took receipt		
Blocked	.95 (.18)	.91 (.24)
Random	1.00 (0)	.94 (.11)
Latency		
Blocked	52.64 (15.55)	88.55 (29.10)
Random	65.94 (41.23)	98.21 (28.03)

$F(1,76) = 4.04$, $MSE = 8.92E\text{-}02$, $p < .048$, and did not interact with age ($p = .83$) or transfer condition ($p = .46$). In all cases, the random practice schedule groups outperformed the blocked practice schedule groups.

Comparisons of absolute performance levels for the near and far transfer conditions provide an indication of how well participants could complete transactions on an unfamiliar ATM. These comparisons reveal benefits of having had random practice. To further evaluate training effects, it is also possible to compute an estimate that represents the percentage of transfer. Given the nature of our task, and the fact that a maximum performance level could be estimated, we used the following equation recommended by Roscoe (1980), adapted from Gagne, Foster, and Crowley (1948):

$$\text{Percentage of transfer} = \frac{\text{LR} - \text{LB}}{\text{T} - \text{LB}} \times 100,$$

where

LR = level of performance for the random practice group,
LB = level of performance for the blocked practice group,
T = total possible score on the task (in the case of accuracy, 100).

This equation represents the percentage of total possible performance for one group relative to another. Percentage transfer directly compares the performance of the random group relative to the performance of the blocked group. When we computed these scores for the young and older adults, near and far transfer, in each case the percentage was positive, indicating a benefit for the random practice schedule group. For young adults, the percentage transfer was 37% for the near transfer and 58% for the far transfer. For older adults, the percentage transfer was 24% for the near transfer and 18% for the far transfer.

Component Analyses

The components of the correct variable were also analyzed in the transfer phase (see Table 5). A 2 (older or younger adults) by 2 (blocked or random practice schedule) by 2 (near or far transfer) ANOVA was done using proportion correct for each component dependent variable. No cash was available in any of the far transfer transactions, so it was not possible to make comparisons for that component.

Menu navigation.—For menu navigation there were main effects of Age, $F(1,76) = 26.30$, $MSE = 6.64\text{E-}02$, $p < .001$, because the younger adults made more correct menu selections than the older adults, and Transfer Condition, $F(1,76) = 10.74$, $MSE = 3.19\text{E-}02$, $p < .002$, because more correct menu selections were made in the near transfer condition than in the far transfer condition. There was also an Age by Transfer Condition interaction, $F(1,76) = 6.60$, $MSE = 3.19\text{E-}02$, $p < .012$. Follow-up analyses revealed that the difference between the near and far conditions was significant only for the older adults, $F(1,38) = 15.88$, $MSE = 3.43\text{E-}02$, $p < .001$.

Took card.—For the card component there was a marginally significant main effect of Transfer Condition, $F(1,76) = 3.20$, $MSE = 2.82\text{E-}03$, $p = .078$, indicating that the card was taken more often in the near transfer condition. There was also a significant Age by Transfer Condition interaction, $F(1,76) = 5.68$, $MSE = 2.82\text{E-}03$, $p < .02$. The older adults took their card significantly more often in the near transfer condition than in the far transfer condition, $F(1,38) = 4.77$, $MSE = 5.13\text{E-}03$, $p < .035$, but this difference was not significant for younger adults ($p = .32$).

Took receipt.—For the receipt component there was a main effect of Transfer Condition, $F(1,76) = 13.15$, $MSE = 6.16\text{E-}03$, $p < .001$. All participants were more likely to remember to take their receipt in the near transfer condition relative to far transfer.

The main effect of Practice Schedule was not significant, nor did it interact with either Age or Transfer Condition, for any of the component variables (all ps $> .10$). However, the overall correct variable, which was the most stringent (and hence, perhaps most sensitive to differences), did yield a significant benefit in performance for the random relative to the blocked practice schedule. Moreover, this benefit of random practice was found for both younger and older adults.

Transfer Latency

Using latency as the dependent variables, a 2 (older or younger adults) by 2 (blocked or random practice schedule) by 2 (near or far transfer) ANOVA was done. This analysis revealed that younger adults were faster than older adults, $F(1,71) = 86.26$, $MSE = 7.40\text{E} + 08$, $p < .001$, performance was faster for the near transfer condition relative to the far transfer condition, $F(1,71) = 144.05$, $MSE = 2.05\text{E+}08$, $p < .001$, and the Transfer Condition effect interacted with Age, $F(1,71) = 7.70$, $MSE = 2.05\text{E} + 08$, $p < .007$. Follow-up analyses revealed that the difference between near and far transfer performance was significant for both the younger, $t(38) = -13.88$, $p < .001$, and the older adults, $t(35) = -7.61$, $p < .001$, although the interaction was due to a larger difference for the older adults (see Table 5). There were no significant effects of practice schedule for the latency data (all ps $> .12$), which suggests that the benefits of the random practice schedule were for performance accuracy rather than speed. (Note that the percentage of transfer cannot be computed for the latency measure because the formula requires that the total performance level be specified and the fastest latency for this task is unspecified.)

Discussion

One of the goals of the current study was to assess whether a random practice schedule would be beneficial for younger and older adults learning to perform a relatively complex task with both motor and cognitive components. Consonant with the existing literature assessing practice schedule effects, we predicted that blocked practice would be superior during acquisition but that random practice would yield better performance for the transfer conditions.

An unexpected finding was the benefit of random practice during acquisition for both younger and older adults. This effect may be due to the nature of the ATM task. In the blocked practice schedule, participants were initially exposed to one path through the menu hierarchy, which they practiced for five transactions. In the random practice schedule, participants were initially exposed to all five paths through the menu hierarchy after five transactions. It has been well documented that providing a framework for organizing to-be-learned information enhances performance (Kraiger, Salas, & Cannon-Bowers, 1995; Stone, 1983). Participants in the random practice schedule may have been better able to extract the structure of the menu hierarchy and use that structure to develop a schema for the ATM task. This idea is in line with the results of Mumford and colleagues (1994), which showed that distributed practice facilitated the formation of knowledge structures, whereas massed practice did not. This would explain why the random practice groups' performance improved more over the course of acquisition than the blocked practice groups' performance. Participants in the blocked practice schedule were not presented with the menu structure in such a way that would allow for accurate schema development, and thus showed little improvement. Therefore, for a multicomponent task such as the ATM, the benefits of a random practice schedule may be due to the induction of a more complete schema for the task.

An expected finding was that older adults performed worse overall on the ATM task than the younger adults did. This is consistent with previous literature, as mentioned earlier. It is possible that older adults' performance could be further decreased by unfamiliarity with computers. Older adults reported less overall experience with computers, as well as a lower rate of using them. However, experience was comparable between the practice schedule conditions. Moreover, similar younger–older performance levels were found in a post hoc analysis. For the final set of acquisition trials, older adults' performance in the random condition was not significantly different from younger adults' performance in the blocked condition ($p = .41$; see Figure 3). This suggests that with specific types of practice, older adults may be able to overcome limited computer experience and perform as well as younger adults on a computer-based task.

In addition to the random practice schedule superiority for the overall correct variable, an interesting pattern emerged when the components of that variable were analyzed. For the older blocked practice group, the likelihood of remembering to take one's card and one's receipt at the end of the transaction actually decreased with practice. On the contrary, remembering to perform these components increased for the older random practice group. These data raise the interesting possibility that blocked practice might actually be somewhat detrimental for older learners. The mechanism for this effect is as yet unspecified. It is possible that with the blocked practice schedule the older adults were more likely to get fatigued or bored and thus forgot to perform some components of the task.

One potential concern for interpreting the results is the high level of performance seen across the acquisition trials, especially for the younger adults. This introduces the potential problem of a ceiling effect. However, post hoc analyses showed significant improvements across practice in the random condition for both the younger, $F(4,76) = 3.16$, $MSE = .003$, $p < .05$, and older, $F(4,76) = 5.24$, $MSE = .002$, $p < .05$, adults. There was no improvement in the blocked condition for the younger ($p = .81$) or the older ($p = .28$) adults, but the performance of the blocked group was *lower* than the random group. Thus, it is unlikely that a ceiling effect was restricting the improvement of the blocked group. Additionally, as reported in the Results section, there were significant reductions in latencies for all conditions over the acquisition period. Taken together, these findings suggest that a ceiling effect was not restricting the pattern of practice schedule effects during acquisition.

The transfer data were as predicted: Performance for the random practice schedule groups was superior to that of the blocked practice groups. Thus, the transfer data for the ATM task are consistent with earlier studies of random practice schedule benefits for movement control (reviewed in Adams, 1987), verbal learning (e.g., Hintzman, 1976; Underwood, 1961), and problem solving (e.g., Carlson & Yaure, 1990). Importantly, this pattern was observed for both younger and older adults. These data document the generality of the theory that random practice is superior to blocked practice when transfer of learning is required to novel task environments.

The ATM simulation used in the experiments was a novel domain for the application of practice schedules. Practice schedule effects have been demonstrated for movement control, verbal learning, and complex cognitive tasks. However, ATMs represent a real-world task that incorporates a number of different components that need to be mastered for successful performance. The results of this study have implications for the improvement of training programs for ATMs, in terms of both acquisition and transfer performance. It is also important to note that design changes in the ATM interface could be paired with training techniques to further enhance performance (see Rogers, Cabrera et al., 1996, for further discussion of these issues).

From a practical perspective the present data show that older adults are capable of learning to use a technology that is new to them, namely an automatic teller machine. Moreover, they were able to transfer their learning to a novel ATM, suggesting some generality to their learning. The ATM simulator used in this research is prototypical of many technological systems in that it is interactive with input from the user, is hierarchically organized, requires navigation through menus, and so on. Thus, the benefits of random practice should be observed in other, similar systems such as an online library catalog, a videocassette recorder, a computerized catalog order system, and an information kiosk. Such additional applications of a random practice schedule remain to be investigated.

One cautionary note: Even after instruction and 50 trials of practice with an ATM, the older individuals remained slower, less accurate in their menu selections, and more likely to forget to take their receipt or their cash. We must be aware that new technologies will require perhaps extensive training and exposure before older adults will be capable of using them to their full functionality.

ACKNOWLEDGMENTS

This research was supported in part by grants from the National Institutes of Health (National Institute on Aging): Grant P50 AG11715 under the auspices of the Center for Applied Cognitive Research on Aging (one of the Edward R. Roybal Centers for Research on Applied Gerontology) and Grant R01 AG18177. This project served as partial fulfillment of the master of science degree for the first author.

Portions of these data were presented at the Human Factors and Ergonomics Society 40th Annual Meeting (September, 1996) and the Human Factors and Ergonomics Society 42nd Annual Meeting (October, 1998). A brief report of some of the results appears in the proceedings of the latter conference (Jamieson & Rogers, 1998). The authors thank Sherry Mead and Dan Fisk for constructive comments on the manuscript. Brian Jamieson is now a user experience designer at anchorSilk, Inc.

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Received March 1, 1999
Accepted March 17, 2000
Decision Editor: Toni C. Antonucci, PhD