THE APPLICATION OF ABOVE REAL-TIME TRAINING (ARTT) FOR SIMULATORS: ACQUIRING HIGH PERFORMANCE SKILLS

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ABSTRACT

The Above Real-Time Training (ARTT) concept is a unique and virtually untested approach to training high performance skills. ARTT refers to a training paradigm that places the operator in a simulated environment that functions at faster than normal time. Such a training paradigm represents a departure from the intuitive, but not often supported, feeling that the best practice is determined by the training environment with the highest fidelity. Such a training paradigm is hypothesized to provide greater "transfer value" per simulation trial, by incorporating novel training techniques and instructional features into the simulator. These techniques may allow individuals to acquire these critical skills faster and with greater retention.

In this study, 25 naive male subjects performed three tank gunnery tasks under varying levels of time acceleration (i.e., 1.0x, 1.6x, 2.0x, sequential, and random). The subjects were then transferred to a standard 1.0x condition for testing. Every accelerated condition or combination of conditions produced better training and transfer than the standard real-time or 1.0x condition. Most effective was the presentation of trials at 1.0x, 1.6x, and 2.0x in a random order during training. These findings appear to be consistent with previous findings that show positive effects of task variation during training. Moreover, ARTT has merit in improving or maintaining transfer with sharp reductions in training time. Other implications for ARTT are discussed in this paper, along with future research directions.

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INTRODUCTION

Training is big business. The armed forces alone spend in excess of $20 billion annually. Most of the emphasis is on training high performance critical skills which allow the individual to perform complex real world tasks requiring smooth integration of numerous subtasks and subskills. Computer-based simulators and trainers are progressively serving as the mechanism for imparting these skills. Simulators are also expensive, with high fidelity flight simulators costing about $30 million each. The problem centers around ways to reduce training time and thus costs, or to obtain greater "transfer value" per simulation trial, by incorporating novel training techniques and instructional features into the simulator. These techniques should allow individuals to acquire these critical *skills faster and with greater retention.*

Much of the literature dealing with skill learning/ skill acquisition relates to learning relatively simple and self-contained skills (e.g., target tracking). Other than continued and extended practice, we know very little about how to foster or accelerate the acquisition of high performance skills. Schneider (1985) defines a high performance skill as one for which (1) more than 100 hours of training are required to develop proficiency; (2) a substantial number of individuals fail to develop proficiency; and (3) there is a qualitative yet distinct difference in novice and expert performances.

The Above-Real-Time Training (ARTT) concept is a unique and virtually untested approach to training high performance skills. ARTT refers to a training paradigm that places the operator in a simulated environment that functions at faster than normal time. In the case of air combat maneuvering, a successful tactical air intercept which might normally take five minutes would be compressed into two or three minutes. All operations of the intercept would correspondingly be accelerated, such as airspeed, turn and bank velocities, weapons flyout, and performance of the adversary. In the presence of these time constraints, the pilot would be required to perform the same mission tasks to the same performance criteria—as he would in a real time environment. Such a training paradigm represents a departure from the intuitive (but not often supported) feeling that the best practice is determined by the training environment with the highest fidelity. ARTT can be implemented economically on existing simulators. It is important to realize that ARTT applications require the increase of the simulated velocity of the targets and other entities, <u>not</u> the increase of the update rate.

The only known published study that investigated the ARTT concept was conducted by Vidulich, Yeh, and Schneider (1983). The researchers in that study examined the utility of time compression as a training aid for training a basic air traffic control skill (a high performance skill). The task required the subjects to direct an aircraft through a single turn in order to have the aircraft pass through a specific point at a specific heading. The researchers trained two groups, each for three hours. One group practiced the intercept with the target plane travelling at 260 knots. The subjects in this group received between seven and nine trials per hour during training. The second group practiced the intercept at 5200 knots—20 times real time! The subjects in this group received between 72-80 trials per hour during training. Both groups were then tested in real time. The time compressed group was significantly better at identifying the turn point; there was no difference between groups on estimating rollout heading for the intercept. The authors stated that these results clearly supported the utility of time compressed training. They were also convinced that many other components of air intercept control skill could benefit from such training.

For years, the professional water skier has used the ARTT principle. When practicing for the slalom event, the boat driver is instructed to exceed the required course speed, thereby decreasing the skier's time to run the course and making the practice runs more difficult. During competition, the course is then run at a perceived slower (and easier) speed.

THEORETICAL UNDERPINNINGS

Humans can judge time extremely well. There is nearly a perfect relationship (i.e., a 1:1 power function based on a log scale) between actual versus perceived time judgements (Stevens, 1975, Fraisse, 1984). The ARTT principle is based in part on accelerated time frames of reference. ARTT seeks to exploit human perception of time, and is analogous to Einstein's space-time frame of reference. Specifically, each person has a time norm frame of reference which links measures of time and space to an observer. This norm is relative and is set by the speed of events around that individual. The norm can be moved up or down by changing the speed of sensory cues. To illustrate, Holubar (1969) was able to alter human judgment of time using light flicker in a darkened room. He was able to show that a temporally conditioned galvanic skin response (GSR) can be specifically altered by changing the flicker rate of the light source. Slower flicker rates of seven, fourteen, and fifteen per second produced a decrease in the GSR intervals. The average response decrease was on the order of one half the originally temporal conditioning. Holubar's findings support the concept of a time norm and its adjustability through environmental visual/perceptual cues. Also consider the example of traveling at different speeds in a car. When you first reach 120 miles per hour (mph) in a car, it seems fast, but after a few minutes your norm resets to the new time frame of reference and 120 mph now seems normal. When you slow down to 60 mph it seems slow, and you seem to have long subjective times between events. The large subjective time remains until the norm resets.

When this subjective time reference is perceived as long, it may offer a unique advantage for providing training on critical high performance skills. This artificially accelerated frame of reference may give the operator more "time" in which to actually perform key elements of the mission. It is important to note that when using ARTT, more compressed training trials can be performed in the same amount of time. The very realization that they have more time may lead to better decision making and situational awareness. It may give them the edge that makes the difference in today's modern battlefield.

More training trials per unit time is reason enough to implement ARTT. As long as no negative training is introduced, more economic training can occur on existing simulators. The simplest case for ARTT is improved simulator usage either by more trials per unit time per trainee, or higher trainee throughput.

There is virtually no literature to directly support or refute the ARTT concept. There is, however, some well-rooted research in skill acquisition and, specifically, the phenomena of automaticity and contextual interference which provide indirect theoretical support for the benefits of ARTT. Much of the impetus to pursue this research came from strong anecdotal evidence from NASA between 1960-1980 in which ARTT was implemented on a few occasions with astounding success (J. Kolf, personal communication, April 12, 1973). Unfortunately, the research was not formally documented.

Implications for Skill Acquisition

The research literature dealing with very high skill training suggests that such skills may be a separate and distinct class of skills. In fact, Lane (1987) reports that much of the mainstream research on learning and training does not generalize well to the unique environments of military training. Shiffrin and Schneider (1977) have provided us with the "automaticity" of behavior in which the execution of a task has evolved over extended practice or performance to a stage of highly integrated semi-voluntary control of task activities. Schneider (1985) states that the acquisition of high performance skills is very similar to the formation of automatic behaviors. Critical high performance skills that are practiced at least in part in an ARTT environment could lead to a faster acquisition of automaticity patterns of performance, less opportunity for memory decay, and a sustained level of motivation during training. Analogously, ARTT can be considered as over-training in the time dimension.

Performing a new task that is inherently difficult will probably lead to poor task performance initially; however, the transfer or retention of that skill may be superior to learning the same skill under real time conditions. This phenomenon is generally referred to as "contextual interference" (Shea & Morgan, 1979) and is well supported in the literature (see Lane, 1987 for an overview). With respect to ARTT, a new task that is practiced and learned in accelerated time (i.e., a difficult task) would require the learner to expend more than normal attention and effort, and hence accelerate the development of automaticity patterns. When the learner then performs the task in the real time environment, less effort and attention would be expended during a perceived "longer" than normal time to perform the task; superior performance would likely result. It could also be advantageous to provide varying levels of acceleration during training. Lee and Magill (1983), among others, have suggested that a broader range of task conditions can enhance both transfer and retention.

The bulk of support for ARTT comes from anecdotal reports from NASA and Northrop. Researchers at the NASA Dryden Flight Center during the X-15 program in the late 1960's needed a mechanism to address the X-15 test pilots' post flight comments of being "always behind the airplane..." and feeling like they "... could never catch up". What was needed, the researchers thought, was a way to provide a fast time simulation. Unfortunately, the analog computers at the time were only simulating some instruments. The first time NASA used fast time simulation was toward the end of the M2F3 lifting body program. Pilots compared practice runs at various time constants with flights they had already flown. A fast time constant of 1.5 felt closest to their flight experience and was planned on being implemented, but the program was canceled before the capability was fully developed.

RESEARCH OBJECTIVES

The objective of this task is to conduct research regarding: (1) the relative effectiveness of ARTT versus conventional training; (2) the relative effectiveness of alternative implementations of ARTT; and (3) the impact of ARTT versus conventional training on total training time.

METHOD

Subjects

Twenty-five male undergraduate students from the University of Central Florida served as subjects for this experiment. The median age of the participants was 23 years. All subjects were recruited on a voluntary basis in accordance with American Psychological Association (APA) Principles for Research with Human Subjects. Prior to testing, subjects were informed as to the general nature of the experiment, and were required to read and sign an informed consent form. Subjects reported themselves to be in good overall health prior to testing.

Apparatus

The M1 Videodisk Interactive Gunnery Simulator (VIGS) was used for this experiment. The VIGS is manufactured by ECC International Corporation, and is designed as a table-top part-task gunnery trainer for M1 or M1A1 tank gunners. The VIGS utilizes computer generated imagery to present engagement scenes to the user. These scenes, along with target identification slides, are presented, modified, and stored via laser videodisc. For the purpose of this study, four "missions" or tasks were selected (for a more detailed explanation of the tasks performed, see the "Tasks" section below). These lessons had previously been stored on the videodisc by ECC. Through the use of synthesized speech, the subject is presented information regarding the target type, required ammunition, and fire instructions.

Experimental Design

This study used a transfer of training experimental paradigm. Data were analyzed within a three-way mixed Analysis of Variance (ANOVA) framework. The between-groups factor was time acceleration group. This factor had five levels: 1.0 (real-time), 1.6x, 2.0x, random, and sequential. In the random group, subjects were presented with a random presentation of the first three time constants. In the sequential group, subjects were exposed to progressively higher time constants (i.e., 1.0, then 1.6, then 2.0). The two within-group factors were segment (either training or transfer), and task (either training task 1, 2, or 3). For the training segment, each subject received 20 trials, the first five of which were considered familiarization, and were not subjected to further analysis. The transfer segment consisted of six trials. Dependent variables included a gunnery index that was calculated using the opening time (i.e. time to fire), time to kill, azimuth and elevation errors, and hit/miss percentages (Hoffman and Morrison, 1987). Also calculated individually were minutes of practice, mean time to kill, and hit/miss percentage. All dependent variables were collected after every trial for every subject.

The power of this experimental design expressed as $1-\beta$ for a given effect was calculated at .86. This value exceeds the recommended power guideline of .80 suggested by Cohen (1988).

Training Tasks

The three tasks that were used for this study are listed and explained below. A task ends when the subject "kills" the target(s) or when the task times-out. Each task is normally about 45 seconds in duration when performed at real-time. The VIGS requires about 25 seconds to load a new task regardless of the assigned time acceleration.

<u>Task 1</u> In this task, the subject was provided with daytime color images depicting a helicopter moving essentially from left to right over trees and grassy terrain at a range of approximately 2000m, and an altitude of 300 ft.

<u>Task 2</u> In this task, the subject was provided with night infrared images depicting a helicopter resting on the ground amid some trees. When the task begins, the helicopter takes-off, climbs to about 200 ft. and begins to move essentially from right to left at a range of 2000m.

<u>Task 3</u> In this task, the subject was provided with night infrared images depicting a tank moving essentially from left to right just beyond some buildings and structures representing a town. The view the subject sees is down a road and just beyond and between two buildings. The range of the tank is 1600m.

Procedure

Subjects were randomly assigned to one of five time acceleration groups (i.e., 1.0, 1.6, 2.0, mixed, or sequential). Prior to participating in this study, each subject read and signed an informed consent form. This form explained the nature of the experiment and the tasks that were to be performed, as well as the basic operating instructions of the VIGS. The experimenter then demonstrated the function of the gunner's control handles, and then asked the subject if he had any questions. The final part of familiarization involved the subject performing five practice trials at real-time (i.e., 1.0). In the familiarization task, the subject was provided with daytime color images depicting a desert-type terrain with two tank moving essentially from right to left. The terrain has gentle hills, but is otherwise without any features. The range of the two tanks is approximately 2000m. The purpose of this familiarization phase is to allow the subject to become acquainted with the operation of the VIGS.

Next, the training phase was presented. In this phase, the subject performed fifteen randomly presented trials, with each of the three training tasks being performed five times under an assigned time acceleration. After the training phase, the subjects were presented with six random transfer trials at real time, with each of the training tasks being presented twice. Finally, each subject was debriefed regarding the precise purpose of the experiment.

RESULTS

Data were analyzed using the GB-STAT statistical package (version 3.0) for the personal computer (Friedman, 1991). The design structure for analysis is outlined in the Experimental Design section. Four separate ANOVAs were conducted using this design, one for each dependent variable. In the presence of significant main effects or interactions, *post hoc* pairwise comparisons among means were performed using the least significant difference (LSD) method.

Separate analyses were first conducted using two measures of tank gunnery proficiency, the gunnery index and the hit/miss percentage. Analysis of the these two dependent variables showed a significant group x testing phase interaction for the gunnery index ($F_{2,149} = 2.8$, $p < .05$), and the hit/miss percentage ($F_{4,149} = 3.70$, $p < .02$), respectively. In both analyses, the group trained under random time accelerations performed significantly better in transfer than either of the other four groups, while the standard 1.0x group performed worse in transfer than in training. Table 1 provides means on the gunnery index and hit/miss percentage variables for training and for transfer phases across all groups. These data are also graphically portrayed in Figures 1 and 2.

Table 1. Means by group and testing phase for gunnery index and hit/miss percentage [1]

Group	Testing Phase: Training	Testing Phase: Transfer
1.0x	56.9 (.45)	44.8 (.35)
1.6x	52.2 (.47)	56.5 (.55)
2.0x	55.3 (.57)	60.2 (.56)
Sequential	55.5 (.51)	58.2 (.62)
Random	62.8 (.56)	66.5 (.80)

[1] Means of the gunnery index are in normal typeface; means on the hit/miss percentage are in parentheses.

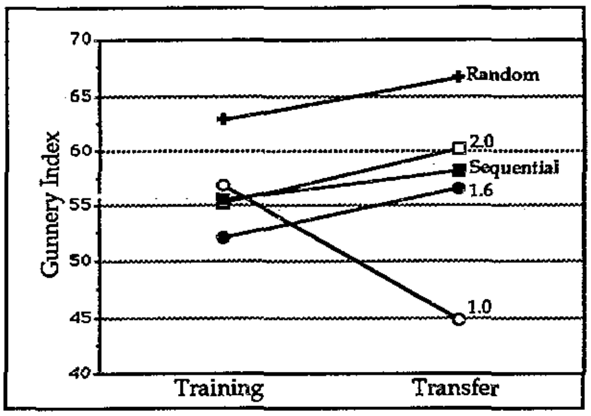

Figure 1. Gunnery index by group and testing phase

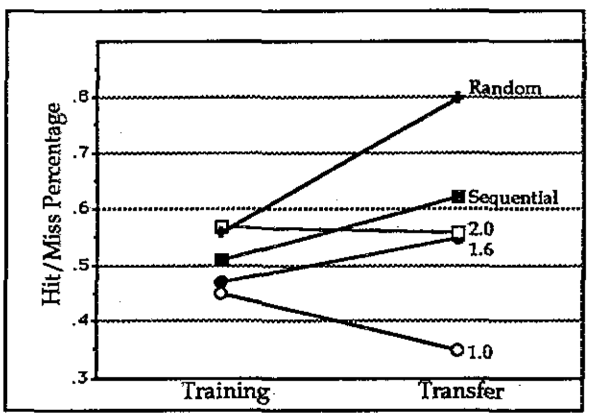

Figure 2. Hit/miss percentage by group and testing phase

There was also a significant main effect for task type using two separate measures as indicators task difficulty. First, using the gunnery index, Task 3 was the easiest, while Tasks 1 and 2 were more difficult ($F_{2,149} = 12.8, p < .0001$). Second, using the mean time to kill measure, the objective of the task was met quicker in Task 3 while Task 1 and 2 took significantly longer ($F_{2,149} = 36.16, p < .0001$). For this latter measure, there was also a significant task x testing phase interaction ($F_{2,149} = 9.06, p < .0008$). Specifically, for the easier task (i.e., Task 3), there was essentially no improvement from training to transfer; however for the other more difficult tasks, there was a significant decrease in the time-to-kill from training to transfer (see Figure 3). This finding may indicate that the effectiveness of ARTT could be linked to task difficulty. This point seems to be in line with what we know about high performance tasks.

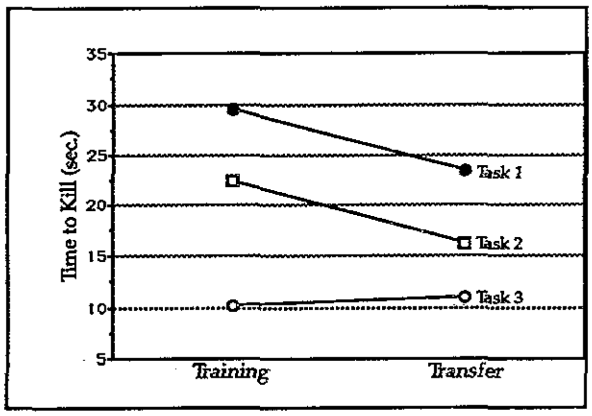

Figure 3. Time-to-Kill by task and testing phase

Finally, as expected, those trained in the four time accelerated groups received significantly less practice time than the real-time or control group ($F_{4,149} = 9577862, p < .0001$). Figure 4 shows actual training time as a function of group assignment. The 2.0x group, for example, received 50% less practice time than the 1.0x group. The sequential and random presentation groups received roughly 25% less practice time than the 1.0x group. This observation, taken with the results of the other analyses, shows that a significant reduction in training time can be achieved with performance staying equal to or surpassing a real-time control group.

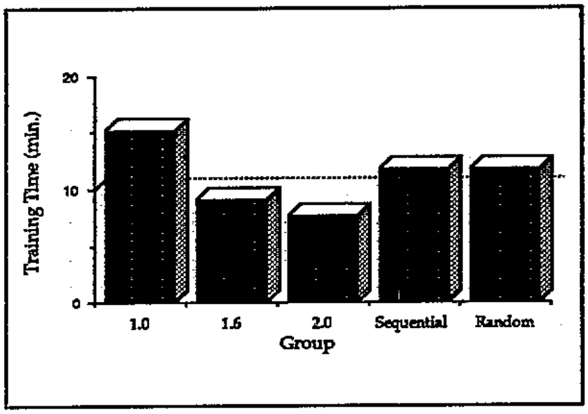

Figure 4. **Training time by group**

DISCUSSION

A random assignment or order among the three time accelerations (i.e., 1.0x, 1.6x, and 2.0x) appears to be the most effective condition for achieving the highest performance, both during training and transfer. ARTT also saves simulator time. It also represents about a 25% reduction in training time compared to the nominal or standard 1.0x condition. This is consistent with suggestions from Lee and Magill (1983), among others, that increasing the variability of task conditions during training might produce greater transfer. However, these findings show that improved performance for accelerated conditions is not consistent with the majority of literature in contextual interference. This literature base predicts degraded performance in training that is then associated with greater transfer performance. Such a discrepancy may be due to a relatively extended training period (five familiarization plus 15 training trials) during which the benefits of accelerated practice were sufficiently realized to enhance performance during the late trials of practice. This discrepancy could also be due to the fact that the accelerations used were not large enough to cause the training/transfer contrast. This is an expected area of future research.

Findings on the hit/miss percentage generally concur with those from the gunnery index analysis. There is a steady trend of increasing performance between the standard 1.0x condition and the random condition, with both 1.6x and 2.0x also superior to 1.0x, while 1.0x shows a performance decrease from training to transfer. Restated, all the experimental conditions involving accelerated trials generally produced improved performance in both training and transfer. Results from the gunnery index analysis showed less differentiation of conditions, both in training and in transfer, than results using the hit/miss percentage. The gunnery index is an extremely complex index involving calculations of ratios and ratio products, and may be differentially sensitive to the accuracy effects reflected in the hit/miss percentage. Part of our further research in the area of ARTT will focus on the development of consistent and appropriate metrics.

While these finding are strongly supportive of enhanced transfer from ARTT, it should be noted that the present tank gunnery tasks using the VIGS involved largely psychomotor coordination, with minimum demand for planning or for higher-order cognitive functioning. These results, while highly encouraging, are not necessarily generalizable to all other tasks regardless of content. Other ARTT work in progress is examining the effects of accelerated training on a series of pilot tasks in an F-16 part-task simulator. Results of these studies will provide important information about the tasks and task content for which ARTT is most likely to be useful.

CONCLUSION

ARTT worked for tank gunnery training using naive subjects with a part-task tank gunnery simulator. Every accelerated condition or combination of conditions produced better training and transfer than the standard real-time condition. Most effective was the presentation of trials at 1.0x, 1.6x, and 2.0x in a random order during training. This is consistent with previous findings regarding the positive effects of task variation during training.

The theoretical implications of these findings are not entirely clear at this point. That is, we cannot at present explain why ARTT works. Further study with a broad range of task content and task difficulties would be required to develop a more refined group of theoretical underpinnings. This initial study, however, suggests strongly that ARTT has merit in improving or maintaining transfer with sharp reductions in required training time.

FUTURE RESEARCH DIRECTIONS

Some future research areas for ARTT include:

- Applications for emergency procedure training.
- "Intelligent" simulators that can be made "time

adaptive". A slower than real-time training environment can give a novice the needed positive reinforcement early in the learning curve, and/or give the instructor the ability to slow the simulation to stress important learning events. Faster than real-time can be used to challenge the performer who may have achieved performance asymptote.

- Development of a model that relates task difficulty, trainee proficiency level, and desired performance level for optimal ARTT acceleration rates.
- Some basic research assessing the area of human time adaptability.
- ARTT applications for mission rehearsal.

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