Examining Operational Skill Decay: Look Beyond the Null?

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ABSTRACT

Skills decay over time without practice or use. During operational tours, fighter pilots may fly fairly uneventful missions (e.g., combat air patrol) with few opportunities to employ their skills (in contrast to peacetime training missions). With fewer opportunities to practice, skill sets will decay. An extended uneventful tour of duty can therefore lead to less capable and less proficient pilots.

This paper reports results of a skill retention study conducted with operational F-16 pilots at the Air Force Research Laboratory (Mesa, AZ). One goal of the study was to identify skills that decayed over time. After participating in a week of Distributed Mission Operations (DMO) training, pilots' performance was assessed using objective mission outcome and process measures. Following a retention interval of three or six months (during which pilots continued normal Air Force duties), pilots' performance was reassessed. The study did not attempt to measure pure skill decay (i.e., no practice during the retention interval), but instead used a more realistic measure—residual skill decay. The operational duties performed by pilots during the retention interval provided some degree of practice that could moderate the decay of some skills.

Execution of the study revealed a host of challenges associated with measuring residual skill decay in an operational training environment, and the results did not reveal convincing levels of residual skill decay. However, we strongly suspect that decay did occur but that a number of factors prevented us from being able to detect it, including (a) small sample size (typical with longitudinal studies); (b) significant training gains for all performance metrics (ceiling effect); (c) highly experienced pilots (moderating decay); and (d) the nature of the practice obtained during the retention interval. We conclude with recommendations for overcoming these challenges and suggest looking beyond the traditional null hypothesis.

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INTRODUCTION

Skills decay over time without practice or use. This can be especially true for today's fighter pilots. During operational tours, pilots may fly many fairly uneventful missions (e.g., combat air patrol) with few opportunities to employ their comprehensive training. With fewer opportunities to practice their skills, it is no surprise that skill sets will decay. An extended tour of duty can therefore lead to less capable and less proficient pilots. This situation has been referred to as the "bathtub effect" (Willingham, 2000) which is characterized by a steep negative trajectory in readiness immediately after deployment that gradually levels out until standard training opportunities return. Another important factor affecting the skill of today's pilots is the decreasing availability of live fly training hours. Less frequent and/or lower quality live flight practice ultimately results in lower skill proficiency. The combined impact of these practice and retention issues can have a significant impact on fighter pilots' skill level.

Identification of the precise skills that decay is an important first step in developing and prioritizing the focus of deployed training. Targeting the skills that are vulnerable to decay can help to prevent decay, thus maintaining proficiency during deployment.

Pure vs. residual skill decay

We call attention to two definitions of skill decay that bear great significance on interpreting the data and drawing conclusions from the current work. Pure skill decay (Figure 1) is the change in performance during a retention interval in which <u>no</u> *additional training, practice or exposure to the required skills occurs.* Studies examining pure skill decay are most often performed in basic research laboratories where control of the retention interval is possible (e.g., allowing no practice).

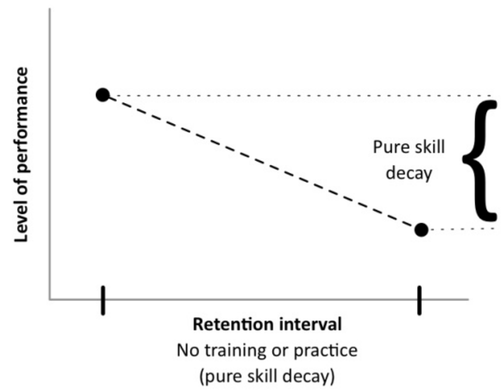

Figure 1. Pure skill decay during retention interval

For the purposes of operational studies, we introduce the notion of an operational retention interval in which *some degree of practice or training of required skills does indeed occur.* Operational retention intervals therefore can include both true retention intervals (where no training or practice occurs) and periods of additional training or practice (as implemented by Ford, Quiñones, Sego, & Speer Sorra, 1992). We therefore refer to the change in performance across the operational retention interval as residual skill decay (Figure 2). The decay is residual because the calculated level of performance at the second time point is the residual decay remaining after the positive impact of the additional training or practice of the required skills.

Examination of pure skill decay in an operational setting would be difficult (if at all feasible). The closest ideal case would be one in which pilots are deployed to a remote location with no ground-based training aids (e.g., no simulators or written or electronic training materials) and are also "grounded" from all flying (e.g., due to a safety concern). The current work examines residual skill decay during an operational retention interval where *no significant deviations from normal Air Force duties/training occurred.*

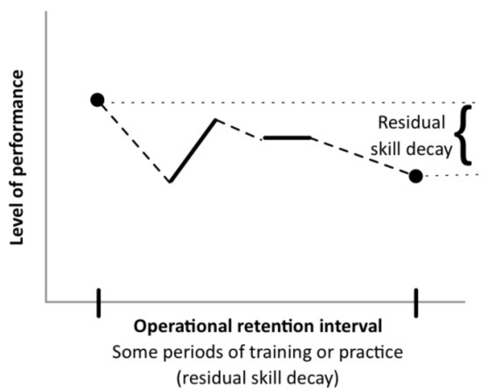

Figure 2. Residual skill decay during operational retention interval

Distributed Mission Operations (DMO)

While live training is an essential part of the warfighter's training curriculum, the integration of virtual and constructive training technologies into the live domain increases the relevance and realism of the training environment. The United States Air Force (USAF) is relying more upon Distributed Mission Operations (DMO) training to maintain pilot proficiency. DMO training environments consist of multiplayer, high-fidelity networked simulation environments enabling frequent training on higher-order individual and team-oriented skills. These DMO environments provide geographically distributed warfighters (local and/or long-haul) the ability to come together as a team to train against manned and/or simulated adversaries (Callander, 1999; Chapin, 2004). DMO training therefore provides important opportunities to gain battle-like experiences that are not frequently gained outside of war (or sometimes within a war), and also provides a number of experiences that could not previously be gained in peacetime training.

Using DMO training for skill maintenance or refresher training can be an effective means of helping pilots retain their skills. In 2006, the Warfighter Readiness Research Division at Air Force Research Laboratory (AFRL) in Mesa, Arizona conducted a series of comprehensive training effectiveness studies to better understand the effects of DMO training. These 2006 AFRL studies represent the largest DMO effectiveness dataset to date, consisting of 76 teams (384 pilots) and more than 3,000 engagements. The data includes objective performance data, participant surveys, subject matter expert (SME) ratings of performance, and knowledge structure tests (Schreiber & Bennett, 2006; Schreiber, Stock, & Bennett, 2006; Schreiber, Gehr, & Bennett, 2006; Schreiber, Rowe, & Bennett, 2006; Schreiber, DiSalvo, Stock, & Bennett, 2006). These studies suggest that DMO training provides an extremely effective environment in which to improve air combat competencies.

Factors affecting skill decay

Despite the strong evidence for the efficacy of DMO training, there is still little known about the decay of skills gained during this training. It is well established that skills decay without continued practice or use (Arthur, Bennett, Day & McNelly. 2002, Farr, 1986; Hancock, 2006; Henik, Brainin, Ze'evi, & Schwarz, 1999; Wisher, Sabol, Sukenikm & Kern, 1991). Research has identified a number of factors that impact the rate of decay (the slope of the dashed lines in Figure 1 and Figure 2).

Cognitive and accuracy-based tasks tend to be susceptible to decay while procedural knowledge (knowing how) decays more slowly than declarative knowledge (knowing what; Arthur, Bennett, Stanush, & McNelly, 1998). The skills required for continuous tasks (i.e., those without a definite beginning and end) tend to be more resistant to decay (Wisher et al., 1999; Henik, Brainin, Ze-evi, & Schwartz, 1999).

Similarly, dyadic or partnered tasks share some elements with continuous tasks (their continuous, interactive nature and numerous variations). They have been shown to be more resilient to decay than similar tasks of equal complexity that are performed individually (Arthur, Day, Bennett, McNelly, & Jordan, 1997), which is of special interest for the current study; examining the decay of *team* performance skills in a simulator environment.

Another important factor affecting skill decay pertains to research methodology. Arthur et al. (1998) found that the more similarity between the conditions of learning and conditions of retrieval, the less observed decay. Generally speaking, testing environments that closely resemble learning environments provide more cues to facilitate retrieval.

Given the task factors of the current study, effects of decay are expected to be limited. The procedural knowledge, continuous dyadic nature, along with the fact that the training environment is extremely similar to the testing environment, all indicate that the amount of observed skill decay may be small.

The most robust finding from research is that skill decay depends on length of the retention interval and opportunities for practice. The overwhelming consensus is that the longer the retention interval (period of no training or practice), the greater the pure skill decay. (Arthur, Bennett, Stanush & McNelly, 1998; Farr, 1986, Hurlock & Montague, 1982).

CURRENT STUDY

The current study had a number of goals including replication of *training gain* results from the within-simulator study (Schreiber & Bennett, 2006), and examination of residual skill decay and skill reacquisition during refresher training. This paper focuses exclusively on the residual skill decay results and attempts to answer the following questions:

Residual skill decay: How much of what pilots learn during DMO training is retained after operational retention intervals of three and six months (with continuous performance of normal Air Force duties)? Do skills decay more after six months than three?

Factors moderating residual skill decay: What factors moderate or lessen the degree of residual skill decay?

Measuring residual skill decay in an operational setting: How is residual skill decay best measured?

Methods

Each fighter pilot team consisted of a "four-ship" (four pilots, one in each cockpit/simulator). Four-ship F-16 pilot teams were randomly assigned to a three- or six-month operational retention interval condition. Upon arrival at the AFRL training research facility in Mesa, Arizona, F-16 pilots were familiarized with the simulator and were "benchmarked," (i.e., their performance was assessed using air-to-air point defense benchmark engagements) before commencing with the five-day training research program. This Pre-test performance measurement served as a baseline. At the conclusion of the five-day "Initial Training," performance was assessed again as a measure of *training gain*.

The pilot teams returned for a two-day "Refresher Training" session after their designated operational retention interval (three or six months). Performance was assessed on Day 1 and Day 2 of the refresher training. The comparison of Day 1 performance to the Post-test (from the initial training week) served as a measure of *residual skill decay*. The comparison of Day 2 performance to the Post-test served as a measure of *skill reacquisition* (another goal of the study, not discussed here).

As discussed earlier, this study examines residual skill decay. Therefore, pilots continued to perform normal duties and training events during the operational retention interval of the study. Demographics surveys were used to gather information about experience and training/practice opportunities as part of the data collection effort. Correlations between these variables and the amount of skill decay were analyzed to identify any *factors moderating residual skill decay*.

Participants

Twenty-seven fighter pilot teams (108 pilots) signed up for participation in the DMO skill retention research study. To be included in the study, operational F-16 squadrons were queried as to their availability during DMO training research weeks. Teams volunteering and available for <u>both</u> the initial and refresher training were selected to participate. As a study requirement, all four pilots in a team had to be available for both the initial and refresher training—no replacements were allowed under any circumstances. Due to the voluntary nature of participation and availability of pilots, the final sample was not completely random. As is common with longitudinal studies (and even more so in the current work where continued participation was required from an entire four-person team), we encountered difficulty retaining all the teams. Despite these issues, overall success in repeat participation was higher than expected.

Of the 27 teams (108 pilots), 18 teams (72 pilots) provided complete data for the entire study. Seven of the original teams were unable to return for the refresher training. Two teams experienced software malfunctions, rendering their data unusable. All study results are discussed in terms of the 72 participants for which a complete data set is available.

Sixty-nine of the 72 participants provided initial demographic information at the start of their DMO week. Participating pilots had a mean age of 31.9 years, a mean of 10.2 years of military service, and a mean of 930.0 hours of F-16 experience. Eleven teams were randomly assigned to the three-month group (N=44); the other 7 to the six-month group (N=28).

Data collected

Performance was assessed using a number of objective metrics automatically collected by the Performance Evaluation and Tracking System (PETS). PETS is a software tool that enables measurement at the individual and team level in complex Distributed Interactive Simulation/High Level Architecture (DIS/HLA) environment (Schreiber, Watz, Bennett & Portrey, 2003). Data was collected electronically at a rate of 5 Hz (five times per second), with many variables (600+) being collected at each time point. The data was extracted, aggregated, and analyzed at a level best suited for the measure of interest, e.g., outcome metrics were aggregated at the scenario level, while process metrics such as shot metrics were aggregated at the individual munition level. This aggregated objective data collected from the benchmark scenarios served as the primary basis for evaluating the residual skill decay.

The objective performance data collected for this study included outcome metrics as well as process metrics (see Schreiber et al., 2006 for a detailed description).

RESULTS

The full study examined training gains during the initial training week, decay over the operational retention interval and skill reacquisition during refresher training. An overview of the residual skill decay results during the operational retention interval are reported here, i.e., changes in performance from the Post-test (administered on the last day of initial DMO training) to Day 1 of refresher training. Complete results can be found in the AFRL Technical Report (Schreiber, Holt, Schroeder, Rowe & Bennett, in press).

Residual skill decay

A series of 2x2 Analysis of Variance (ANOVA) tests were conducted to identify differences in the means for each outcome and process metric.

Contrary to expectations, there were no significant changes (residual decay or gain) during the operational retention interval for the following:

- All outcome metrics, e.g., number of enemy strikers denied, closest distance achieved by strikers, number of viper mortalities, and proportion of viper missiles resulting in a kill.
- All weapons employment metrics, e.g., range, mach or g-loading at missile launch.
- All controls intercept geometry metrics, e.g., altitude between viper and threat.
- Four of eight weapons engagement zone (WEZ) management metrics, e.g., hostiles in minimum abort range and minimum 2D range to hostile.
- Three of four radio communication metrics, e.g., step-over duration.

A significant difference was found for one of the four radio communications metrics (step-over frequency among vipers), but the difference was an *improvement in performance* rather than the expected decay.

Similarly, performance *significantly improved* during the operational retention interval for four of the eight WEZ management metrics, e.g., time spent in minimum abort range.

There was a significant interaction effect of interval, length but only for five WEZ management metrics (an interaction was expected across all metrics). We expected the six-month group to show more residual skill decay than the three-month group (as predicted by research literature). However, for each of the five WEZ management metrics the three-month group showed significant decay as expected, while the six-month group showed *significant improvement* (Table 1).

Factors moderating residual skill decay

Despite the fact that only some residual skill decay was actually observed in the study, we wanted to see if we could identify factors that moderated the amount of residual skill decay. During the study, we attempted to collect experience information during the operational retention interval using a website survey.

Unfortunately, participation was poor, and information about the intervening experience was not adequately collected for analysis. As a result, we were unable to examine 'individual experience acquired during the operational retention interval' as a moderating factor.

A Pearson correlation was used to examine the relationship between team experience (calculated from individual F-16 flight hours and instructor pilot hours using a calculation developed by F-16 SMEs) and the magnitude of residual skill decay observed for various performance metrics.

Table 1. Interaction effect: WEZ management metrics

Metric name *(some metric scales reversed to show improvement)*	**Percentage improvement**	
	3-month group	**6-month group**
Hostiles in MAR (count) (scale reversed)	-37.10	+25.00
Hostiles in MAR (time) (scale reversed)	-41.51	+52.35
Hostiles in MAR-1 (time) (scale reversed)	-34.64	+55.42
Hostiles in N-pole (time) (scale reversed)	-15.15	+58.54
Minimum 2D range to hostile	-7.07	+23.40
All changes are statistically significant ($p < 0.05$).		

Any experience variable found to be negatively correlated to residual skill decay can be considered to be a moderating factor, i.e., greater experience corresponds to less residual skill decay. Only two significant correlations were found among the entire set of performance metrics. Both were detailed process metrics (e.g., loft angle at missile launch). No significant correlations were found for outcome metrics, therefore we conclude that team experience did not moderate residual skill decay in this study.

DISCUSSION

This study did not attempt to examine pure skill decay (i.e., no practice whatsoever during the retention interval), or even reduced skill decay (e.g., the "bathtub effect" while performing less than optimal training). Rather, we examined the residual skill decay after other *positive* intervening training and job events had been experienced by the participants. Therefore, participants in this study *continued to practice/train/hone their skills* under very normal training routines (thereby minimizing the likelihood of observing decay). This common situation has a number of very important implications for measuring decay.

Residual skill decay

Residual skill decay results revealed no significant residual decay for any of the outcome metrics. The fact that we observed statistically significant training gains (results not reported here) for nearly all outcome metrics may help to explain the lack of an observed residual decay effect. Ceiling effects during initial training would make decay difficult to measure.

Examination of residual decay on process metrics revealed some interesting results. We expected to observe significant residual decay for metrics examining hostile penetration into potentially dangerous regions (e.g., minimum abort range). We did consistently observe this precise effect on these metrics, *but only for the teams who participated in the three-month condition*. We observed the exact opposite effect—actual improvement—by teams in the six-month condition. This is a highly unusual and unexpected result. We would have expected that *both* groups would have exhibited residual decay on these metrics, and that the residual decay would be more pronounced for the six-month teams.

Moderators of skill decay

We attempted to track pilots' weekly duty activities during the operational retention interval. Normal day-to-day events were to be documented via website data collection methods. Each week, participating pilots were asked to fill out a web form that asked for the major activities they performed each day (e.g., continuation training sortie, day off, Flag participation, administrative, AMRAAM school, etc.). Participation was strictly voluntary, and not a single pilot completed all the tracking requirements asked of them. This was a major disappointment in the current work. In future studies, we highly recommend that participation in tracking efforts should be mandatory.

We also attempted to use demographic data (e.g., updates in flight qualification, number of total flight hours, number of IP hours, etc.) to document experience obtained during the operational retention interval. Our intent was to examine the amount of job-related practice obtained during the operational retention interval as a moderating factor of residual skill decay.

The only moderating factors we were able to examine were those associated with pilot experience at the start of the initial training. Despite the relatively small residual decay effects observed, we did find statistically significant moderators of residual decay, but the moderators were limited to a few process metrics and not mission outcomes. Consistent with the literature, we did find that experience in general (e.g., F-16 hours, IP hours, years in service) moderated the amount of decay for these metrics. Participating pilots in this study were high in experience overall (over 900 F-16 hours). Replicating this study with lower experience pilots may reveal larger residual decay effects and possibly reveal moderating effects for more metrics. At this higher overall level of experience, we might expect the moderator effect to have reached asymptote (that is, once you are experienced, adding yet more experience may not further the moderating impact).

RECOMMENDATIONS

Residual skill decay results were not as prominent as we expected. There are several factors in this study that we believe reduced both the number of significant residual decay results and the magnitude of the residual decay effect. Each factor is discussed in turn along with recommendations for overcoming them in future studies.

We suspect that the **small sample size** had some impact on the residual skill decay results. Only 18 teams completed the longitudinal study. Though the residual skill decay results did not achieve statistical significance on many of the metrics, residual decay was observed relatively consistently across most metrics (primary exception being WEZ management for 6 month teams). Assuming additional teams would perform in a similar manner, a larger sample size would reveal these same residual decay effect sizes as statistically significant. We speculate that the true residual decay effect size is actually larger than that observed here.

Another factor affecting the residual skill decay results was the **experience level of the participants**. The literature strongly supports the assertion that experience moderates decay. In this study, the *average* experience was quite high (over 10 years in the Air Force and over 900 F-16 hours). Replicating the study with less experienced pilots would likely reveal greater residual skill decay.

Ceiling effects are another potential factor contributing to the failure to observe residual skill decay results. By the end of the training (first) week, pilots were performing largely at ceiling as virtually all missions were successful. Actual pilot performance may have been *above* what we were able to detect (i.e., their performance may have been exceeding maximum measureable performance of 100%). Even if pilot performance did indeed actually decay during the operational retention interval (e.g., from 120% to 95%), it was measured as an insignificant level of residual decay due to observed performance at the end of training being constrained by a ceiling effect. Future studies can circumvent this limitation by developing more accurate measures of maximum performance (and/or by using more complex missions).

An even greater threat to observing/measuring residual skill decay effects in this study was the **advance preparation of teams**. A number of the pilots had previously participated in DMO training at Mesa before the study so they had prior knowledge of the nature of the engagements and overall training syllabus. It is also highly possible that some teams specifically practiced or prepared for their refresher training trip. Before the initial training visit, pilots did not know exactly what to expect. The benchmarks were designed to be complex and challenging; subsequently, many teams were humbled by their performance at Pre-test (beginning of the initial training week). Motivation and practice was typically intense during the rest of the initial training week and performance at Post-test (end of the week) was noticeably higher, both in this study and in our prior work with a different sample of pilots (Schreiber & Bennett, 2006). It is possible that some of the participants prepared for their return trip; even if they did not explicitly set aside specific training time, they likely thought about challenges from their first visit and, expecting a similar experience, mentally prepared for many of those same challenges.

Perhaps the strongest factor impacting the results is the fact that the study measured residual skill decay. The **pilots actively practiced** during the operational retention interval, rather than sitting idle for three or six months. The study participants were operational pilots who performed their *normal, uninterrupted duty training events during the operational retention interval.* Hence, not only did this study examine residual decay, but the examination was of an extreme (i.e., minimal) condition of residual decay. The pilots continued to do their operational job day after day, week after week, month after month throughout the operational retention period. They gained experience and practiced their skills during the operational retention interval (two important decay moderators). Many of the intervening days involved continuation training of one form or another.

As soon as the pilots left the initial week of DMO training in this study, they continued on-the-job daily training and practice. This may very well have resulted in periods during the operational retention interval where performance actually *improved* or the practice was sufficient to negate any decay effects (resulting in a maintained level performance). Pure skill decay may therefore only have occurred during portions of the operational retention interval (as depicted in Figure 2).

Traditional skill retention studies aim to reject the null hypothesis of "no change in performance" by looking for changes over the retention interval. Recognizing the impact of the periods of training or practice require us to look beyond the null. We must not only look for changes in performance, but we must also closely examine the operational retention interval to identify the true retention interval (where no training or practice occurs and skill decay is expected) to arrive at an accurate estimation of rates or pure skill decay.

This approach would significantly impact the interpretation of study results. In the current study, the operational retention intervals were three and six months in length, but without information about the opportunities for training and practice, we have no accurate measure of the length of the actual retention intervals. Without more detailed information on pilots' day-to-day duties, and training and practice opportunities, we also have no information about which skills are targeted during those periods.

The confounds associated with the operational retention interval provide a possible explanation for the surprising result that the three-month group showed decay on some measures while the six-month group showed improvement. The three month group could have been tested during a period of no training or practice (where their skills were actually decaying) while the six month group may have been tested during a time when they were actively improving their skills.

We encourage the educated reader, while interpreting the decay results reported herein, to recognize that the three- and six-month intervals were not true retention intervals. Some training and practice was occurring and this must be accounted for in the results.

To obtain continual improvement of skills without significant decay, we need to identify the skills which are susceptible to decay then target them in training. As this study illustrates, measurement of skill decay in an operational setting has its challenges. We believe many of the challenges can be overcome so that decaying skills can be accurately identified.

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