Transfer of Training from Simulations in Civilian and Military Workforces: Perspectives from the Current Body of Literature

Advanced Distributed Learning

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Abstract

Computer-based simulations are an important training tool for teaching skills, in a low-risk environment, that are too dangerous, high-stakes, or expensive to acquire through real-life, on-the-job experience. They have been shown to produce positive learning outcomes, but learning does not necessarily equate ability to perform tasks on the job. Even if learning does occur within a simulated environment, if that learning does not result in transferable skills, the training is for naught. Though reviews on the subject of transfer of training from simulations have been done in the past, but have focused almost exclusively on flight simulators. This review surveys the existing body of literature on the history of simulations, methods for assessing transfer from simulations, and the effectiveness of simulation-based training on skill transfer, in the fields of both civilian and military workforces. It also examine what features of simulations may improve the level of training transfer from simulations, and gives recommendations for future study.

Transfer of Training from Simulations in Civilian and Military Workforces: Perspectives from the Current Body of Literature

Simulations, broadly defined, are artificial representations of one process, system, event, or situation through the use of another process, system, event, or situation, meant to operationally model that which it represents (Lammers, 2007; Ruggenberg, 2008; Simulation, 2009). Computer-based training simulations are advanced technology-based apparatuses designed to teach learners work-related skills by modeling, in a low-risk environment and with some degree of realism, on-the-job situations (Sitzmann & Ely, in press). Simulations are an important training tool. They are an obvious way to train skills, in a low-risk environment, that are too dangerous, high-stakes, or expensive to acquire through real-life, on-the-job experience. Though it was at one time the only option, we wouldn't dream nowadays of putting a pilot into a plane and saying "learn as you go." Similarly, we would not expect a surgeon to learn to perform operations through trial-and-error on live human patients. In some cases, it is actually illegal to purposefully subject trainees to the types of experiences they would need to learn certain skills. For instance, it is illegal to purposefully subject multi-engine aircrafts and most general aviation aircrafts to the stress that would induce the kind of aerial acrobatics commercial pilots need to learn to recover from when flying planes (Rogers, Boquet, Howell, & DeJohn, 2007, 2009). Additionally, in the military field, peacetime rules may impose weather and altitude restrictions on flight, limited resources may constrain the number of crafts and pieces of equipment obtainable for training, and security restrictions may prevent the use of certain systems or tactics (Bell & Waag, 1998).

Of course, this is why we have textbooks, flight manuals, and cadavers. But it is well established in the existing body of literature that simulations have the potential to reduce the number of training hours necessary to reach proficiency compared with other methods of training (as shown in Smode, Hall, and Meyer's 1966 review). Additionally, Sitzmann & Ely's (in press) meta-analysis on the effectiveness of simulation games (defined as "instruction delivered via personal computer that immerses trainees in a decision-making exercise in an artificial environment in order to learn the consequences of their decisions," p. 7, a similar enough definition to the one in this review to be considered valid) highlighted the ability of desktop-delivered simulations to increase post-training self-efficacy, declarative knowledge, procedural knowledge, and retention (Sitzmann & Ely, in press). These are all positive learning outcomes, but learning does not necessarily equate ability to perform tasks on the job. Being able to take the material learned in training and apply it to dynamic situations outside the training environment is called *transfer* (Baldwin & Ford, 1988; Newstrom, 1984; Wexley & Latham, 1981). Even if learning does occur within the simulated environment, if that learning does not result in transferable skills, the training is for naught.

Reviews on the subject of transfer of training from simulations have been done in the past, but have focused almost exclusively on flight simulators (Bell & Waag, 1998; Koonce & Bramble, 1998; Smode, Hall, & Meyer, 1966; Valverde, 1966). The goal of this review is to update and expand upon such reviews by surveying the existing body of literature on the history of simulations, methods for assessing transfer from simulations, and the effectiveness of simulation-based training on skill transfer, in the fields of both civilian and military workforces. It will also examine what features of simulations may improve the level of training transfer from simulations, and give recommendations for future study.

History of Simulations

Simulations, albeit not computerized ones, have been utilized in training since the 1920s (Valverde, 1968). The Link Trainer, an early flight simulator developed by Ed Link between 1927 and 1930, was an engineless plane that sat on a series of organ bellows. An instructor would inflate and deflate the bellows to various heights to make the trainer plane bank, climb, and dive, and the trainee would respond accordingly inside the plane (Roberson Museum and Science Center, 2000). A similar engineless plane trainer was tethered to the ground and mounted from a pylon atop a windy field. The wind would then blow over the control surfaces and provide motion cues to the pilot, who would then respond. The only problem—a fatal one—was that while the wind would provide bodily motion cues within the vestibule of the plane, it had the effect of warping the plane's control surfaces, teaching pilots to rely on bodily cues rather than trusting the instruments they were using (Koonce & Bramble, 1998).

Some of the problems of early flight simulations were solved by the development of electro-mechanical simulations. These were able to generate motion cues for the pilots that were synced with the controls of the simulator, allowing them to rely on their instruments (though their capabilities were limited to a handful of maneuvers such as pitch and roll and yaw). Most of these simulations, in their inception, relied on "cyclorama," a circular curtain or wall with a horizontal stripe on which moving pictures were projected, for their visuals. However, with the advent of television, simulators started utilizing realistic terrain model boards, though in a limited capacity. As time went on, they also started to feature larger screens or arrays of screens and better projection techniques for visuals (Koonce & Bramble, 1998).

When the earliest analog computer simulations were invented, they were initially developed for purposes other than training. The first large-scale use of a computer simulation was a product of WWII and the Manhattan Project: a simulation that consisted of 12 hard spheres that used a Monte Carlo algorithm to simulate the course of a nuclear bomb detonation (Lavery, 2008). Subsequently, in 1947, a simple computerized simulation that modeled a missile firing at a target, whose trajectory and speed were adjusted by knobs, was developed by Thomas T. Goldsmith, Jr. and Estle Ray Mann. Then in 1958, Willy Higginbotham invented a computer simulated tennis game, displayed on an oscilloscope, that could be played by two people at once using hand controls, making it the first multi-player simulation (Winter, 2006-2010). It was not long after the development of these simulations that the potential for simulation technology to be used as a training device began to be realized. The analog computers that were available at the time began to be utilized to rapidly resolve the dynamic models of flight simulation and control the "strip charts" on which a trainee's performance in a simulator was charted (Koonce & Bramble, 1998). As simulation technology was embraced and integrated into training programs more frequently, studies were undertaken to determine their effectiveness. In the late 1960s, Trans World Airlines (1969) and American Airlines (1969) both published reports indicating that simulations were effective enough at delivering the kind of instruction once only available through real flight that they could be used for all training related to the upgrade of first officers to the rank of captain. As a result, the Federal Aviation Administration (FAA) granted airlines permission to move more of their training to simulation-based programs (Koonce & Bramble, 1998).

Analog computers, however, were not the be-all end-all of computing technology, as history has come to see. With the move to digital computing technology came greater degrees of freedom of motion as well as improved motion cue translation. A new feature previously unknown to simulations also resulted from digital computing technology: computer generated imagery (CGI) (Koonce & Bramble, 1998). CGI was first applied, in primitive form, to aerospace and scientific engineering in the mid-1960s; however, the first example of its widespread use by the public for replicating realistic imagery digitally was in the 1982 movie *Tron* (Carlson, n. d.). When utilized for creating the visuals for simulations, CGI allowed for more realistic imagery, such as depictions of day and night scenarios, various weather conditions, etc. And, as with the emergence of analog computers, as the technology continued to improve, more and more training was approved to be carried out through simulations (Koonce & Bramble 1998).

Another technological shift that marked the beginning of a new era for simulations was the advent of the personal computer (PC). When IBM released their first PC in 1981 (Sadlow, 1991), it wasn't immediately jumped upon as "the next great simulation platform." In fact, what could be considered early desktop simulations were marketed as games, solely for purpose of entertainment. Initially, PC games relied on input from computer keys, but soon the controls for these simulation-like games became more realistic. Simulated flight games, for instance, started being released with the addition of flight sticks, control yokes, rudder pedals, and brakes (Saldow, 1991), that could be hooked into the computer and used to control the simulated aircraft being flown in the game. Some of these devices provided tactile feedback, like vibration, to the player to further heighten the fidelity to an actual flight experience (Koonce & Bramble, 1998). It wasn't long before the leap was made and PC-based desktop simulations began being developed specifically as training tools. The origin of desktop simulations as commercially-marked entertainment products is one that has proved to benefit their development as training tools. Since the market for commercially-available desktop simulations for personal computers was—and is—still thriving, many of the advances to simulation training technology (advancements in fidelity, add-ons to enhance visuals or add realistic flight controls, etc.) are conceived in a competitive market environment (Koonce & Bramble 1998), one that drives developers by economic incentive to come out with the best, most realistic product.

Methods & Issues of Assessing Transfer from Simulations

From surveying the literature, there appear to be several methods for assessing if and how much transfer occurs from training with a simulation. Arguably, the most inexpensive way to do this is to assess trainees' performance on a second simulator that more closely resembles the real environment to which they would apply the skills they learned. The reliability of this method for assessing transfer, of course, would likely be the most suspect; the trainees are demonstrating that they have skills that can adapt to new situations, yes, but they are only demonstrating that those skills can adapt and transfer to a new simulator, not the actual environment in which they'll be expected to perform their job.

In terms of accurately diagnosing transfer, the second-best option for evaluation is to measure trainees' performance in a mock real-life situation that models, as closely as possible, plausible circumstances in which the trainees would have to demonstrate the skills they learned. This could include demonstrating skills learned in a flight simulator by flying in an actual plane, though in controlled settings where the emergency or combat moves learned in the simulator are not actually necessary; demonstrating CPR or drug administration on a dummy; or demonstrating customer service skills in a role-playing environment. Baldwin, Benton, Petriel, and Koonce (1995) used a tool called the Semi-Automated Flight Evaluation System (SAFES) to measure flight performance in this way. The SAFES device essentially puts the same flight criteria monitoring device that is used in the flight simulator into an actual airplane, so performance in flight exercises in a plane can be measured and compared accurately to performance in the simulator.

Related to this is a measure of transfer as a factor of time savings in reaching proficiency (most often assessed in the kind of instructor-supervised mock real-life situations mentioned above). This measure, developed by Povenmire and Roscoe (1971), is referred to as the Transfer Effectiveness Ratio (TER). TER measures the amount of time saved in training (using simulation) to reach a level of proficiency in performing the skills in real life, relative to the time spent in a simulation. This measure deals not with the amount of transfer, but the time it takes for sufficient transfer to occur.

Nothing, of course, is as accurate a measure of transfer as comparing training performance to actual job performance. The difficulty in this lies in actually measuring job performance. In some cases, it is easy to see if certain skills have transferred: if a pilot was trained in how to recover a plane from a nosedive, and then does so in a real-life situation, it is obvious that the skill has transferred. However, it can be difficult to know how long it took him to recover the plane, or how many mistakes he made along the way if the situation occurred when he was not being monitored. Most often, trainees who receive simulator training do not go through the rest of their careers having their performance monitored for the sake of a study; a nose-diving plane, coding patient, industrial machinery malfunction, or other perilous situation that was trained for in a simulator cannot always be predicted to occur at a certain time, or at all, and can make measuring transfer in organic, non-engineered job situations extremely difficult. There are exceptions—for instance, Orlando's (2010) study of resident doctors in the Lehigh Valley Health Network in Pennsylvania who trained with a simulation designed to teach them to reduce the probability of central line-associated infections in their patients. The hospital in this study exhibited a significantly reduced central line-associated infection trend in the five years since simulation training was first implemented, thus indicating transfer from the simulation to the doctors' performance on the job. But for the most part, on an individual level, this kind of transfer measure is difficult to capture.

There are some issues to bear in mind when assessing transfer from simulations. One such issue is the compounding effect of instructors. The presence and nature of instructors can affect both the trainee's performance and the measurement of that performance. Care must be taken to ensure that the effects of different instructors on the performances of trainees are identified and parsed out from the variances in trainee performance due to the simulation itself (Caro, 1977). Care must also be taken to ensure that measurement of a trainee's post-simulation performance on the job or in a mock-job-scenario is not based on subjective instructor ratings. Instructor bias can significantly affect results; for instance, Gray and Fuller (1977) showed significant transfer gains from a simulation when using objective measures of weapons delivery ability, but no effect when using instructor ratings of trainee performance. Additionally, it is important to recognize that the effects of a simulation on transfer may not be seen early on in training; the first hour of training might not show the same transfer effects as the ninth hour of training, or the thirty-second hour of training. An expansion of the TER concept that recognizes the incremental nature of training transfer is referred to as the Incremental Transfer Effectiveness Ration (ITER) (Povenmire & Roscoe, 1971). Though ITER was developed specifically with measures of time savings in transfer in mind, it is an approach that can be applied to any measure of transfer, and is a framework for looking at assessment that should be noted when evaluating simulations.

Simulations vs Other Learning Media

Comparing the effectiveness of simulations in fostering transfer to that of other learning media is crucial in determining their value as training tools. The incentive to use simulations over other media is, theoretically, that the hands-on learning experience that simulations provide either increases transfer or increases the efficiency with which transfer is achieved. Meyers, Strang, and Hall (1989) evaluated the effectiveness of a microcomputer simulation at developing student-clinicians' ability to carry out successful interventions, using effective verbal techniques, with pre-school-aged children with stutters. They analyzed the effectiveness of practicing on virtual child stutterers in a simulation against the effectiveness of coding and analyzing audio recordings of children with fluency disorders. When both groups engaged in intervention sessions with actual child stutterers, those trained with the simulation performed a significantly higher number of effective verbal intervention techniques and significantly fewer ineffective or detrimental techniques or tendencies.

Waddick (1994) evaluated a simulation designed to teach use of a spectrophotometer (a device used to measure light intensity as a function of the wavelength of the light source) to university students. As in the study by Meyers et al. (1989), though the simulation was tested on students, the skills it taught were directly job-applicable. Spectrophotometers are used by scientists in the fields of physics, chemistry, and molecular biology, as well as professionals in the fields of printing and forensic investigation (Spectrophotometry, 2010). Waddick developed and tested a computer simulation to train students to use a spectrophotometer, and compared its effectiveness against a teacher demonstration. Waddick found the simulation and the teacher demonstration to produce equally effective performances using an actual spectrophotometer.

Schwid, Rooke, Ross, and Sivarajan (1999) examined the effectiveness a computer simulation to foster transfer of advanced cardiac life support (ALCS) knowledge in anesthesiology residents and faculty at a hospital. ACLS is a set of guidelines for managing the care of patients with acute cardiac dysfunction, and is a particular area that tends to show rapid deterioration of knowledge after training. The simulation was compared against the use of textbooks, and participants in both the experimental and control groups were videotaped performing Mega Code examinations—mock resuscitations in which they would have to demonstrate application of ACLS skills—10 to 11 months after training. Schwid et al. found that use of the simulator resulted in significantly higher scores for performance on the Mega Code examination, indicating higher levels of transfer.

Stewart, Dohme, and Nullmeyer (2002) examined TER for initial entry rotary-wing (IERW) training for UH-1 helicopters as a standalone method of instruction in one of four quasi-experiments performed in their study. They found no significant differences in performance or grades, but found that trainees using a simulation as the sole means of instruction took less time to reach proficiency, and that use of the simulation for training resulted in a net savings of approximately $36,000 for 10 students.

Brannick, Prince, and Salas (2005) evaluated transfer from a desktop flight simulation in comparison to a series of problem-solving exercises combined with a computer-based video game for training crew resource management (CRM) as well as technical skills. The results, gathered when both groups were evaluated in a high-fidelity simulator, showed superior CRM transfer for the desktop flight simulation group, and no difference between the two groups in terms of technical problem-solving skills.

Savage (2007) examined a mixed-reality simulator called the Battlefield Augmented Reality System (BARS) that uses a head-mounted display and tracks the user's head position and orientation through a wireless system. The BARS simulator was used to train wayfinding, and was measured against the orienteering rehearsal/training methods of drawing the route on a map and rehearsing in the actual physical space. In terms of route knowledge (measured in the time taken to complete the route and the number of errors made) and survey knowledge (ability to orient oneself to the environment and identify the beginning and end of the route), trainees using the BARS simulator performed the task in real life as well as those who drew the route on the map, but not as well as those who rehearsed in the actual space, without reporting simulator sickness. Witmer, Bailey, Knerr, and Parsons (1996) reported similar results for their study using a virtual reality simulator to train wayfinding and transfer route knowledge to a real environment. Rehearsal in a virtual environment proved to be more effective at promoting transfer to the real task than verbal rehearsal, but less effective than rehearsing in the actual space.

Additionally, Loar (2007) measured the effect of a desktop case study simulation, SimClinic, on the clinical performance of nurse practitioner students. In addition to lectures which all students received, one group completed an online text-based case study and the other completed a computer-based case study simulation. After this, both groups performed a mock-examination. No significant difference in transfer was found between the groups during these mock performances.

Simulations as a Training Supplement

Though Loar (2007) did compare the effect of a simulation against another media of learning (a text-based simulation), the simulations were used as a supplement to classroom lecture. The use of simulations as a supplement to training is a much more widely studied application of the technology than use of a simulation as a standalone medium for instruction. It also may be the most effective application. Sitzmann and Ely's (in press) meta-analysis found that use of simulation games resulted in more learning than other methods if used as a supplement, rather than a standalone instructional tool. Though this only speaks to learning, not to transfer, a myriad of studies examining transfer from supplemental simulations seem to speak to a similar trend.

Many of the early supplemental simulation transfer studies involved pilot training for air-to-surface weapons delivery (i.e., dropping bombs). As far back as 1977, Gray and Fuller were testing the effectiveness of supplemental simulation instruction on transfer in this arena. They examined use of the high-fidelity Advanced Simulator for Pilot Training (ASPT) as a supplement to traditional training. When the performances of participants from both the experimental and control groups were examined in an F-5B aircraft, student pilots trained in the ASPT had significantly higher scorers on all measures of bombing accuracy. Hagin, Dural, and Prophet (1979) performed a similar experiment to examine transfer of weapons delivery skills, this time using the Navy's Device 2B35/2F90 flight simulator, and though those who were trained with the addition of a simulator to the traditional training exhibited fewer pattern errors in their bomb deliveries, the groups showed no significant differences in bomb miss distances. Both Wiekhorst (1987) and Lintern, Sheppard, Parker, Yates, and Nolan (1989) also conducted studies on bomb-delivery skill transfer in military pilots from supplemental simulations. Both studies produced positive results for simulations as well; when trainees performed qualifying tests in an actual aircraft, students who received simulation training in addition to the control group's training qualified faster in Wiekhorst's study and exhibited less radial bomb error in Lintern et al.'s study.

Lintern, Roscoe, Koonce, and Segal (1990) measured TER from the use of a desktop simulator with a high-fidelity computer-animated contact landing display with students from the University of Illinois flight training program. Their results showed that students who had the simulation training as a supplement to the training received by the control group needed an average of 1.5 hours less flying time to perform pre-solo landings in an actual airplane before reaching proficiency.

Ortiz (1994) used a desktop simulation, AzureSoft's Electronic Instrument Flight Rules Environment (ELITE™), as a supplement to the classroom training of the Introduction to Aviation class at Andrews University. They found that, when tested in an actual aircraft, students (none of whom had any previous flight experience) who had used the simulation performed significantly better than those only receiving classroom instruction.

Taylor, Lintern, Hulin, Talleur, Emmanuel, and Phillips (1999) examined transfer from a desktop-based flight simulation with high-fidelity control mechanisms. The experimental group was trained using the simulation, then re-trained in an actual airplane, while the control group was trained only in the airplane (neither group had any previous flight experience). Taylor and colleagues measured transfer in terms of TER, to get a measure of transfer savings. They found that during flight performances following training, transfer savings for the simulations were generally significant and positive when new tasks, for which the students had not specifically trained, were introduced during flight, but low (indicating negligible effects of the simulation to foster transfer more effectively than in-plane training) when trainees were performing tasks for which they had already trained, either in the simulation and airplane, or just the airplane.

Stewart et al. (2002) found more wholly positive measures of TER using a flight simulation to augment traditional training for IERW training. Trainees who received the flight simulation took less time to reach proficiency in the actual aircraft on most of the tasks they pre-trained for in the simulator in all four quasi-experiments performed in the study.

Converse to the results of other studies that measured transfer from supplementary simulations, Roessingh (2005) found that, when given as a supplement to the traditional in-flight training received by novice pilots, PC-based simulator training (both simple and higher-fidelity) resulted in no difference in demonstrated flight skills in actual flight. However, trainees in both experimental groups received better instructor ratings than the control group. Differences were also found in the number of maneuvers trainees performed in a set amount of time, but this variable was not controlled by the experiment, so could not be counted as a true show of positive transfer.

Finally, in a somewhat different supplemental experiment, Sukhai (2005) tested the effect of different combinations of text explanations, animated demonstrations, and computer-guided simulations in a Web-based course to train customer service representatives on transfer to a mock-performance. No significant differences in task transfer were found.

Simulations vs No Training in Populations With Previous Experience or Knowledge

In some cases, simulation training is used not in place of or as a supplement to specific other media to teach new skills, but as a means of practicing certain capabilities to enhance aptitude or combat skill decay. Studies that examine the transfer from a simulation as compared to a control group who receives no equivalent training but has similar previous experience or knowledge are applicable to these circumstances. Jenkins (1982) conducted a study of this nature where the transfer effects of the high-fidelity Simulator for Air-to-Air Combat (SAAC) were measured against the performance of trainees not receiving any training in the SAAC. Both groups were experienced pilots, and their performances were analyzed in the Fighter Weapons Instructor Course that both groups took part in after the experimental group trained in the SAAC. Results, captured by a gun camera whose film was then analyzed in terms of number of missile and gun shots each trainee attempted and successfully executed, showed that pilots with SAAC training had significantly more successful missile and gun shots.

Hughes, Brooks, Graham, Sheen, and Dickens (1982) performed a study in which MR A-10 pilots received two hours of unstructured practice in a simulator prior to flying the Red Flag operational exercise. Their performance in Red Flag was compared to MR A-10 pilots who had received no practice in the simulator prior to the exercise. The results showed that the group that practiced in the simulator had significantly higher rates of survivability in their performance, but only when the threat warning and countermeasures avionics configuration in the plane flown during Red Flag were the same as in the simulator; when they were different, survivability decreased. Wiekhorst and Killion (1986) conducted a similar study in which A-10 pilots with no simulator experience were compared against those who practiced in the same simulator as Hughes et al. (1982) prior to participating in the Green Flag operational exercise. Results were more wholly positive in this study; survivability and effective use of defensive countermeasures both were higher in those who practiced on the simulator prior to the exercise.

Duffy, Ng, and Ramakrishna (2004) also conducted what could be considered a variation on the "addition of simulation to prior experience and knowledge" study. In the case of their experiment, the "prior knowledge/experience" was the simulation itself; both the experimental and control groups were industrial workers being trained using a desktop simulation (derived from a fully-immersive version) on the operation of milling machines. The difference between the two groups was that the experimental group trained with a simulation which included a simulated accident caused by a tool breakage. The simulated accident incorporated visual (animation of the malfunction, text) and auditory cues (the sound of breaking glass). The study examined the decision-making skills of both groups when asked to operate a real milling machine, and when faced with the unsafe conditions that cause the kind of tool breakage that the experimental group experienced in the simulator. Results showed that inclusion of this additional simulated element resulted in a higher percentage of correct decisions made on the real milling machine. This indicates higher levels transfer with the addition of a simulated event measured against trainees with similar background knowledge and experience.

Most recently, Rogers et al. (2007, 2009) performed several studies to test the effectiveness of a flight simulation for fostering transfer of upset recovery skills and combating *General Aviation Syndrome*, or "a general aviation pilot's long-reinforced habit of using small control inputs when maneuvering an airplane," and reluctance "to apply maximum allowable G forces during dive recovery" (Rogers et al., 2007, p. 13). Their experiment studied general aviation pilots (students at Embry-Riddle Aeronautical University) as opposed to the military pilots who most often participate in flight simulator studies. As mentioned earlier, it is illegal to purposefully subject most general aviation aircrafts to the stress that would induce the kind of aerial acrobatics commercial pilots need to learn to recover from when flying planes. Thus, Rogers et al. tested the effectiveness of a simulator at fostering transfer of skills that general aviation pilots cannot learn through practice on an actual aircraft. Students were trained in the simulator, then tested on a military plane (which was not illegal to subject to the kinds of upsets and loss-of-control situations that cannot be purposefully induced in general aviation crafts). The results showed that while there were no significant differences in the number of successful recoveries from aeronautical upset (~95% vs ~93%), when looking at the recoveries in terms of specific task elements (e.g., control of G forces, roll control yoke inputs, rapid throttle responses, etc.—16 measures in all), the experimental group's performance was significantly better than the control group's 44.4% of the time. Additionally, the experimental group tended to return the plane to a straight-and-level position faster than the control group. While the pilots in the experimental group still exhibited General Aviation Syndrome and failed to apply the large control inputs they'd applied during practice in the simulator, the conclusion was that General Aviation Syndrome is apt to take over no matter what the training is (as long as it is anything less than actual experience), and pilots are quick to lose situational awareness and revert to old control input habits not tailored to an emergency situation. However, simulator training is far superior to *no training at all*, which is all that most general aviation pilots can receive if not for simulations.

Pre-Post Evaluations of Transfer from Simulations

A handful of studies have conducted pre-post examinations of transfer from simulations, i.e., have measured trainees' performance before and after using the simulation, and analyzed the degree of change attributable to the simulation. Waag and Bell's (1995) study of the McDonnell Douglas (MACAIR) simulation facility is one such study. It is also one of the few studies that measured transfer in group training from a simulation. In this study, teams of two mission-ready pilots and a mission-ready air weapons controller (AWC) flew offensive and defensive scenarios in an actual aircraft, in a controlled environment, before and after simulator training. Performances were measured through digital data and video footage of their flight performance; results showed that mission effectiveness and survivability scores rose significantly from pre-training to post-training.

Cohen, Edwards, and Szold (2009) performed a pre-post simulation transfer experiment with surgical students. The students performed pre-tests of their laparoscopic surgical skills on a video trainer before training for three tasks on the LAP Mentor virtual reality simulator. The students then performed post-tests on the video trainer immediately afterwards, and again three to four weeks after completing the virtual reality simulation. For all three tasks, completion times were significantly better on both post-tests. Error rates significantly decreased two of the three tasks immediately after training, and remained the same for the third task. After the three to four week period, error rate continued to decrease for one of the tasks that showed improvement immediately after training, but rose for the other.

Fraser et al. (2009) performed a pre-post examination of a medical simulation as well, in this case a cardiorespiratory simulator (CRS). Their study also yielded mixed results: after training, the medical students in the study showed improved clinical performance in terms of identifying abnormal findings and making correct diagnoses; however, when the situation demanded that they adapt the skills they learned in the simulator to different problems or situations they had not been directly trained for in the simulator, their performance remained the same as it was before training.

Low-Fidelity vs High-Fidelity

Another area of examination in the arena of simulations is the issue of fidelity and its effect on transfer. Several studies have assessed the degree to which a simulator's place on the spectrum of fidelity—from low to high, and for a myriad of features, such as controls, visuals, and simulated motion—affects the skills that trainees are able to apply to real-life situations. One such study is Dennis and Harris' (1998) examination of two different flight simulators: one a desktop simulation with keyboard controls and one a high-fidelity simulator with controls similar to those found in a cockpit. The results of their study showed that both simulations fostered positive transfer to actual flight performance, but that fidelity had no significant impact on transfer. They suggest that this may indicate that the value of simulations lies not in promoting psychomotor skill development (which would have lent itself to improvement with high-fidelity controls), but in helping students to construct the proper *cognitive template* of what flight will be like.

Two subsequent flight simulator studies seem to support this assertion. Phillips, Hulin, and Lamermayer (1993) and Ortiz, Kopp, and Willenbucher (1995) both conducted similar studies comparing desktop flight simulations to simulators with high-fidelity flight controls and how the skills they teach transfer to actual flight. The results of both seemed to fall in line with Dennis and Harris' (1998) claims: Phillips et al. found that students actually had a better pass/fail rate in a real airplane if they had trained with the desktop simulation instead of the high-fidelity simulator, and Ortiz et al. found no performance differences between the two, but significantly large cost savings from using a desktop simulator in place of its high-fidelity counterpart.

Additionally, de Giovanni, Roberts, and Norman (2009) affirm this theory in the field of medicine by comparing transfer from a low-fidelity CD-based desktop simulation to transfer from the high-fidelity Harvey® simulator, a realistic, full-size mannequin that can simulate nearly any cardiac condition through simulated blood pressure, pulse, heart sounds, and murmurs. When performing exams on actual patients, the Harvey®-trained group showed slightly, but insignificantly, better performance at identifying heart sounds, but there was no difference in the performance of the two groups in terms of diagnosis, communication skills, or examination skills.

Only one study was found that contradicted the results of these studies; in the second quasi-experiment that Stewart et al. (2002) performed, in which they upgraded the visual displays and flight modeling systems of the simulators, greater TERs were observed than in the first quasi-experiment. However, the upgrades only improved the visual system (so that the frame rate and polygon count increased, surface texturing was added, and the Flat Earth visual model was replaced by a realistic terrain model), and did not did not add any extra features to increase the physical fidelity of the simulator experience (i.e., adding controls that mimicked that of an aircraft instead of using a keyboard or adding a seat that simulated in-craft motion). Additionally, it is unknowable if the resulting greater TERs were due to the increased visual fidelity of the simulator, or to the use of novice pilots in this particular experiment, whose gains from the simulator would have been greater than those of the trainees in the first experiment, who had already completed the first phase of IERW training.

Digital Skill Adaptability: The Way Ahead With Simulations?

The ability of simulations to teach skills that transfer to real-life, on-the-job situations seems abundantly positive, from the existing body of literature. Computer-based simulations—assessed as an alternative to other means of training, as a supplement to other means of training, as a device to combat skill decay in experienced trainees, and as a means of improving performance levels as they stand prior to training—show positive results for transfer a majority of the time: in 22 out of 26 such studies, trainees demonstrated equal or superior transfer to the control group from simulations. The remaining studies yielded mixed results; in no study did a simulation produce wholly negative results. Simulations have proven their value at promoting transfer in a wide range of occupations, including those in medical (anesthesiology, cardiology, surgery, nursing, speech pathology), corporate (customer service, industrial work), scientific (spectrophotometry), and aeronautical (both military and commercial) fields. And, somewhat surprisingly, studies have shown that the benefits of simulation-training can be had from low-cost, desktop-based simulations, equally or more so than from expensive, high-fidelity simulators. Perhaps, as Dennis and Harris (1998) suggest, it is not the psychomotor skills potentially learned during training that foster transfer, but the cognitive templates of the experience of performing the job—the steps the mind goes through when performing a task, that are directly practiced, experienced, and applied when using a simulation, no matter what the fidelity.

This idea fits with Priest and Gass' (1997) model of experiential learning, or learning that occurs through direct participation (Houle, 1980; Smith, 2003) in events or processes, such as that which is had through engaging in learning through simulations. Priest and Gass' Experiential Learning and Judgment Paradigm, adapted from Priest (1990), shows experiential learning as a six-part cycle, whose six parts consist of Experience—Induce—Generalize—Deduce—Apply—Evaluate (see Figure 1 below).

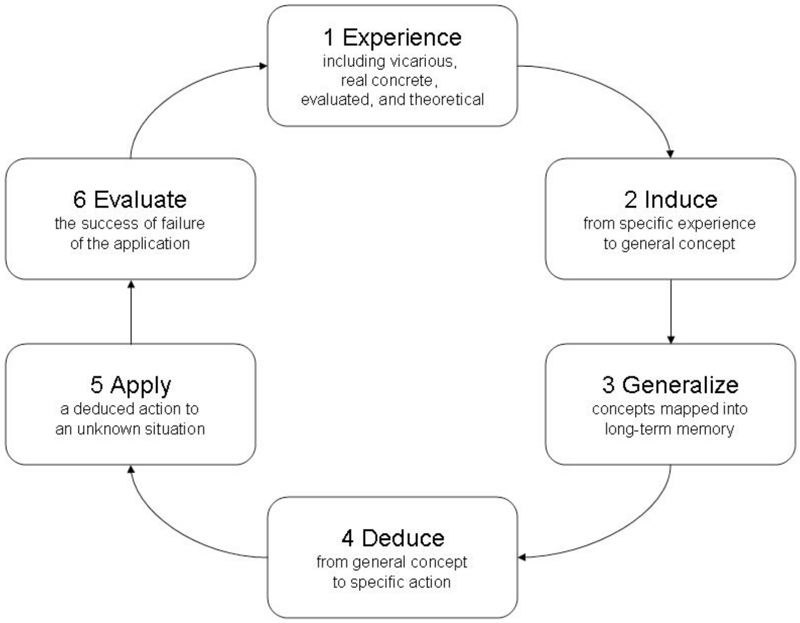

Figure 1. Priest and Gass' (1997) Experiential Learning and Judgment Paradigm.

These six parts can easily be adapted to apply to the process of transfer from simulations (see Figure 2 below).

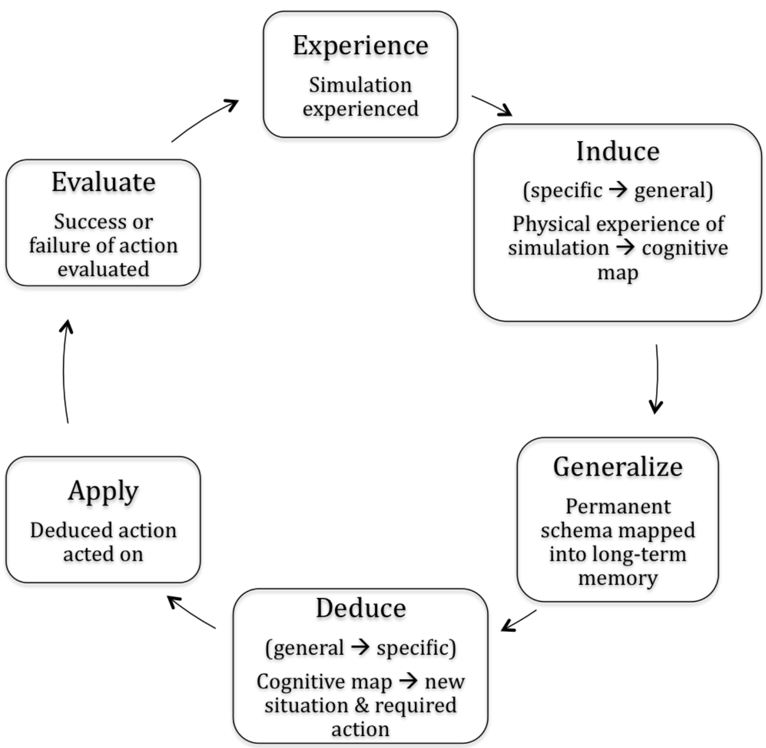

Figure 2. Cycle of experiential learning and transfer from simulations (adapted from Priest & Gass, 1997).

A simulation is first *experienced* when the trainee engages with it; the trainee *induces* from the physical and psychological experience of the simulation a cognitive map of what the actual experience—of flight, or surgery, or what have you—is like; the trainee *generalizes* that cognitive map into a permanent schema that is engraved into his or her long-term memory; the trainee then *deduces* from the general schema acquired during training what specific action is required in a new situation (i.e., an on-the-job situation); the trainee proceeds to *apply* said action (i.e., transfers skills from training to real-life); and finally, the trainee *evaluates* the success or failure of that action. Applying Priest and Gass' model of the experiential learning cycle to simulations reveals a process of transfer in which trainees form the kind of cognitive map that Dennis and Harris (1998) refer to, which trainees then transpose over each new situation to deduce what kind of action is required in those particular circumstances.

This cognitive mapping process is the basis of what makes transfer what it is: the *adaptation* of skills to be *applied* in different or changing environments. It is not only the skills themselves that are important to be gained from simulations; it is also the underlying cognitive schemas the trainees create that allow them to apply and adapt those skills. This concept, broadly applied to any medium of training, is called *digital skill adaptability* (Hess, Alliger, Littleton, MacMillan, & Titus, 2001; Hess et al., 2003). This means teaching the ability to use technology in a way that is generalizable and transferable; it is teaching the ability to adapt the digital skills learned through the use of one device to new technology as it keeps evolving over time. Hess et al. (2003) assert that this cannot be taught in a vacuum. It is impossible to teach digital skill adaptability on its own; it must be taught through the teaching of specific tasks and of the use of specific devices, but in a way that fosters the ability to transfer those skills to a broad range of ever-changing technology.

Aptima, Inc. and the Group for Organizational Effectiveness, Inc. have created the Learning Skills Bridge (LBS) learning accelerator training package intended to do just this. It is a computer-based (non-simulation) training program designed to increase basic computer knowledge over the course of more device-specific training on the use of the Advanced Field Artillery Tactical Data System (AFATDS). Through testing, revising, and re-testing, the LBS has been proven to eliminate group differences due to previous experience with computer technology, result in higher scores on measures of transfer (i.e., demonstrated application of skills related to AFATDS networks, visualization, and mapping), and result in an 88% satisfaction rate among trainees, who claim that it improved their understanding of AFATDS (Hess et al., 2001; Hess et al., 2003).

Additionally, work by Schaab and Dressel (2001) has shown that using constructivist (i.e., using realistic vignettes to teach knowledge of digital systems and jobs) methods of training to teach digital skills, as opposed to traditional methods, resulted in equally strong learning outcomes and superior transfer of adaptable digital skills.

It seems apparent that the future of promoting transfer from computer-based simulations relies on utilizing the concepts of cognitive mapping and teaching digital skill adaptability, and applying them to simulations. It is an area in which there seems to be a dearth of research and examples application. But with the advances made by Hess et al. (2001), Hess et al. (2003), and Schaab and Dressel (2001) in exploring these concepts in non-simulation-based training, their integration into simulations seems like the logical next step. We know that transfer is possible from simulations; we also know that the core tenet of transfer—adaptability—is enhanced by consciously designing training to promote cognitive mapping and digital skill adaptability. If we explore the possibility of merging the two concepts together, we may open the door to being able to consistently design simulation training that fosters adaptable, transferable skills to the job in a cost-saving way.

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