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Decay, Transfer, and the Reacquisition of a Complex Skill: An Investigation of Practice Schedules, Observational Rehearsal, and Individual Differences

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14. ABSTRACT
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Abstract

This study fills a void in the literature on skill decay by incorporating a cognitively complex task and an extended nonuse period. Using 192 paid participants who trained for approximately 17 hours on a command-and-control microworld simulation, we examined the effectiveness of distributed versus massed practice and post-acquisition observational rehearsal in minimizing skill decay and facilitating adaptive transfer and reacquisition after an 8-week nonuse period. We also examined how individual differences in ability and motivation predicted retention, transfer, and reacquisition as well as participation in voluntary post-acquisition observational rehearsal. Results showed that distributed practice had a positive effect on skill retention and post-observational rehearsal had a positive effect on transfer. Although some individual differences (e.g., self-efficacy) were consistently associated with retention, transfer, and reacquisition, overall levels of prediction were relatively weak, especially for transfer. Differences in motivation rather than ability differentiated individuals who participated in voluntary rehearsal from those who did not.

Author's Notes

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Decay, Transfer, and the Reacquisition of a Complex Skill: An Investigation of Practice Schedules, Observational Rehearsal, and Individual Differences

Skill decay refers to the loss or attenuation of trained or acquired skills (or knowledge) after periods of nonuse. This phenomenon is particularly salient and problematic in situations where individuals receive initial training on skills and knowledge that they may not be required to use or may not have the opportunity to perform for extended periods of time. For example, reserve personnel in the military may receive formal training only once or twice a year with the expectation that they will only need a limited amount of refresher training to reacquire any skill that has been lost when they are called up for active duty (Wisher, Sabol, Hillel, & Kern, 1991). Likewise, disaster teams and first responders may work for years without evacuating residents from affected areas, managing evacuation routes, and rescuing and treating survivors of major disasters. Although these personnel may experience extended periods of nonuse, they are still expected to perform at high proficiency levels—with no retraining—should an emergency or disaster arise. Consequently, the identification of factors that enhance post-training skill retention is potentially of vital importance and value. However, previous research on skill decay has involved relatively simple tasks with relatively short nonuse intervals, thus rendering tenuous generalizations to real-world contexts.

Therefore, the purpose of the present study was to assess the comparative effectiveness of distributed versus massed practice (during acquisition as well as reacquisition) and the use of post-acquisition observational rehearsal in minimizing skill decay (i.e., maximizing retention) and facilitating skill transfer and reacquisition after an *extended* period of nonuse using a complex command-and-control microworld simulation. Transfer was operationalized in terms of adapting ones' skill to novel performance demands. We also examined how well individual differences in ability and nonability factors predicted skill retention, transfer, and reacquisition as well as participation in voluntary post-acquisition observational rehearsal.

Skill Decay

A core set of factors that influence the retention of trained skills over extended periods of nonuse have been identified in the extant literature. Arthur, Bennett, Stanush, and McNelly (1998) categorized them as task-related and methodological factors. Task-related factors are inherent characteristics of the task and are typically not amenable to modification by the trainer or researcher. Examples of task-related factors include characteristics such as the distinction between closed- and open-looped tasks, and physical and cognitive tasks. Methodological factors, on the other hand, can be modified in the training or learning context to enhance retention. Examples of these factors include the degree of overlearning, conditions of retrieval, evaluation criteria, and method of testing. This present study focused on the manipulation of methodological factors: (a) practice schedules and (b) post-training observational rehearsal.

A limitation of the skill decay literature in particular, and the training and educational literature in general, is the tendency to treat learning (i.e., skill acquisition), decay, transfer, and reacquisition as separate phenomena which are subsequently studied independently (Arthur & Bennett, 1996; Schmidt & Björk, 1992). In highlighting the limitations of this approach, Schmidt and Björk (1992), for example, showed that manipulations which maximize performance during training may not necessarily be the most effective in the long term. That is, protocols which maximize skill acquisition may not necessarily lead to the best retention and transfer compared to other protocols which may have slower speeds of acquisition. Thus, these authors argued that acquisition, retention, and transfer are inseparable and need to be considered together when conducting research on skill acquisition. In a similar vein, although skill transfer to novel performance demands can be distinguished conceptually from skill retention, transfer and retention are logically interconnected given that the need for skill transfer may arise after a period of nonuse. Thus, it is not difficult to envision a scenario where the sudden need to make use of a skill under novel circumstances arises when the skill has gone unutilized for an extensive period of time. Such is frequently the case in military, emergency rescue, and disaster relief operations. Therefore, we believe that the present investigation makes an important contribution to the literature on adaptable performance by including tests of transfer after the nonuse interval.

Distributed versus Massed Practice

The spacing of practice is an important consideration in the design of training programs because it has been shown to influence learning (Schmidt & Björk, 1992; Singer, 1980). Massed practice conditions are those in which individuals practice a task continuously with limited breaks. In contrast, distributed practice conditions incorporate appreciable time intervals between practice sessions. The notion that distributed practice is superior to massed practice is close to a received doctrine in the learning and task performance literatures. Yet there are several caveats to this statement. For instance, it has been noted that the research demonstrating this superiority has principally involved simple motor tasks (Donovan & Radosevich, 1999; Lee & Genovese, 1988) or simple cognitive tasks such as recalling lists of words (Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Janiszewski, Noel, & Sawyer, 2003). Relatedly, research investigating the effects of distributed practice on complex motor tasks has been limited and less conclusive (Goldstein & Ford, 2002). Indeed, contrary to the received doctrine, the results of Donovan and Radosevich's (1999) meta-analysis indicated that the nature of the task, the intertrial time interval, and the interaction between these two variables moderated the relationship between practice conditions and performance. Similarly, it has been posited that because of its shorter rest intervals, massed practice may foster skill acquisition and retention for complex nonmotor tasks, especially when the trainee is likely to forget critical responses or the propensity for errors is high (DeCecco, 1968).

We were unable to locate any studies that investigated the comparative effectiveness of massed and distributed practice schedules in terms of the retention and transfer of a *cognitively complex* skill over an *extended* nonpractice interval. As previously noted, such a comparative assessment is important because protocols which maximize skill acquisition may not necessarily lead to the best retention and transfer compared to other protocols with degraded speeds of acquisition (Schmidt & Björk, 1992). Thus, acquisition, retention, and transfer are inseparable and need to be considered together when conducting comparative assessments of skill acquisition interventions. Consequently, the present study investigated the comparative effectiveness of massed and distributed practice protocols in terms of skill acquisition, decay, transfer, and reacquisition after an 8-week nonpractice interval. To address critiques of past research pertaining to the use of simple motor and cognitive tasks, we used a complex command-and-control task that met the requisite criteria for high cognitive complexity and information-processing demands. Specifically, our training task was a real-time micro-simulation of modern naval warfare that provides the user with the ability to wargame carrier battle group strategy, tactics, and resource allocation. We consider this a significant contribution to the extant literature because, as previously noted, we are unaware of any studies that investigated the distributed practice effect in terms of the retention and transfer of a complex skill over an extended nonpractice interval. Accordingly, the present study is consistent with Kraiger's (2003) recent admonishments urging caution when generalizing the findings from the cognitive-experimental literature to real-world training environments. The present study further extends the literature by crossing the spacing manipulation in acquisition with another spacing manipulation during reacquisition. In general, we tested the hypothesis that distributed practice relative to massed practice would be beneficial to skill acquisition, retention, transfer, and reacquisition.

Post-training Rehearsal during Nonuse

The progressive deterioration of knowledge and skills when they are not used over extended periods of time is a robust phenomenon (Arthur et al., 1998; Arthur, Day, Bennett, McNelly, & Jordan, 1997). In addition, the longer the period of nonuse, the greater the decay. One obvious strategy to enhance skill retention is to provide opportunities to perform the task during the nonuse interval. However, because this may not be possible or feasible for a variety of organizational, logistical, structural, and administrative reasons (Ford, Quiñones, Sego, & Speer Sorra, 1992; Noe, 1986; Peters & O'Connor, 1980), the use of alternative strategies, such as mental rehearsal or imaginary practice (Driskell, Copper, & Moran, 1994; Farr, 1987) have been investigated.

Along these lines, the second objective of the present study was to investigate the comparative effectiveness of three rehearsal protocols (i.e., no rehearsal, mandatory rehearsal, and voluntary rehearsal) in minimizing skill decay during the post-training nonuse interval and facilitating skill transfer and reacquisition. Although we investigated the effectiveness of all three rehearsal protocols, of particular interest was the effectiveness of a structured and formalized voluntary rehearsal protocol. Based on the previous work in social learning, observational learning, and modeling (Bandura, 1986; Caroll & Bandura, 1990) and capitalizing on the technologies of the internet, in the voluntary and mandatory rehearsal conditions, trainees rehearsed by watching video clips of both effective and ineffective performance of the trained task—rehearsal involved observational learning only and no hands-on practice.

Although early research suggested that including examples of negative models (i.e., ineffective performance) was detrimental to learning (Bandura & Walters, 1963; Berliner, 1969), more recent research has shown that the inclusion of negative models in combination with positive models can enhance learning, particularly generalization (Baldwin, 1992, Taylor, Russ-Eft, & Chan, 2005; Trimble, Nathan, & Decker, 1991). There are several reasons why including negative models may be beneficial to learning. For instance, including negative models promotes the "unlearning" of preexisting negative habits and helps trainees avoid using ineffective strategies (Russell, Wexley, & Hunter, 1984). In addition, including negative models generates task-related interference, which forces the learner to more actively concentrate and refine information to comprehend underlying principles of the task (Battig, 1972, 1979). In a similar vein, including negative models enhances the distinctiveness of key learning points and the recognition of important behaviors (Baldwin, 1992; Jentsch, Bowers, & Salas, 2001). Based on the previous empirical support for observational learning and the use of both negative and positive models in facilitating generalization, we tested the general hypothesis that trainees would benefit from post-training observational rehearsal particularly in terms of their skill transfer.

Individual Differences, Voluntary Participation, and Performance after Nonuse

Ability Factors

The role of individual differences has been recognized as an important but under-represented factor in the skill retention literature (Arthur & Bennett, 1996; Arthur et al., 1998).

Nevertheless, it is generally argued that higher ability individuals, compared to lower ability individuals, retain more knowledge and skill over periods of nonuse because they acquire more knowledge and skill in the same amount of time (Carron, 1971; Carron & Marteniuk, 1970; Farr, 1987; Fox, Taylor, & Caylor, 1969; Grimsley, 1969a, 1969b; Purdy & Lockhart, 1962; Schendel et al., 1978; Vineberg, 1975). However, there is dissenting research suggesting that there is also a qualitative difference between higher and lower ability individuals that may explain the enhanced skill retention exhibited by higher ability individuals. Farr (1987), for example, suggested that the differential rates of decay observed between higher and lower ability individuals may be due to higher ability individuals using more effective strategies to acquire knowledge and skills. This is consistent with Hall, Ford, Whitten, and Plyant (1983) who required Navy sailors to complete two self-paced courses in basic electricity and electronics to a criterion of mastery. After a nonpractice interval ranging from 18 to 34 days, Hall et al. found that higher ability sailors retained significantly more than lower ability sailors.

In short, general cognitive ability (g) has been demonstrated to display a robust relationship with training and job performance (Schmidt & Hunter, 1998). Research also has shown that this relationship is mediated by knowledge acquisition (Hunter, 1983, 1986; Schmidt & Hunter, 1993) such that individuals with greater levels of g acquire more job/task knowledge, and it is this higher level of knowledge acquisition that leads to greater performance. This relationship is supported by research indicating that knowledge structures mediate the relationship between g and skill-based performance (Day, Arthur, & Gettman, 2001). Research has also shown that measures of cognitive ability are predictive of adaptive performance (LePine, Colquitt, & Erez, 2000; Pulakos et al., 2002). Despite the preponderance of empirical support for the predictive value of g, there is a lack of research examining how well measures of *g* predict skill retention and adaptive performance after an extended period of nonuse. Nevertheless, despite this lack of research, we tested the hypothesis that a measure of *g* would predict skill retention, transfer, and reacquisition after an extended nonuse period. Furthermore, we were also interested in examining the incremental prediction provided by a measure of *g* beyond assessments of declarative knowledge and skilled performance taken just prior to the start of the nonuse interval (i.e., at the end of skill acquisition).

Nonability Factors

The premise that performance is determined by a combination of ability and motivation is well established in the training literature. Although there is a host of nonability individual differences shown to be associated with training outcomes (for a review, see Colquitt, LePine, & Noe, 2000), three variables associated with training motivation have received particularly increasing research attention over the last 15 years. These variables are conscientiousness, achievement motivation (also referred to as goal orientation), and self-efficacy. The common theoretical basis for linking these variables to training outcomes is based on cognitive and information-processing conceptualizations of motivation which describe motivation as the combined effects of three choices or decisions, namely decisions pertaining to the direction, level, and persistence of one’s effort. These decisions create differences in self-set goals, assessments and interpretations of situations, and reactions to these interpretations. Based on this conceptualization of motivation, we were especially interested in examining the extent to which these variables were related to participation in voluntary post-training rehearsal.

Conscientiousness. Within the framework of the five-factor model of personality (Digman, 1990), conscientiousness has been demonstrated to be related to training performance and learning outcomes (Barrick & Mount, 1991; Hurtz & Donovan, 2000; cf. LePine et al., 2000). Conscientiousness is associated with behavioral tendencies such as dependability, perseverance, deliberation, and striving for success. Conscientious individuals are organized and systematic, set more challenging goals, and are more committed to these goals (Barrick, Mount, & Strauss, 1993; Hollenbeck & Klein, 1987). In addition, conscientiousness is related to the motivation to learn (Colquitt & Simmering, 1998). So, in the context of the present study, we tested the general hypothesis that conscientiousness would be positively associated with participation in voluntary post-training rehearsal as well as skill retention, transfer, and reacquisition.

Achievement motivation. Achievement motivation is broadly conceptualized as an implicit goal-oriented framework used by individuals to behave in learning and achievement settings (Dweck, 1986). Currently, three dimensions of achievement motivation are widely researched: mastery, performance approach, and performance avoidance (Elliot & Church, 1997; VandeWalle, 1997). A mastery orientation involves a focus on improving one's competence by developing new skills—in other words, learning for the sake of learning. A performance-approach orientation refers to a focus on demonstrating one’s competence to oneself and others. A performance-avoidance orientation involves a focus on avoiding demonstrating one’s lack of competence.

Past research indicates these three dimensions are related to a variety of achievement-related outcomes. In addition to adaptive cognitive processes like self-regulation and deep cognitive engagement, numerous investigations have shown that a mastery orientation is positively correlated with positive attitudinal outcomes like enjoyment and sustained interest as well as with grades and other performance-based outcomes (e.g., Button, Mathieu, & Zajac, 1996; Day, Radosevich, & Chasteen, 2003; Elliot & Church, 1997; Payne, Youngcourt, &

Beaubien, 2007; Stevens & Gist; 1997; VandeWalle, Brown, Cron, & Slocum, 1999). Although a performance-approach orientation sometimes yields positive relationships with achievement-related outcomes, links between performance orientations and achievement-related outcomes reflect motivational processes that are distinct from those associated with a mastery orientation (Elliot, McGregor, Holly, & Gable, 1999). For example, performance orientations tend to undermine intrinsic motivation and enjoyment in achievement settings (Elliot & Church, 1997; Elliot & Sheldon, 1997). With a concern for attaining extrinsic outcomes rather than learning and understanding per se, performance orientations tend to be associated with superficial learning strategies and performance-oriented thoughts that are unrelated to developing competence (Elliot & Church, 1997; Elliot & McGregor, 1999). In the present study, we tested the general hypothesis that mastery orientation at the end of acquisition training would be positively associated with participation in voluntary post-training rehearsal as well as skill retention, transfer, and reacquisition. Because empirical results have generally been mixed for performance-approach orientation, we did not test a directional hypothesis for performance-approach orientation. Performance-avoidance orientation, on the other hand, has been shown to yield negative relationships with achievement- and performance-based outcomes (Day, Yeo, & Radosevich, 2003; Payne et al., 2007). Therefore, we tested the general hypothesis that performance-avoidance orientation at the end of acquisition training would be negatively associated with participation in voluntary post-training rehearsal as well as skill retention, transfer, and reacquisition.

Self-efficacy. Self-efficacy refers to a person's belief that he or she has the capacity to successfully perform specific behaviors or tasks (Bandura, 1977, 1986; Wood & Bandura, 1989). On the one hand, meta-analytic investigations have shown that self-efficacy is positively related to performance in a variety of work-related settings (Sadri & Robertson, 1993; Stajkovic & Luthans, 1998). In particular, it has been shown that self-efficacy plays a prominent role in training motivation, yielding positive associations with learning and performance throughout the training process and in post-training transfer contexts (Colquitt et al., 2000). On the other hand, there is a body of research suggesting that the causal roles played by self-efficacy may not be as straightforward and direct as many might think. For example, there is currently a debate in the literature regarding causality between self-efficacy and performance (Heggestad & Kanfer, 2005), and recent meta-analytic research has demonstrated that self-efficacy displays little if any main effects on performance after controlling for prior performance (Arthur, Bell, & Edwards, 2007) and other individual differences related to motivation and performance (Judge, Jackson, Shaw, Scott, & Rich, 2007). Moreover, recent research (e.g., Vancouver & Kendall, 2006) has even demonstrated that under certain conditions self-efficacy may be negatively related to performance. However, we are unaware of any previous research in the literature that has examined the relationship between self-efficacy and performance after an extended period of nonuse. Thus, the present study contributes to the extant literature by investigating the predictive and incremental validity of self-efficacy assessed at the end of acquisition with respect to retention, transfer, and reacquisition after an extended period of nonuse after training. Furthermore, we examined the extent to which self-efficacy was associated with participation in voluntary rehearsal. Accordingly, we tested the general hypothesis that self-efficacy at the end of skill acquisition would be positively associated with participation in voluntary post-training rehearsal as well as skill retention, transfer, and reacquisition after an extended period of nonuse.

Method

Participants

Our initial sample consisted of 236 volunteers (23% female) from the university and campus communities at Texas A&M University and the University of Oklahoma. Participants were paid $16.00 per hour. They also competed for three bonuses of $100, $60, and $40, which were awarded to the three trainees with the highest average task performance scores. Participants were assigned to one of two acquisition training conditions (distributed or massed practice), one of three rehearsal conditions during the 8-week nonpractice interval (mandatory, voluntary, or no rehearsal), and one of two reacquisition training conditions (distributed or massed practice) for a total of 12 training conditions. A total of 29 participants withdrew from the study after training began (13% attrition). Attrition rates were roughly equal across conditions. For example, 15 participants in the distributed acquisition condition withdrew from the study and 14 participants in the massed acquisition condition withdrew from the study. In addition, data from 15 participants were removed from our analyses because the participants consistently did not follow the training instructions. Consequently, our final sample size was 192 (22% female) with a mean age of 20.94 years (*SD* = 3.67).

Measures

Performance task—Jane's Fleet Command. The performance task was Jane's Fleet Command (Sonalysts, Inc., 2004, Air Force Research Laboratory ver. 1.55) which is a PC-based real-time micro-simulation of modern naval warfare featuring ships, aircraft, submarines, and airbases on land. It provides the user with the ability to wargame carrier battle group strategy, tactics, and resource allocations and enables flexible, immersed, and interactive training. Fleet Command meets the requisite criteria for cognitive complexity and information processing demands (Ericsson & Charness, 1994; Ericsson, Krampe, & Tesch-Roemer, 1993; Schneider,

1985) including short- and long-term memory load, high workload, dynamic attention allocation, decision making, prioritization, and resource management. Consequently, it is an ecologically valid laboratory analogue of the types of cognitive, information processing, and decision making tasks and activities present in operational command-and-control environments in military, civilian first-responder, and other similar settings. This is highlighted by the use of Fleet Command for training purposes by several groups such as the U.S. Naval Academy, the Surface Warfare Development Group, the Surface Warfare Officers School Command, and the U.S. Naval Academy Division of Professional Development. Performance was operationalized as the mission effectiveness of test missions. Specifically, the mission effectiveness represents a ratio of points earned for destroying enemy platforms (aircraft, surface ships, submarines and land bases) and completing assigned goals, and points lost for friendly or neutral platforms destroyed, divided by the total number of points available in the mission. The ratio of points earned to points possible was multiplied by 100 to rescale the value to approximate a percentage of points earned during the mission. However, because trainees could lose more points than they could earn during a mission (e.g., an unharmed enemy destroying all friendly and neutral platforms), trainees could earn score less than -100 but not greater than 100 points.

Jane's Fleet Command missions. Six different missions were used in the present study (referred to as Missions A-F in the Tables). Each of the six missions was slightly modified to produce 3 to 4 variations depending on the number of times the mission was used across the different training sessions. Trainees practiced using one variation of a mission and then tested using another variation of the same mission. The variations of a particular mission differed only in the location of own-side and enemy platforms. For example, a trainee might have been attacked by an enemy fleet from the North during the practice mission, but attacked from the West during the test mission; otherwise, the missions were identical.

The missions were presented to trainees in an order of increasing difficulty. As the study progressed, the missions required trainees to implement new strategies and systems as well as those presented and learned in the preceding training sessions (e.g., SONAR, RADAR, specialized platforms, and/or specialized weapons). In addition, as the study progressed, mission goals required an increasingly greater degree of planning, the mission tasks required greater accuracy in navigation, and trainees were required to coordinate and monitor more platforms (both own-side and enemy). Thus, the mission played during the baseline session, Session 1, and Session 2 was the least difficult (Mission A), while the mission played during Session 11 was the most complex and difficult (Mission F; also considered to be the transfer mission) and required trainees to implement all of the strategies and techniques presented in all of the preceding training sessions. Whereas in other missions trainees may have used proficiency in one area (e.g., sensor and weapons use, strike coordination, and resource management) to compensate for a deficiency in another area, effective performance on Mission F required proficiency in all tasks simultaneously. Furthermore, Mission F also presented trainees with an environment that was novel, both in terms of the platforms under their command and the strategy necessary to achieve the mission objectives and goals. This mission required trainees to employ new platforms with unique capabilities, search for and engage an enemy fleet that was defended unlike any other fleet previous, while for the first time defending their fleet from two separate attacks at once.

g. The Raven Advanced Progressive Matrices (APM; Raven, Raven, & Court, 1998) was used to assess *g*. The APM is a measure of general intelligence that consists of 36 matrix problems arranged in an ascending order of difficulty. The APM was scored by summing the number of problems answered correctly. We used an administration time of 40 minutes. The test manual reports a test-retest reliability of .91 for the APM scores. We obtained a Spearman-Brown odd-even split-half reliability of .84 for the APM scores. Trainees completed the APM prior to completing the baseline mission.

Declarative knowledge. We developed a 21-item multiple-choice test to assess knowledge of JFC instructions, procedural rules, and information presented during training. Each item consisted of three alternatives. The test was scored by summing the number of items answered correctly. Trainees completed this test after completing their final mission at the end of acquisition (Session 9).

Conscientiousness. Goldberg's 100 Unipolar Markers (1992) was used to assess personality. Using a nine-point scale (1 = extremely inaccurate; 9 = extremely accurate), trainees described themselves by rating a list of 100 adjectives. For purposes of this study, only the 20 items for conscientiousness were examined. Item responses were summed to derive scores. We obtained an internal consistency of .90 for conscientiousness scores. Trainees completed the Unipolar Markers prior to completing the baseline mission.

Achievement motivation. A 17-item scale adapted from Elliot and Church (1997) was used to operationalize the three task-specific achievement motivation dimensions. Example items included, "It is important to me to do better at Fleet Command than the other trainees in this study" (performance approach), "I want to learn as much as possible about Fleet Command during this study" (mastery), and "I would prefer to avoid playing Fleet Command in front of someone else because I might perform poorly" (performance avoidance). Trainees responded using a 5-point scale (1 = strongly disagree; 5 = strongly agree). Item responses were averaged to derive each dimension score. We obtained coefficient alphas of .94, .91, and .87 for the performance approach, mastery, and performance avoidance scores, respectively. Trainees completed the achievement motivation scales after completing their final mission at the end of acquisition (Session 9).

Self-efficacy. The self-efficacy scale used in this study was based on sample items from scales used in several previous studies (e.g., Bell & Kozlowski, 2002; Martocchio & Judge, 1997; Nease, Mudgett, & Quiñones, 1999) as well as items developed specifically for this study. The scale consisted of twelve items, including "I can meet the challenges of Fleet Command" and "I am confident that I have what it takes to perform Fleet Command well." Trainees responded using a 5-point scale (1 = strongly disagree; 5 = strongly agree). Item responses were averaged to derive a score. We obtained a coefficient alpha of .93 for the self-efficacy scores. Trainees completed the self-efficacy scale after completing their final mission at the end of acquisition (Session 9).

Experimental Procedures

Distributed versus massed acquisition practice. Table 1 provides an overview and summary of the training procedures used for acquisition. Upon being recruited, trainees were informed during a screening and scheduling session that they would be training to perform a complex decision making computer-based performance task. The screening session also entailed the completion of a demographic and contact form, and a video/computer game experience measure. The intention of the video/computer game experience measure was to exclude trainees who reported extensive experience and familiarity with Fleet Command. However, no one was eliminated on this basis. Trainees were selected into the study based on their availability and then randomly assigned to their specified condition. Although we attempted to assign all the trainees randomly to their respective training conditions, random assignment was not completely possible due to difficulties encountered with accommodating participants' weekly schedules and 4-month calendars. Examination of the mission effectiveness scores at baseline (Session 0) indicated that training conditions were roughly equivalent at the start of training: t (acquisition practice [190]) = 0.20, $p > .10$, $d = 0.03$), F (observational rehearsal during the nonpractice interval [2, 189]) = 0.65, $p > .10$, $\eta^2 = .01$), and t (reacquisition practice [190]) = 0.46, $p > .10$, $d = 0.07$).

Prior to training on the first day of the study, trainees completed the baseline mission (Session 0) of Fleet Command. For this baseline mission (A), trainees were simply given time to read the standard mission briefing, which specified the goals and objectives of the mission. No other instructions were provided. After completing the baseline mission, trainees then received instruction and tutorials on how to "play" Fleet Command. Training was delivered by an instructor who guided trainees through the training sessions as trainees followed along on their individual workstations using a fully functional Fleet Command mission. Following the training portion of a session, trainees then completed a practice mission followed by a test mission. Subsequent sessions (1-9) and missions (A-E) followed the training sequence presented in Table 1. Sessions were scheduled to be an hour long, consisting of 20 minutes of practice and 25 minutes of testing—unless there was a tutorial or training which used up approximately 15 minutes and the practice and testing were then 15 minutes and 25 minutes long, respectively. Acquisition training took place over a 2-week period in the distributed acquisition condition (n = 100) compared to 1-week in the massed acquisition condition (n = 92).

Distributed versus massed reacquisition practice. Table 2 provides an overview and summary of the training protocols used for testing retention (skill decay), transfer, and reacquisition. After the 8-week nonpractice interval, trainees returned on a Monday to complete tests of skill decay (retention) and transfer, Sessions 10 and 11, respectively. Session 10 involved the same mission (E) that trainees practiced and performed during Session 9 at the end of acquisition training. The test of transfer, Session 11, was a mission (F) that trainees had never practiced or performed before. Trainees then completed four reacquisition sessions (12-15, Missions B-E, respectively) followed by a repeat transfer mission (Session 16, Mission F). Reacquisition training took place over 4 days in the distributed reacquisition condition (n = 95) compared to 2 days in the massed reacquisition condition (n = 97).

Post-training Observational Rehearsal

As previously stated, trainees were assigned to one of three post-training, observational rehearsal conditions: mandatory rehearsal (n = 60), voluntary rehearsal (n = 76), and no rehearsal (n = 56). Trainees in the mandatory condition returned to the lab each week to view a different action-review refresher video. These videos were developed to refresh trainees on specific aspects of Fleet Command (e.g., weapons employment, issuing orders, RADAR and Airborne Early Warning aircraft, RADAR jamming, and weapons use near friendly and neutral forces). The duration of these videos was 10 minutes on average. Each video began with an example of maladaptive or ineffective performance followed by an explanation and an example of adaptive or effective performance. The videos showed trainees the Fleet Command game screen, and trainees could see specific actions being executed while hearing (through headsets) a voice describe and explain the actions. Trainees not only viewed the actions, they also viewed the consequences associated with the actions. Trainees in the voluntary condition were given a logon identification number, which gave them internet access to the same action-review refresher videos. Although voluntary trainees had unlimited access to the videos, they were constrained to accessing the videos in sequential order. For example, once the first video was accessed and viewed, both the first and second videos were then available. Once the second video was accessed and viewed, the first three videos were then available, and so on. Trainees in the voluntary condition were not paid for their time spent viewing the videos. However, voluntary trainees were offered bonuses of $75 and $50 for the two highest scores achieved on the first mission performed upon immediately returning from the 8-week nonpractice period. Trainees in the no rehearsal condition were given no access to the videos.

Results

Distributed versus Massed Practice

Acquisition. Table 3 shows the descriptive statistics and effect size differences for the distributed and massed acquisition practice conditions for all of the training sessions. Mission effectiveness scores during acquisition were analyzed using a 2 (distributed versus massed practice) × 10 (training session) mixed analysis of variance (ANOVA). The results indicated a statistically significant main effect for session reflecting a positive effect of training, F (9, 1719) = 169.17, $p < .01$, $\eta^2 = .47$. Although the mission effectiveness scores generally reflected a negatively accelerating positive trend typical of skill acquisition curves, scores sometimes decreased in later sessions (e.g., from Session 4 to 5 and from Session 6 to 7) when trainees were performing new missions for the first time. Consistent with our hypothesis that distributed practice would be beneficial, trainees in the distributed condition obtained higher scores at the end of acquisition than trainees in the massed condition, t (190) = 1.65, $p < .05$ [one-tailed], d = 0.24. However, neither the main effect for practice condition (F [1, 190] = 0.96, $p > .10$, η^2 = .01) nor the interaction between practice condition and training session was statistically significant, F (9, 1719) = 0.28, $p > .10$, $\eta^2 = .00$. As such, the above results offer only weak support for the hypothesis that trainees would benefit from distributed practice.

To test for a difference in skill decay between the two acquisition practice schedules, we compared the initial performance of the two protocols after the 8-week nonpractice interval (Session 10) using an analysis of covariance (ANCOVA) with the last acquisition session (Session 9) as the covariate. The correlation between mission effectiveness scores from Sessions 9 and 10 was .27, $p < .01$. Consistent with the hypothesized benefits of distributed practice, the results of the ANCOVA indicated a significant difference in favor of the distributed condition in terms of retention performance after the 8-week nonpractice interval, $F(1, 189) = 8.04$, $p < .01$, $\eta^2 = .04$. Similar analyses were repeated for the tests of transfer (Session 11) and immediate reacquisition (Session 12); the correlations between Sessions 9 and 11 and Sessions 9 and 12 were .14 ($p < .05$) and .25 ($p < .01$), respectively. In contrast to the effects for retention performance, the results did not reveal a significant effect for distributed practice on either transfer (F [1, 189] = 0.03, $p > .10$, $\eta^2 = .00$) or immediate reacquisition, $F(1, 189) = 1.32$, $p > .10$, $\eta^2 = .01$.

To further examine the effects of distributed versus massed acquisition training on reacquisition, we conducted a 2 (distributed versus massed practice) × 4 (training session) mixed ANOVA for Sessions 12 through 15. The main effect for training session was statistically significant (F [3, 570] = 10.33, $p < .01$, $\eta^2 = .05$), reflecting a marked decrease in mission effectiveness scores in Session 14 for Mission D compared to the other sessions/missions. Consistent with our hypothesis that distributed practice would be beneficial, trainees in the distributed condition obtained higher scores at the end of reacquisition (Session 15) than trainees in the massed condition, $t(190) = 1.79$, $p < .05$ [one-tailed], $d = 0.26$. However, neither the main effect for rehearsal condition (F [1, 190] = 1.08, $p > .10$, $\eta^2 = .01$.) nor the interaction between rehearsal and session was statistically significant, $F(3, 570) = 1.58$, $p > .10$, $\eta^2 = .00$. Finally, we conducted two ANCOVAs for Session 16, which involved the same transfer mission as Session 11. The first ANCOVA used mission effectiveness scores from Session 9 as the covariate; the same covariate used previously. However, the correlation between scores from Sessions 9 and 16 was not statistically significant ($r = .07$, $p > .10$). The second ANCOVA used mission effectiveness scores from Session 11 as the covariate; the correlation between scores from Sessions 11 and 16 was .30, $p < .01$. Neither ANCOVA revealed a significant effect (both η^2s = .00). In sum, our results did not offer strong support for the general hypothesis that trainees would benefit from distributed practice during acquisition training. Nevertheless, our results did show a benefit in terms of skill retention.

Reacquisition. Table 4 shows the descriptive statistics and effect size differences for the distributed and massed reacquisition practice conditions for the relevant sessions (12 through 16). Analyses similar to the ones above for the acquisition manipulation were conducted for these session scores. Other than a similar main effect for session, no statistically significant effects were observed (all η^2s = .00). Moreover, we also searched for synergistic effects for undergoing both distributed acquisition and reacquisition practice by conducting 2 (distributed versus massed acquisition) × 2 (distributed versus massed reacquisition) analyses and found no statistically significant interactions for any single session (all η^2s = .00). These results offered no support for the hypothesized benefits of distributed practice.

Post-training Observational Rehearsal

As previously stated, trainees were assigned to one of three post-training, observational rehearsal conditions: mandatory rehearsal ($n = 60$), voluntary rehearsal ($n = 76$), and no rehearsal ($n = 56$). Evaluation of the time spent watching the videos by trainees assigned to the voluntary condition revealed a wide range of values (min = 0 minutes, max = 115 minutes). Only 22 of the

76 trainees (29%) in the voluntary condition actually viewed the videos. Therefore, to evaluate the effectiveness of observational rehearsal, we combined the 54 trainees from the voluntary condition who did not view the videos with the trainees assigned to the no rehearsal condition, resulting in the following sample sizes: mandatory rehearsal ($n = 60$), voluntary rehearsal ($n = 22$), and no rehearsal ($n = 110$). We conducted ANOVAs using these three conditions as well as planned comparisons collapsing the voluntary and mandatory conditions into a single observational rehearsal condition.

Table 5 shows the descriptive statistics and effect sizes for the observational rehearsal conditions for Sessions 9 through 16. There were no significant differences among the conditions at the end of acquisition (Session 9) before the rehearsal manipulation occurred, $F\ (2, 189) = 1.58$, $p > .10$, $\eta^2 = .02$. Similar to the above analyses for distributed versus massed acquisition, we tested for differences in skill decay (Session 10), transfer (Session 11), and immediate reacquisition (Session 12) using ANCOVAs with the last acquisition session (Session 9) as the covariate. In contrast to our hypothesis that trainees would benefit from observational rehearsal, the results showed no statistically significant differences regarding skill decay ($F\ [2, 188] = 0.36$, $p > .10$, $\eta^2 = .01$) or immediate reacquisition ($F\ [2, 188] = 0.36$, $p > .10$, $\eta^2 = .01$). However, the results indicated a significant effect for transfer performance, $F\ [2, 188] = 3.23$, $p < .05$, $\eta^2 = .04$. Results of a planned comparison supported our hypothesis that observational rehearsal would lead to benefits with respect to transfer performance, showing that trainees who viewed the rehearsal videos (mandatory and voluntary conditions combined) obtained higher transfer performance scores than trainees who did not participate in observational rehearsal, $t\ (190) = 2.63$, $p < .01$, $d = 0.38$.

To further examine the effects of observational rehearsal on reacquisition, we conducted a 3 (rehearsal condition) × 4 (training session) mixed ANOVA for Sessions 12 through 15. The main effect for training session was statistically significant (F [3, 567] = 10.33, $p < .01$, η^2 = .05), reflecting a marked decrease in mission effectiveness scores in Session 14 for Mission D compared to the other sessions/missions. Neither the main effect for rehearsal condition (F [2, 189] = 1.08, $p > .10$, η^2 = .01.) nor the interaction between rehearsal and session was statistically significant, F (3, 567) = 1.58, $p > .10$, η^2 = .00. Finally, to examine the stability of the transfer performance effects observed at Session 11, we conducted two ANCOVAs for Session 16, which involved the same transfer mission as Session 11. The first ANCOVA used mission effectiveness scores from Session 9 as the covariate (the same covariate used previously). The results revealed a statistically significant difference among the rehearsal conditions, F (2, 188) = 5.06, $p < .01$, η^2 = .05. The second ANCOVA used mission effectiveness scores from Session 11 as the covariate; it also revealed a statistically significant effect, F (2, 188) = 3.33, $p < .05$, η^2 = .03. Similar to the effects from Session 11, the results of a planned comparison showed that trainees who viewed the rehearsal videos (mandatory and voluntary conditions combined) obtained higher transfer performance scores than trainees who did not participate in observational rehearsal, t (190) = 3.02, $p < .01$, d = .44. In sum, our results did not support the general hypothesis that trainees would benefit from observational rehearsal during an extended period of nonpractice. However, our results did show consistent benefits for observational rehearsal in terms of transfer performance. As a point of note, we explored interactions between observational rehearsal and the distributed versus massed manipulations and found no statistically significant results (η^2s ≤ .01).

Individual Differences, Voluntary Participation, and Performance after Nonuse

In our final set of analyses we examined the extent to which individual differences (1) differentiated those who availed themselves of voluntary rehearsal from those who did not and (2) predicted skill retention, transfer, and immediate reacquisition after an extended period of nonpractice. Table 6 shows a summary of the results. As shown, those trainees who availed themselves of voluntary rehearsal had significantly higher levels of mastery orientation (d = 0.50, p < .05) and self-efficacy (d = 0.59, p < .05) than those who chose not to partake in rehearsal. Conscientiousness (d = 0.37), performance approach (d = 0.24), and performance at the end of acquisition (d = 0.26) yielded moderate yet statistically nonsignificant differences. The effects were smaller for declarative knowledge, performance avoidance, and *g* (ds ≤ |0.15|). Regarding the prediction of skill retention, transfer, and immediate reacquisition, we examined both simple correlations and coefficients from single multiple regression equations for each outcome. Self-efficacy, *g*, and performance at the end of skill acquisition yielded significant correlations across the tests of retention, transfer, and reacquisition. None of the other predictors consistently yielded significant correlations. Correlations with transfer were consistently smaller (rs ≤ |.17|) than the correlations for retention and reacquisition. In fact, there was little if any value in using multiple regression to predict transfer (R^2 = .06, p > .10) compared to skill retention (R^2 = .14, p < .01) and reacquisition (R^2 = .14, p < .01). As reflected by the standardized regression coefficients shown in the Table 6, self-efficacy and performance at the end of acquisition yielded incremental prediction for both skill retention and reacquisition; *g* yielded incremental prediction only for skill retention.

Discussion

The empirical literature on skill decay is replete with studies involving simple tasks and relatively short (less than 1 week, and much of the time less than 1 day or even 1 hour) nonuse intervals. As such, one could argue that the extant literature on skill decay suffers from relatively poor ecological validity. Thus, this study makes an important contribution to the extant literature on skill decay by incorporating a cognitively complex command-and-control simulation and an extended, 8-week period of nonuse. In looking at our findings overall, one general conclusion that could be made is that the effects for both the training interventions and the individual differences were smaller and less consistent than what has typically been reported in studies using simpler tasks and shorter nonuse intervals. It would appear that accounting for the variance in the performance of complex tasks after extensive periods of nonuse is a challenging undertaking. In considering the difference in effect sizes we obtained and those of more micro-scaled studies and the vital importance of minimizing skill decay and facilitating transfer and reacquisition in such applied contexts as military and rescue operations, we believe that substantially more ecologically valid research on skill decay is needed before strong practical recommendations can be made. In the sections below, we discuss our findings in relation to the extant literature, make tentative practical recommendations, and highlight the need for future research.

Distributed versus Massed Practice

One key objective of our study was to evaluate the comparative effectiveness of distributed versus massed practice schedules. Although researchers generally agree that distributed practice is superior to massed practice for the acquisition of simple skills, the effect of practice schedules on the retention and transfer of cognitively complex tasks is less clear. Given that most organizational training programs involve the application of skills or knowledge learned at some later time (Arthur, Bennett, Edens, & Bell, 2003) potentially in a different environment with novel performance demands, this topic merits investigation. Our results were generally mixed compared to Schmidt and Björk's (1992) review of instructional and practice interventions. First, they demonstrated that effects observed during acquisition frequently do not reflect effects observed on tests of retention and transfer. Second, Schmidt and Björk observed that protocols (i.e., training interventions) maximizing skill acquisition may not necessarily lead to the best retention and transfer compared to protocols with degraded speeds of acquisition—in fact, reversals in effectiveness between two protocols from acquisition to tests of retention and transfer sometimes occur. With respect to the present findings, although our results never reflected a reversal in protocol effectiveness, our results across 16 test sessions indicated that the effects observed at one session did not necessarily portray the effects occurring at a later session. That is, although our results generally supported the notion that distributed practice is superior to massed practice, our effects were not consistently significant across tests of acquisition, retention, transfer, and reacquisition. Specifically, our results indicated that although both practice conditions resulted in relatively similar rates of skill acquisition with a weak benefit for the distributed condition, the massed condition displayed a significantly higher amount of skill decay than the distributed condition. Indeed, the distributed condition did not display any skill decay. In addition, although the two practice schedules differed in skill retention, they did not differ in terms of transfer, and reacquisition rates were relatively similar with a weak benefit for the distributed condition.

Our acquisition results are consistent with Donovan and Radosevich's (1999) meta-analysis in which they concluded that the strong distribution of practice effect previously reported in the extant literature appears to be limited to relatively simple motor tasks. Specifically, tasks high in overall complexity were associated with smaller distributed versus massed practice effect sizes. Consistent with this, Arthur et al. (1998) also demonstrated that the amount of skill decay is moderated by whether the task in question is physical (motor) or cognitive (nonmotor).

A plausible explanation for our finding—that the distributed practice condition exhibited less skill decay than the massed practice condition—may be that although both practice conditions facilitate skill acquisition equally well, features of a distributed practice schedule may also serve to inoculate trainees against skill decay. Specifically, trainees in a distributed practice protocol are exposed to a greater number of breaks between training sessions. For example, in our study, trainees in the distributed practice condition experienced eight breaks in training during the skill acquisition phase (seven 23-hour breaks, and one 71-hour break over a weekend). This was in contrast to trainees in the massed practice condition who experienced only four 22-hour long breaks during skill acquisition. These breaks in training may have served as short nonuse intervals, after which skill loss was reacquired during the following training session. Thus, a distributed practice schedule may not only provide task specific training, but may also provide trainees with added experience with lessening skill loss and/or facilitating reacquisition (reconstruction; Schmidt & Björk, 1992) following a period of nonuse.

Regarding practical implications, our results suggest that investing in the additional amount of time needed to execute distributed practice may indeed be worthwhile if no period of reacquisition is to be expected. In other words, if a period of reacquisition or hands-on refresher training is likely, then implementing distributed practice may not be worthwhile. However, practitioners should consider distributing practice in training if preparing individuals for immediate action with no warning or preparation after an extended period of nonuse is an important objective. If there are time constraints placed on training and providing multiple periods of rest during training is not logistically possible, then we speculate that randomizing (rather than blocking) the practice of different skills in a given amount of training time may be a viable option for inducing a distributed practice effect (Schmidt & Björk, 1992).

One possible limitation to our distributed versus massed practice manipulations is that the schedule of practice sessions in the massed manipulations, both in acquisition and reacquisition, were not entirely massed. That is, the distinction between our distributed and massed practice schedules was a matter of degree considering that some of the practice sessions in the massed manipulations were separated by nearly 1 day of nonpractice. Thus, one could argue that our study underestimated the effects of distributed practice. However, we were concerned with the ecological validity associated with entirely massed practice schedules. For example, training individuals for 10 hours straight without rest or attention to other activities does not seem like a likely occurrence in applied settings. We believe the vast majority of training practitioners recognize the need to incorporate some degree of distributed practice in their training efforts; our manipulations reflect this assumption. Nevertheless, the effects observed in our study may indeed be underestimates of the potential benefits of distributed practice, and we believe the examination of different intersession (intertrial) nonpractice intervals during acquisition vis-à-vis different periods of nonuse following acquisition holds promise as an avenue for future research (cf. Cepeda et al., 2006).

Post-training Observational Rehearsal

Another key objective to this study was examining the effectiveness of post-training observational rehearsal as a means of minimizing skill decay and promoting skill transfer and reacquisition. We were particularly interested in how our observational rehearsal strategy, which combined both positive and negative models, facilitated transfer to a scenario involving novel performance demands. Like the effects for distributed practice, post-training observational rehearsal did not yield consistently significant benefits across tests of retention, transfer, and reacquisition. Specifically, post-training observational rehearsal only had a positive effect on transfer performance, that is, adaptability. This beneficial effect on adaptability is consistent with Baldwin's (1992) seminal research on mixed models in interpersonal-skills training as well as Taylor et al.'s (2005) recent meta-analysis of the behavior modeling literature. Not only does this study contribute to the extant literature by incorporating an 8-week nonuse period, it also makes a significant contribution by examining the effects of observational learning on a cognitively complex command-and-control task. Previous research on the use of mixed models has been limited to interpersonal-skills training (Taylor et al., 2005). Although observational rehearsal did not have a beneficial effect on skill retention and reacquisition, the fact that it did not have a detrimental effect is noteworthy, because scholars of instructional design sometimes argue that incorporating both negative and positive models will detract from simple reproduction of learned skills (Baldwin, 1992). Thus, the use of mixed-model observational rehearsal could be a viable means of facilitating adaptable performance without degrading skill retention and reacquisition (i.e., reproduction).

However, because we did not manipulate the presence and absence of negative models in our observational rehearsal videos, one should exercise caution when drawing conclusions and making recommendations regarding the use of mixed models based on our study. Although it would contradict the extant literature, one could argue that larger benefits might have occurred for a condition that only included positive models. Given the limitations in our manipulation of observational rehearsal and Taylor et al. (2005) reporting only seven studies that compared mixed-model displays to positive-model displays in their meta-analysis of behavior modeling training, we believe that more research is needed on the use of mixed-model displays in promoting skill retention and transfer through post-training observational rehearsal.

Regarding the expectation that individuals would voluntarily participate in post-training rehearsal via the internet, the fact that only 29% of the trainees in our voluntary condition actually made use of the online videos does not support such an expectation. With the advent of computer-based training and the ease in which it can be administered online, providing opportunities for refresher training via the internet seems viable. However, the extent to which individuals will want to make use of such opportunities on a voluntary basis is a separate matter to consider. Issues pertaining to motivation are salient, and applying reinforcement (Skinner, 1969) and value-expectancy (Vroom, 1964) theories of motivation to address voluntary refresher training appears worthwhile for future investigation. One could argue that our study did not provide the same sense of importance as an actual organizational training situation. Consequently, our study may have underestimated voluntary participation in online refresher training. This is another issue warranting future research.

The Role of Individual Differences

In support of the statements above regarding the importance of motivation to voluntary refresher training, our findings showed that mastery orientation and self-efficacy significantly distinguished those trainees in the voluntary condition who participated in post-training observational rehearsal from those who did not. Neither *g*, nor knowledge, nor skill yielded statistically significant effects. Accordingly, using training interventions during acquisition to promote mastery orientation (cf. Kozlowski et al., 2001; Utman, 1997) and self-efficacy (cf. Bandura, 1986; Haccoun & Saks, 1998) may be a viable means to increasing participation in voluntary refresher training.

Regarding the extent to which individual differences distally predicted performance after the 8-week nonuse period, our results showed modest if not weak effects, especially in terms of transfer. In contrast to our results pertaining to the prediction of voluntary post-training observational rehearsal, *g* and skill at the end of acquisition consistently yielded significant correlations with tests of retention, transfer, and immediate reacquisition. Knowledge at the end of acquisition correlated significantly with transfer and immediate reacquisition but not retention. Moreover, *g* provided incremental predictive value beyond knowledge and skill at the end of acquisition, thus supporting claims that the link between *g* and skill decay is not fully mediated by knowledge (or skill acquisition) and there are qualitative differences in learning strategies between high- and low-ability individuals (e.g., Farr, 1987).

In contrast to recent research questioning the incremental value of self-efficacy in predicting future performance beyond prior levels of performance (e.g., Arthur et al., 2007; Heggestad & Kanfer, 2005; Judge et al., 2007), our results showed significant incremental prediction for self-efficacy with respect to skill retention and reacquisition. One plausible explanation for this difference in reported findings may be the extensive nonuse period separating the assessment of self-efficacy and the tests of retention and reacquisition. Perhaps self-efficacy contains motivational properties not reflected in prior performance that have more influence on performance after extensive nonuse rather than more immediate performance. Our observed incremental validity for self-efficacy warrants replication in future research, and the examination of specific mediating processes is also needed.

The effects for mastery orientation were nonsignificant in terms of predicting performance after the extended nonuse period. These findings may not be too surprising given the relatively weak correlations found between mastery orientation and performance-based outcomes (Day et al., 2003; Payne et al., 2007). Consistent with our findings for voluntary rehearsal, it may be more fruitful to consider more volition-based consequences of mastery orientation than actual performance-based outcomes (cf. Brown, 2001). The effects for conscientiousness and performance orientations were consistently nonsignificant in our analyses predicting voluntary participation as well as predicting performance after the extended nonuse period. Although this might be expected for performance-approach orientation given the mixed results found across the body of previous research, the lack of significant negative relationships for performance-avoidance orientation is at odds with previous research (e.g., Payne et al., 2007). On the one hand, the lack of effects for conscientiousness is inconsistent with previous studies linking conscientiousness to training outcomes (Barrick & Mount, 1991). On the other hand, the lack of effects might be expected in the light of more recent research (LePine et al., 2000) showing that some dimensions of conscientiousness (e.g., order, dutifulness, and deliberation) are differentially and negatively related to adaptability compared to other dimensions of conscientiousness (e.g., competence, achievement striving, and self-discipline).

When relating the results of the present study to the extant empirical literature, it is important to keep in mind that there is a paucity of research examining the links between individual differences and performance on complex tasks after extended periods of nonuse (Arthur et al., 1998). Hence, there is a strong need to replicate and expand upon our findings, and conclusions regarding our observed effects in relation to previous research should be qualified until replicated and further supported by future research.

The Nature of Acquisition in Research on Skill Decay and Performance after Extensive Nonuse

In our study, we defined the skill acquisition phase as a fixed amount of training time (i.e., 10 hours of training) as opposed to a specified level of performance (e.g., one errorless trial, three errorless trials, or asymptote). In their quantitative review of the skill decay literature, Arthur et al. (1998) commented on the lack of consensus concerning the criteria used to determine the point at which acquisition ceases and reacquisition begins. Arthur et al. noted that several dimensions of performance have been used throughout the literature to identify the end of skill acquisition; some studies have used an accuracy criterion (e.g., one errorless trial), whereas other studies have required trainees to complete a specified amount of material or train for a certain amount of time. Since training to a specified level of accuracy and training for a fixed amount of time represent two distinct dimensions of performance, it is important that both are considered when investigating skill decay and performance after extended periods of nonuse. However, in our present study, we considered only one of these dimensions of performance. Although we did not *experimentally* control for the amount of skill each trainee acquired during training, we did address the issue statistically by using ANCOVAs to control for differential levels of acquisition before assessing decay, transfer, and reacquisition effects. Nevertheless, it would be worthwhile to examine the results of controlling for acquisition methodologically (e.g., training to asymptote during acquisition) versus statistically in future research.

Conclusions

There is a near absence of empirical investigations concerning the retention and transfer of trained complex skills after extensive periods of nonuse. Empirical investigations of retention and transfer typically involve simple tasks and short periods of nonuse. Nevertheless, these empirical investigations with simple tasks and short periods of nonuse, as reflected in Schmidt and Björk's (1992) review, have led to important findings that have caught the attention of applied researchers and training practitioners. Although our results did not fully correspond to the pattern of effects regarding acquisition, retention, and transfer that Schmidt and Björk (1992) characterized in their critique of how scholars should perceive learning and study training interventions, this study does reinforce a very important lesson learned from their influential article. Namely, tests of acquisition are not adequate surrogates for retention and transfer. Furthermore, and not discussed by Schmidt and Björk, tests of skill retention are not adequate surrogates for transfer. Accordingly, we believe our inclusion of transfer as an evaluation criterion is important because future performance demands may indeed be qualitatively different from those in which individuals were trained. The importance of transfer and adaptable performance is even more pronounced in the context of skill decay because it is not uncommon to have a nonuse interval between training and the moment when adaptable performance is required (Arthur et al., 2003). However, in spite of the importance of this issue, it appears to have received almost no attention in both the skill decay and adaptable performance literatures.

When considering how to conduct training with the dual purpose of minimizing skill decay and promoting adaptability after extensive periods of nonuse, our findings suggest that practitioners should consider incorporating multiple techniques that separately target retention and adaptability. One intervention may not serve both purposes well, and finding potent combinations of interventions to address the dual purpose of facilitating retention and adaptability would appear to be a worthwhile challenge for future research. Based on the present study, using a combination of distributed practice and post-training observational rehearsal could be a viable means of addressing both retention and transfer in practical settings.

Moreover, we believe substantially more research is needed to better understand the roles that individual differences play in performance after extended periods of nonuse. This need is apparent when considering both the paucity of existing research and the relatively weak effects we found using assessments of individual differences at the end of acquisition to distally predict performance after extensive nonuse. We recommend expanding the number and variety of individual differences as well as examining causal networks that include both distal and proximal predictors. Proximal predictors could include the same state attributes as in the present study but assessed on multiple occasions with some assessments occurring temporally closer (i.e., toward the end of the nonuse period) to the tests of skill decay, transfer, and reacquisition. Proximal predictors could also include self-regulatory (e.g., goal-setting) and cognitive processes (e.g., metacognition and elaborative rehearsal) that might mediate the effects of more distal individual differences (e.g., conscientiousness, mastery orientation, and self-efficacy) and training interventions (e.g., distributed practice and post-acquisition observational rehearsal).

In short, individuals frequently do not get the opportunity to practice and perform trained skills after formal training (Ford et al., 1992). After an extensive period of nonuse, they may find themselves in dire need of these skills. This is common in military, emergency rescue, and disaster relief settings. The applied scientific literature on training is vast. Yet, there is a need for more ecologically valid research addressing issues of skill decay and adaptable performance after extensive periods of nonuse. We believe the present study is a small but important step toward addressing this need.

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Table 1

Overview of Training Procedures: Acquisition

DISTRIBUTED ACQUISITION		MASSED ACQUISITION	
2 Weeks of Training (10 Sessions)		**1 Week of Training (10 Sessions)**	
Schedule	**Activity**	**Schedule**	**Activity**
Week 1 Tuesday	Session 0 (JFC baseline, instructions & tutorial; Mission A) Session 1 (JFC tutorial, practice & test games; Mission A)	Monday	Session 0 (JFC baseline, instructions & tutorial) Sessions 1 & 2 (JFC tutorial, practice & test games; Missions A & B, respectively)
Wednesday-Friday	Sessions 2, 3, & 4, respectively (JFC tutorials, practice & test games; Mission B)	Tuesday	Sessions 3 & 4 (JFC tutorial, practice & test games; Mission B)
Week 2 Monday	Session 5 (JFC tutorial review, practice & test games; Mission C)	Wednesday	Sessions 5 (JFC tutorial review, practice & test games; Mission C)
Tuesday	Session 6 (JFC practice & test games; Mission C)		Sessions 6 (JFC practice & test games; Mission C)
Wednesday-Thursday	Sessions 7 & 8, respectively (JFC practice & test games; Mission D)	Thursday	Sessions 7 & 8 (JFC practice & test games; Mission D)
Friday	Session 9 (JFC practice & test games; Mission E)	Friday	Session 9 (JFC practice & test games; Mission E)
8-Week Nonpractice Interval			

Note: JFC = Jane's Fleet Command.

Table 2

Overview of Training Procedures: Retention, Transfer, and Reacquisition

8-Week Nonpractice Interval			
Distributed and Massed Acquisition/ Distributed Reacquisition		**Distributed and Massed Acquisition/ Massed Reacquisition**	
5 Days of Skill Retention, Transfer, & Reacquisition (7 sessions)		**3 Days of Skill Retention, Transfer, & Reacquisition (7 sessions)**	
Schedule	**Activity**	**Schedule**	**Activity**
Monday	Sessions 10 & 11 (JFC tests of retention & transfer, Missions E & F, respectively)	Monday	Sessions 10 & 11 (JFC tests of retention & transfer, Missions E & F, respectively)
Tuesday	Session 12 (JFC tutorial review, practice & test games; Mission B)	Tuesday	Session 12 (JFC tutorial review, practice & test games; Mission B)
Wednesday	Session 13 (JFC practice & test games; Mission C)		Session 13 (JFC practice & test games; Mission C)
Thursday	Session 14 (JFC practice & test games; Mission D)		Session 14 (JFC practice & test games; Mission D)
Friday	Sessions 15 & 16 (JFC practice & test games; Missions E & F, respectively)	Wednesday	Sessions 15 & 16 (JFC practice & test games; Missions E & F, respectively)

Note: JFC = Jane's Fleet Command.

Table 3

*Descriptive Statistics and Standardized Mean Differences between **Acquisition** Schedules on all Fleet Command Sessions*

Session	Distributed Acquisition		Massed Acquisition		d^a
	Mean	*SD*	*Mean*	*SD*	
Baseline					
0_A	-89.74	42.83	-90.97	43.78	0.03
Acquisition					
1_A	-56.51	45.55	-59.91	45.85	0.07
2_B	-56.99	48.23	-55.94	50.40	-0.02
3_B	4.98	12.93	1.77	16.56	0.22
4_B	14.51	25.01	5.60	19.37	0.40 **
5_C	-5.86	76.35	-7.21	59.48	0.02
6_C	7.91	36.19	7.12	38.58	0.02
7_D	-11.02	42.27	-15.99	47.10	0.11
8_D	-2.67	40.46	-2.14	37.82	-0.01
9_E	20.06	19.45	15.57	18.07	0.24 *
Retention					
10_E	19.01	16.81	11.01	17.98	0.46 **
Transfer					
11_F	-13.63	16.08	-14.56	16.49	0.06
Reacquisition					
12_B	22.50	20.65	17.86	21.32	0.22
13_C	23.21	31.11	17.57	33.18	0.18
14_D	6.79	41.76	2.41	37.66	0.11
15_E	23.71	18.06	19.22	16.54	0.26 *
Transfer					
16_F	-9.92	13.13	-11.21	14.74	0.09

Note. This training manipulation began with Session 2. Subscript, uppercase letters indicate the mission performed in each session. [a]In computing the *d*s, the distributed condition was treated as the experimental group (n = 100) and the massed condition as the control (n = 92). *p < .05, **p < .01 (one-tailed univariate tests based on the Hypothesis: distributed > massed).

Table 4

Descriptive Statistics and Standardized Mean Differences between ***Reacquisition*** *Schedules on all Fleet Command Reacquisition Sessions*

Session	Distributed Reacquisition		Massed Reacquisition		d^a
	Mean	*SD*	*Mean*	*SD*	
Reacquisition					
12_B	20.36	20.59	20.20	21.59	0.01
13_C	24.13	32.78	16.96	31.30	0.22
14_D	4.05	41.34	5.32	38.44	-0.03
15_E	23.51	15.52	19.66	19.04	0.22
Transfer					
16_F	-11.55	14.37	-9.56	13.43	-0.14

Note. This training manipulation began with Session 13. Subscript, uppercase letters indicate the mission performed in each session. [a]In computing the *d*s, the distributed condition was treated as the experimental group (n = 95) and the massed condition as the control (n = 97).

Table 5

Descriptive Statistics and Effect Sizes for the ***Nonpractice Rehearsal Conditions*** *on all Fleet Command Retention, Transfer, and Reacquisition Sessions*

	Mandatory Rehearsal		**Voluntary Rehearsal**		**No Rehearsal**		
Session	***Mean***	***SD***	***Mean***	***SD***	***Mean***	***SD***	η^2
Acquisition							
9_E	17.61	18.71	24.66	19.34	16.73	18.78	.02
Retention							
10_E	13.34	18.90	18.12	17.15	15.60	17.34	.01
Transfer							
11_F	-10.26	14.26	-11.42	16.38	-16.70	16.86	.04 *
Reacquisition							
12_B	21.26	25.34	19.05	18.54	19.98	19.01	.00
13_C	25.82	34.58	26.35	37.39	16.45	29.27	.02
14_D	7.52	33.26	4.64	31.50	3.16	44.49	.00
15_E	21.23	18.20	21.27	17.31	21.80	17.22	.00
Transfer							
16_F	-6.14	10.90	-9.73	12.07	-13.10	15.13	.05 **

Note. This training manipulation began after Session 9. Subscript, uppercase letters indicate the mission performed in each session. Mandatory rehearsal (n = 60), Voluntary Rehearsal (n = 22), and No Rehearsal (n = 110). *p < .05, **p < .01.

Table 6

Individual Differences Associated with Voluntary Rehearsal and Skill Retention, Transfer, and Immediate Reacquisition

Variable	Did view videos (n = 22) *Mean*	*SD*	Did not view videos (n = 54) *Mean*	*SD*	d^a	Retention r^b	β^b	Transfer *r*	β	Reacquisition *r*	β
Conscientiousness	128.41	18.38	120.89	21.98	0.37	-.04	-.05	.03	.04	-.11	-.13
Performance approach	3.69	0.87	3.48	0.87	0.24	.10	-.02	.02	-.04	.05	-.02
Mastery	3.93	0.70	3.60	0.63	0.50*	.08	-.07	.04	.01	-.01	-.15
Performance avoidance	2.39	0.85	2.31	0.83	0.10	-.09	.01	-.08	-.02	-.14*	-.01
Self-efficacy	3.98	0.58	3.61	0.67	0.59*	.25**	.25*	.12*	.05	.22**	.24*
Declarative knowledge	17.49	1.43	17.22	2.06	0.15	.11	-.03	.17*	.11	.21**	.10
g	26.18	4.58	26.81	4.56	-0.14	.22**	.20**	.15*	.12	.12*	.06
Skill acquisition	24.66	19.34	19.28	21.38	0.26	.27**	.19**	.14*	.09	.25**	.16*
R^2							.14**		.06		.14**

Note. Skill acquisition = mission effectiveness score in the last acquisition session (9). Retention, transfer, and reacquisition = mission effectiveness scores at Sessions 10, 11, and 12 respectively, after an 8-week nonpractice interval. β = standardized regression coefficient. [a]In computing the *d*s, the "did view videos" condition was treated as the experimental group and the "did not view videos" condition was treated as the control. [b]$n = 192$. *$p < .05$, **$p < .01$ (one-tailed testing the hypothesis that *r*s and βs would be positive, with the exception of performance approach and avoidance).