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Varying Feedback Strategy and Scheduling in Simulator Training: Effects on Learner Perceptions, Initial Learning, and Transfer

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VARYING FEEDBACK STRATEGY AND SCHEDULING IN SIMULATOR TRAINING:

EFFECTS ON LEARNER PERCEPTIONS, INITIAL LEARNING, AND TRANSFER

by

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ABSTRACT

VARYING FEEDBACK STRATEGY AND SCHEDULING IN SIMULATOR TRAINING: EFFECTS ON LEARNER PERCEPTIONS, INITIAL LEARNING, AND TRANSFER

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This experimental study investigated the effects of visual feedback on initial learning, perceived self-efficacy, workload, near transfer, far transfer, and perceived realism during a simulator-based training task. Prior studies indicate that providing feedback is critical for schema development (Salmoni, Schmidt, & Walter 1984; Sterman, 1994). However, its influence has been shown to dissipate and is not directly proportionate to the frequency at which it is given (Wulf, Shea, & Matschiner, 1998). A total of 54 participants completed the study forming six treatment groups. The independent treatment, visual feedback, was manipulated as scheduling (absolute—every practice trial or relative—every third trial) and strategies (gradual decrease of visual cues within the interface, gradual increase of visual cues within the interface, or a single consistent cue for each trial). Participants completed twelve practice trials of welding under one of six feedback manipulations; then, participants completed twelve practice trials of welding without it. Lastly, participants performed the weld task on actual equipment in a shop area. No treatment showed significant difference among groups with regard to initial learning, retention, near transfer, and far transfer measures. However, a statistical significance was found during initial learning and retention within each treatment group. Findings support empirical evidence that a variability of practice paradigm promotes learning (Lee & Carnahan, 1990; Shea & Morgan, 1979). Learner perceptions of realism suggest that novice learners perceive simulator fidelity as high, however, these perceptions may dissipate as the learner practices. Those groups that involved the greatest number of cues at the onset of practice or having cues available at every other trial reported the greatest amount of workload. All groups reported increases in perceptions of self-efficacy during practice on the simulator, but those perceptions decreased when participants performed the weld task on actual equipment. Findings suggest that contextual-interference of increasing, decreasing, or changing feedback counteracts the guidance effect of feedback as found in previous studies.

This manuscript is dedicated to my two sons, Mr. Carl Williams, III and Mr. David Williams. Your innocent love and unwavering faith propelled me through the trials and tribulations of creating this manuscript. I achieved because you believed.

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CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

The VRTEX™360 weld simulator incorporates dynamic visual feedback as interactive, real-time multimedia elements within an immersive virtual environment. The learner enters the virtual environment through the lenses of the weld helmet. Contiguous visual graphics within the virtual environment provide feedback regarding performance. When the learner removes the helmet, additional feedback in the form of multiple graphical representations, weld images, and text is available within the single interface of a computer monitor. Not only must instructional designers create training protocols that incorporate these multimedia elements, but they must also ensure that protocols activate the learning process, decrease training costs, and maintain the authenticity of the presented instruction.

Interactive Simulator Multimedia

A growing body of research investigates the effectiveness of multimedia elements found in computer-based simulations and simulators such as the VRETX™360 (Mitchell, 2004; Romme, 2004; Washbush & Gosen, 2001; Wolfe, 1997). Empirical studies (Mayer & Moreno, 2003; Mayer, 2008; Mayer, Mautone, & Prothero, 2002) investigate basic design principles for multimedia learning environments where single systems incorporate one or more of the following: motion, voice, data, text, graphics, or images (Moore, Burton, & Myers, 2004). Understanding that a learning environment is not linear with single causal relationships, multimedia should not be restricted to describing one variable in a systemic learning environment. Each variable reveals a dimension to learning.

However, each dimension produces a composite of observations, experiences, and practice needed to learn.

Studies dedicate little attention to new technological developments which yield multiple feedback sources of dynamic forms of multimedia. Studies should explore the impact of multiple sources of feedback during simulator training on retention but also skill transfer. The fundamental challenge remains—will the training protocol result in mastery of fundamental skills and competencies—but also, will this mastery transfer to the real task environment? A look at feedback effects juxtaposed with cognitive and constructivist theory may provide some insight to the design of multimedia for motor learning.

Cognitive Effort and Motor Learning

Motor learning of a skill such as welding involves implicit memory evidenced by improvement in individual performance and behaviors. These implicit memories provide the learner with an ability to know how to do things (i.e. motor and cognitive skills) and are typically acquired through practice and repetition. Schema theory of motor learning (Schmidt, 1974) describes the governing of implicit motor memory primarily as an abstraction of relationships, a schema, of elements in a mechanistic process.

Whether about error or calibration to some movement goal, empirical evidence supports the premise that feedback is critical for schema development during motor learning (Salmoni, Schmidt, & Walter 1984; Sterman, 1994). Empirical support for the administration of feedback, on the other hand, unveils an oxymoron. Feedback variables show a strong guidance effect during initial learning; yet, its influence is transient and not directly proportionate to the frequency at which it is given (Wulf, Shea, & Matschiner, 1998). To account for the transient effects of feedback on motor learning, a distinction between initial learning and retention is particularly important (Salmoni, Schmidt, Walter, 1984; Kantak & Winstein, 2012). The distinction posits that effects should persist beyond practice.

Specificity of Practice Hypothesis

Feedback occurs naturally while practicing how to do something. Learners use their senses to observe the results of their movement—that is, welding a lap-joint and seeing the arc flame from the welding gun melt filler metal into the joint. According to the specificity of practice hypothesis, learners determine the source of sensory information that is more likely to ensure optimal accuracy early in practice. This determined source gets processed to the detriment of any additional sources as practice continues.

Specificity of practice also stipulates context. Practice conditions should reflect those conditions relevant to the criterion performance. Empirical evidence supports the idea that performance is contingent on the context in which the information is presented during practice (Proteau, Marteniuk, Girouard, & Dugas, 1987). However, a second contradiction is evident in the motor learning literature. When specific practice is compared to variable practice conditions, findings show that variations to practice conditions lead to better retention (Maslovat, Brunke, Chua, & Franks, 2009). Again, those conditions which facilitate initial learning have been detrimental to retention.

Cognitive Flexibility Theory

Although motor learning has a mechanistic end state of skill execution, initial learning is a problem-solving process in which the goal of the end state represents the learner discovering the rules of a movement configuration (Ennis & Chen, 2011). During initial learning of welding, the learner must discover the conceptual complexity of multiple body positioning (i.e., travel angle, work angle, travel speed, arc length, etc.) governing skill performance under varied environmental conditions (e.g., weld positions, base metal composition, wind conditions, etc.). Skill mastery results from executing the complex movement goal under all possible conditions, hence, methods of reaching the desired state is not easily achieved by the novice learner. Based on cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1992), switching between multiple perspectives of an ill-structured domain such as welding benefits transfer of knowledge and skills. Likewise, learning within the context of multiple perspectives and examples strengthens knowledge and skill beyond initial learning.

Skill mastery occurs when the learner is given opportunity to practice with multiple representations because a single representation may miss key facets. By repeating the presentation from different perspectives, the learner gains additional aspects of the same context. This form of variable practice promotes development of an internal representation, or schema, while building on existing knowledge. As found in contextual interference studies, the transient effects of feedback dissipate when feedback targets different perspectives of a task (Lee & Carnahan, 1990; Shea & Morgan, 1979). Such findings suggest that although initial learning may suffer, a variability of practice paradigm promotes retention and transfer.

Variable Practice Conditions for Motor Learning

Given the strong historical evidence of feedback as critical for learning, the first, functional alignment of the specificity of practice hypothesis and the cognitive flexibility theory ascribes to the importance of a predetermined learning outcome. Although cognitive flexibility theory describes learning from a constructivist framework, the use of general constructivist assumptions is conservative and focuses on the construct of multiple representations rather than the learner's creation of meaning without a basic objectivistic assumption. Second, the learner and the environment afforded by feedback are critical. The interaction between learner and content becomes enhanced for motor learning when the content is offered, not only, within context, but multiple perspectives of that context. Variable practice conditions can offer these multiple perspectives.

Motor learning inherently ensures that learners can elaborate and interpret information. Therefore, cognition must occur during performance of motor skills (e.g. welding). Memory attained during motor learning develops schema through task engagement. Feedback as interactive, real-time multimedia elements is crucial because of the schema they mediate in the process of stimulus, as well as, the selection and execution of precision motor skills (Grierson, 2014). The specificity of practice hypothesis alongside tents of the cognitive flexibility theory may give insight for the disparities found in feedback studies. Particularly, this study will focus on the effects of various feedback strategies and scheduling on training outcomes for novice trainees who are learning to weld using a moderate fidelity welding simulator. In addition, learner perceptions (i.e., perceived realism, perceived self-efficacy, and workload) will be explored.

Definitions of Key Terms

The terms in this section are defined as they relate to this study. Each definition is provided to ensure uniformity and understanding of the term throughout this writing. Listed definitions, not accompanied by a citation, were developed by the researcher.

Absolute consistently-single (AbsCon). Describes the frequency and number of visual cues available at each trial during practice. In this treatment group, feedback is given at every trial, but only one visual cue is available at a time in a round-robin method as practice continues.

Absolute-decrease (AbsDec). Describes the frequency and number of visual cues available to the learner during a practice session; the absolute-decrease treatment group involves augmented feedback at each trial of practice, and the number of visual cues gradually lessens as practice continues.

Absolute scheduling. Describes the number of times augmented feedback is provided in a series of trials; where feedback is available at every trial.

Absolute-increase (AbsInc). Describes the frequency and number of visual cues available at each trial during practice. In this treatment group, feedback is given at every trial, and the number of visual cues gradually becomes greater as practice continues.

Augmented feedback. Extrinsic or supplemental information manipulated by the researcher and provided to the learner for the acquisition of new movement skills (Schmidt & Wulf, 1997). Technology can be utilized and manipulated to provide information specific to a movement goal by highlighting a single subcomponent or multiple perspectives of the movement.

Contact-to-work distance. In welding, the distance between the tip of the rod and the metal; used to control the degree to which the metals are fused together; incorrect contact-to-work distance may cause the weld bead to become defected with small holes.

Consistently-single. Describes the administration of feedback characterized by a round robin of four cues where only one visual cue is available at a time.

Far transfer. A post-acquisition condition within the actual operational context where the learner performs a motor skill similar, but varied in some manner, from the initial learning condition; this post-acquisition condition tests the extent to which the training of the acquisition phase produced the level of learning needed to prepare the learner for a new variation of the practiced motor skill (Kantak & Winstein, 2012).

Feedback Scheduling. A plan for providing feedback during a practice sequence; in which case, feedback is manipulated during every trial in a practice sequence (absolute) or a relative percentage of the total number of trials in a practice sequence (relative).

Feedback Strategies. The instructional plan, often afforded by some form of multimedia, aimed at achieving the performance goal. In this study, refers to the sequence plan for visual feedback administered during initial learning.

Fidelity. This term refers to the many factors that contribute to a simulator's ability to replicate the operational context for which it was designed. One factor, *perceived realism*, refers to the learner's perceptions of fidelity.

Initial learning. A set of practice trials where augmented feedback is made available as the learner first acquires a new motor skill; sometime referred to as acquisition phase of motor learning (Kantak & Winstein, 2012).

Motor learning. The process in which the learner acquires the skill to control movement proficiently for the performance of a task; a change may occur in the body's spatial orientation or in the timing and sequencing of the body's movement (Schmidt, 1975).

Multimedia. The all-inclusive term that describes technology's ability to store and process information, display multiple representations of that information to the learner, and create interactive exploration of that information (Schnotz & Rasch, 2005).

Near transfer. A post-acquisition condition within the actual operational context where the learner performs the same motor skill from the simulator condition; this post-acquisition condition tests the extent to which the simulator training prepared the learner for the operational context of the practiced skill (Kantak & Winstein, 2012).

Perceived realism. The learner's personal judgment of the simulator's ability to replicate reality; varies from learner to learner.

Perceived self-efficacy. The perception of one's ability to complete cognitive and behavioral actions required to perform a task; this belief about self is a personal factor that is perceived by the learner and interpreted prior to a response to environmental cues (Bandura, 2012; Bruning, Schraw, Norby, & Ronning, 2004)

Relative consistently-single (RelCon). Describes the frequency and number of visual cues available at each trial during practice. In this treatment group, feedback is given at a proportion of the total number of trials, but only one visual cue is available at a time in a round-robin method as practice continues.

Relative-decrease (RelDec). Describes the frequency and number of visual cues available at each trial during practice. In this treatment group, feedback is given at a proportion to the total number of trials, and the number of visual cues gradually lessens as practice continues.

Relative scheduling. Describes the percentage of trials for which feedback is provided in a series of trials; the number of trials which included feedback divided by the total number of trials in the practice sequence (Schmidt & Lee, 2005).

Relative-increase (RelInc). Describes the frequency and number of visual cues available at each trial during practice. In this treatment group, feedback is given at a proportion to the total number of trials, and the number of visual cues gradually greatens as practice continues.

Retention. As an indicator of learning, learner performance measured during a set of trials administered after initial practice. This set of trials is characterized by the absence of augmented feedback. This concept suggests that what is measured during acquisition may or may not imply learning (Kantak & Winstein, 2012; Schmidt & Lee, 2005).

Schema. In motor learning, cognitively-based memories which describe the relationship between the outcomes received and the actions which necessitated those outcomes (Schmidt, 2003). Schema can integrate informational elements and rules regarding movement to the point that production becomes automated, thus requiring less storage and controlled processing. Mastery of skilled performance consists of building increasingly complex schemas by combining multiple informational elements (Kirschner, 2002).

Simulator. A training apparatus that replicates the hardware and, to some degree, those conditions found in the actual operational context.

Travel angle. In welding, the left-to-right measurement from the weld rod to the base of the joint of the weld; an incorrect travel angle may cause the weld bead to miss the intended joint location.

Travel speed. In welding, describes how fast the welder drags or pushes the rod of the weld gun along the joint of the weld; moving too fast or too slowly along the weld joint may cause cracks in the weld bead.

Visual feedback: The presentation of information by a pictorial, graphical, or other form that appeals to the sense of sight. This information is provided to signal the learner to some perspective of their movement. (Adams, 1987). Can also be considered as v*isual cue;* this visualization increases the details of what is naturally seen by the human visual sense (Ainsworth & VanLabeke, 2004).

Work angle. In welding, the up-down measurement describing the placement of the electrode during the welding process; measures from where the electrode touches the middle of the joint to the base metal; incorrect work angle may cause unwanted cuts in the base metal above the joint.

Workload: Under the premise that the mind has a limited capacity, then workload is the percentage of that capacity that is in use at a given time-point (Byrne, Tweed, & Halligan, 2014); indicates how much effort and attention that the learner perceives as needing to obtain mastery of a task.

Literature Review

Simulators use mixed-methods to replicate actual experiences of experts as authentic learning events (Bell, Kanar, & Kozlowski, 2009). Research in this area looks at the efficiency of instructional strategies afforded by the technology under varying tasks, conditions, and learning domains. In doing so, those conditions which media are effective as learning tools are examined rather than comparing one technology against another.

Issenberg et al. (2005) reviewed 109 empirical studies and found that effective features of medical simulators are much like any other instructional system. Each study used an affordance of a simulator as an educational intervention and measured learning outcomes. Each affordance created an instructional system that led to effective learning. Of the ten features found within the instructional systems studied, feedback was the single most important feature of simulation-based medical education (Best Evidence Medical and Health Professional Education, 2005).

Other features included repetitive practice, individualized learning, defined benchmarks, and simulator validity. Instructional systems using medical simulators as learning tools have been found effective when feedback is provided during learning with all levels of experience across many medical specialties (McGaghie, Issenberg, Petrusa, & Scalese, 2006). The support for the effectiveness of simulators as learning tools is well supported in other fields such as aviation, surgical training, and the military (Domuracki, Mouleb, Owen, Kostandoff, & Plummere, 2009; Mitchell, 2004; Romme, 2004; Washbush & Gosen, 2001; Wolfe, 1997).

Visual Feedback

Mixed-reality simulators allow manipulation of physical objects with in-situ visual information to assist learners in becoming skilled in the psychomotor components of the task. As a result, learners develop the schema needed to perform the task in real-world contexts. The performance-related visual information available to the learner, or feedback, can be either provided by an external source or inherently provided by a learner's sensory receptors during the normal course of movement. Modern procedural simulators employ external sources of feedback in the form of graphs and tables or interactive visuals as dynamically changing feedback within one interface. This visualization increases the details of what is naturally seen by the human visual sense (Ainsworth & VanLabeke, 2004). Moreover, the simulator's interface displays these additional visualizations as extra information external to the visualization of the phenomena represented, but internal to the interface of the simulator. Each contiguously integrated representation serves to supplant mental representations and perform translations for the learner (Ainsworth, 1999; Schnotz & Kurschner, 2008). Empirical evidence supports physically integrating and dynamically linking representations over separated non-linked conditions in computer-based simulations (derMeij & deJong, 2006).

Ranganathan and Newell (2009) investigated the influence of different types of visual feedback on learning a two-finger discrete force-production motor skill. Of the four independent groups, one group received feedback in the form of a horizontal bar graph which indicated how much additional pressure was needed to exert peak force. A second group also received the concurrent horizontal graph as feedback plus was told that they would be required to perform the same task under a no-feedback condition. The third group was only given terminal feedback in the form of a horizontal bar indicating the maximum amount of force exerted accompanied by a numerical display of that force produced. The fourth group received the concurrent feedback indicating how much additional pressure to exert as well as terminal feedback on the maximum amount of force exerted accompanied by a numerical display of the maximum amount, but only after every other trial. Results supported previous empirical data indicating that practicing a motor skill with concurrent feedback leads to improved initial learning, but poor retention on non-feedback retention test trials (Park, Shea, & Wright, 2000; Schmidt, 1997; Weinstein et al., 1996; Weinstein & Schmidt, 1990).

Feedback Scheduling

Feedback has been shown to have a positive influence on initial learning, but a negative impact on retention of motor skills. Recent studies (Anderson, Magill, & Sekiya, 2001; Chang, Chang, Chein, Chung, & Hsu, 2007; Kantak, & Winstein, 2012; Scaringe, Chen, & Ross, 2002) also support the guidance effect of feedback during initial learning. Typically, the scheduling of feedback is divided into two subtypes: (a) frequency; how much feedback is given throughout iterative practice and (b) timing; when feedback is given--either during or after a practice trial.

Frequency of feedback. Evidence supporting the idea of relative frequency as an important variable to retention examines the ratio of feedback-provided trials to the total number of practice trials. These studies also measure performance during retention tests as opposed to performance during practice. This research paradigm supports Salmoni et al. (1984) reappraisal of the definition of learning in the motor domain. When research findings are reviewed by the distinction between initial learning and retention, evidence for relative frequency is substantiated; a positive feedback effect is found in retention. Groups that receive relative feedback (i.e., 0%, 33%, 66%, and 100%) during practice outperform absolute feedback (i.e., 100% feedback after every trial) groups (Anderson, Magill, & Sekiya, 2001; Salmoni et al., 1984; Wulf & Schmidt, 1988; Young & Schmidt, 1992). One study involving grasping a lever handle to replicate a goal movement pattern under four independent conditions of relative feedback found similar results (Winstein & Schmidt, 1990).

Timing of feedback. Gibson (2000) argues that it is necessary in dynamic environments to have immediate delivery of feedback as opposed to delaying it because delayed delivery loses the task's context. Results for this argument were found by Boyle et al. (2011) where a simulator provided instructions and annotations on a video monitor within an interactive environment. In contrast, better retention has been found when delaying feedback by as little as several seconds after each practice session when compared to concurrent or instantaneous delivery on a simple motor task (Swinnen, Schmidt, Nicholson, & Shapiro, 1990). Evidence has also been found where both groups (concurrent and terminal feedback with practice) performed similarly on the pre-, post-, and retention tests. Yet, the terminal group performed significantly better as measured by execution time and global rating scores (Walsh, Ling, Wang, & Carnahan, 2009). In another study (Chang et al., 2007), no obvious superior performance was shown by the terminal group compared with the concurrent group for retention.

These findings suggest that while practice trials are conditions for motor learning, repetitive actions of practice should be arranged such that the learners are encouraged to interpret sources of feedback. Delaying feedback allows the learner to dedicate cognitive resources to the feedback source; it also reduces the likelihood that the feedback will become an extraneous source that degrades subsequent performance (Schmidt & Bjork, 1992). For example, initial learning for groups who receive delayed feedback suffers compared with learners receiving concurrent feedback, but gains in long-term retention remains significant (Smith & Kimball, 2010). In other words, delaying feedback increases the probability of correct response preservation on retention tests, but had minimal effects on error correction or error preservation probabilities during practice (i.e., initial learning). The same is true when a task includes metacognitive skills for error detection and correction (Mathan & Koedinger, 2005).

Immediate delivery of feedback does not allow enough time for self-assessment and self-error correction because it interferes with the learning process (Kulhavy & Anderson, 1972; Kulhavy & Stock, 1989; Lewis & Anderson, 1985; Schroth, 1992). This finding supports schema theory of motor learning (Schmidt, 1988) which posits that feedback is only present to guide the learner until he or she can accurately self-assess. Optimally, feedback should be presented to the learner in such a way that it aids in interpretation of natural sources of intrinsic feedback.

Little Evidence for Multiple Feedback Strategies

Feedback can be manipulated to provide information specific to a single perspective of a movement goal by highlighting subcomponents of the movement. This information can be provided in one of three perspectives: (a) by only showing learners the pattern of their response sequence with the learner being expected to infer error movement patterns; (b) by showing learners their patterns of response sequence along with the ideal pattern; and (c) by pointing out some or all error information to the learner (Adams, 1987). In simulator training, learners can receive multiple representations of subcomponent movement for a single task. A feedback strategy protocol where the learner receives these multiple perspectives of the movement pattern has been given little empirical attention although modern simulators are designed with this capability. Such a protocol may also eliminate erroneous dependence on sources of feedback. While little investigation has accounted for the impact of multiple feedback strategies, even fewer investigations examine the impact of varying those strategies within a training protocol. Yet, empirical evidence supports positive results for varying practice conditions during motor learning (Lee & Carnahan, 1990; Shea, Lai, Wright, Immink, & Black, 2001).

Multiple feedback strategies, as a rule-of-thumb when teaching procedural skills, involve learning a complex motor skill with multiple feedback strategies under variable practice conditions. Each feedback source would highlight the context from different perspectives or subcomponent of movement. Conventional feedback administration protocols manipulate the frequency of feedback. Feedback may be given during practice. Feedback may be delayed until after practice. Application of the specificity of practice hypothesis posits that feedback should be authentic to the real-world context. Application of the cognitive flexibility theory suggests that presentation of the context should be given at differing perspectives. Keeping true to the assumptions of both, multiple feedback strategies can create varying perspectives within the same context to have positive effects on retention (Jordan, Gallagher, McGuigan, McGlade, & McClure, 2000).

Scheduling and Strategies on Transfer

Studies in fields outside of instructional design revisit the historical media debate (Clark, 1994; Kozma, 1994; Morrison, 1994; Reiser, 1994). This debate examined whether one technology as compared against another could impact learning. The resulting consensus was that the interplay between media and instructional strategy serve as the vehicle for generating learning (Clark, 1983, 1994; Kozma, 1994, 2000). Findings from the medical field support the idea that no significant difference can be found when comparing one technology to another. Findings from other fields (i.e., welding, Stone, Wattts, Zhong & Wei, 2011) found differences in initial learning. However, participants merely practice with the simulator without consideration of instructional features such as visual feedback or design considerations such as workload. As technology advances simulator developments, the historical media debate becomes even more crucial and must be extended beyond media comparison to transfer tests in operational contexts.

Summary of Feedback Scheduling and Strategy

In reviewing separate investigations on motor learning and feedback, an array of tasks and measures of performance has been used in the design of feedback studies. Arguably, many variables interact with each other at some level during simulator training. However, only certain interactions have empirical support. The literature suggests that immediate and frequent feedback are associated with faster and better initial learning of nominally easy tasks (Guadagnoli & Lee, 2004). A reversed trend for retention; however, is found under the same conditions. Delayed but frequent feedback has been associated with greater retention of complex motor tasks (Wulf, Shea, & Matschiner, 1988). Varying feedback conditions may serve as one way to vary practice conditions such that multiple perspectives of the same context are presented to impact transfer.

Learner Perceptions

Learning involves a complex cognitive organization of information, beliefs, and social principles that guide retrieval needed to solve novel problems. Findings in industrial settings suggest that a large correlation between the intent to invest effort to engage in a learning experience and training outcomes (Facteau, Dobbins, Russell, Ladd, & Kudisch, 1995; Colquitt, LePine, & Noe, 2000). There is a growing body of empirical research devoted to discovering effective training conditions as well as understanding how learner perceptions influence learning in training settings (Campbell & Kuncel, 2001). The designed environment alone no longer serves as the only conditions to examine. Learner perceptions (e.g., perceived realism, self-efficacy, and workload) replace static snapshots of behavior (Bereiter & Scardamalia, 1993).

Perceived realism. A learner's perceptions of fidelity are referred to as *perceived realism*. Fidelity measures multimedia's ability to simulate replications of reality. Fidelity of presentation, guidance, system feedback, and user actions are crucial components to the design of multimedia instruction (Alessi & Trollip, 2001). When a simulation mimics closely the reality of the phenomenon, model, event, or process, fidelity is considered high. As a simulation differs from the constants of reality, fidelity is considered low. Learners' perception of fidelity, or perceived realism, impacts initial learning and transfer.

Evidence of low fidelity for initial learning. Best learning occurs when new knowledge is presented in such a way that working memory resources needed are reduced (Sweller, Ayres, Kalyuga, 2011). Learners' working memory reaches its capacity to process when the to-be encoded information exceeds the maximum possible resources. Computer-based simulations with high fidelity impose higher cognitive demands on novice learners because of the lack of pre-existing schema. These higher cognitive demands placed on novice learners during high fidelity computer-based simulations decrease initial learning and far transfer. Low fidelity removes extraneous elements of the task. Learners devote available cognitive resources to practicing intrinsic portions of the task. Unessential elements can be removed until which time the learner has acquired the cognitive architecture to handle more demand. Low fidelity has been found effective for initial learning with novice learners (Boreham, 1985). Recent studies find little evidence that novice students trained with a high-fidelity simulator are more able to transfer skills to actual tasks (de Giovanni, Roberts, & Norman, 2009).

In one study (Friedman et al., 2009), novice participants practiced epidural needle insertion on a high-fidelity epidural simulator or on a low-fidelity model. Both low- and high-fidelity practice over a 6-month period resulted in significant improvement when compared to participants who had no simulation-based training. However, no significant differences were found between the low-and high-fidelity group.

Evidence of high fidelity for transfer. Low- and high-fidelity cardiopulmonary resuscitation simulators (CPR) have been found to hinder knowledge retention of novice learners over time (Ahmad & Ahmad, 2014). These same findings were evident in a review of 23 studies of part-task trainers and high-fidelity simulators (Laschinger et al., 2008). There have been little empirical studies on transfer of training for expert learners despite their popularity. Norman, Dore, and Grierson (2012) reviewed studies comparing low- to high-fidelity simulators and found no significant advantages in initial learning of one simulator over the other. However, studies were found to result in better transfer performance when comparing simulator training to no simulator training.

Expert otologists from six academic institutions were asked to evaluate the fidelity of an inner-ear simulator after practicing a stapedotomy procedure. Although 83% agreed that the simulator was highly accurate in dimensions and tactile feedback, 54% disagreed that performance on the simulator would improve (Monfared et al., 2012). In one empirical study, novice emergency medicine residents took significantly longer to complete surgical airway using a high-fidelity simulator than experienced residents (Girzadas, Clay, Caris, Rzechula, & Harwood, 2007).

Perceived self-efficacy. Perceived self-efficacy is one's belief in one's ability to complete the actions required to complete a task. As a result, perceived self-efficacy influences the amount of cognitive effort invested by learners (Bandura, 2012). Little is known about whether manipulating feedback scheduling and strategies will impact self-efficacy in the same manner as initial learning. Measuring self-efficacy during initial learning and retention of a motor task may provide heuristic conclusions to researchers and instructional designers.

Li, Lee, and Solmon (2007) examined the role of perceptions of task difficulty to performance and found that participants who perceived an object manipulation task as more difficult had lower levels of self-perceptions of ability and exhibited low performance. In this study, participants were asked to self-report their level of experience in object manipulation skills, locomotor skills, and non-locomotor skills using a 7-point scale. Participants viewed videotaped instructions of the object manipulation task then completed the questionnaire a second time. Participants practiced the task for three days during their regularly scheduled gym class. After day three, participants completed the questionnaire for the final time. A skills test was administered two days following the last practice session. Those who initially perceived the manipulation task as less difficult had higher self-perceptions of ability.

Self-efficacy judgments such as self-perceptions of ability are regulatory appraisals which can occur before, during, and after learners undertake a task. Compared with less efficacious learners, those with high self-efficacy will persist, expend effort, and perform at a higher level (Bandura, 2012). Examination of three case reports suggested that knowledge and ability to perform a clinical motor skill (i.e., pediatric resuscitation) did not result in actual performance. Unless the clinician possessed a strong belief in those abilities, the clinician failed to perform (Maibach, Schieber, & Carroll, 1996). In other words, training should aim to produce high skill as well as high self-efficacy.

Mann and Eland (2005) assessed the self-efficacy produced by a four-step instructional sequence aimed at teaching a therapeutic motor skill. All (N= 83) osteopathic medical students attended each of the four steps: (1) instructor demonstration, (2) paired practice with student, (3) independent practice integrating video and print materials, and (4) independent practice of student performing technique on an instructor with feedback from the instructor immediately after practice. Instructor demonstration and paired practice represented a traditional model of psychomotor skill instruction and resulted in low self-efficacy scores by most students. High self-efficacy scores were found for most students during independent practice with feedback from an instructor and independent practice without feedback.

Workload. The term, workload, indicates how much effort and attention are required to acquire a certain level of performance in a given task. Learners engage in more effective practice sessions when more effort and attention are brought to bear when cognitively processing the task. The learner monitors both internal and external components and changes internal mental models, if necessary, to formulate schema development and strengthening. It is when learners neglect this internal self-regulatory processing and memory retrieval that little to no change occurs in the cognitive system of the learner. Empirically supported reasons are attributed to learners' failure to engage in self-regulatory processes and cognitive engagement. The learner may be unmotivated to engage because existing knowledge and beliefs filter the new information before it enters the learner's cognitive system (Immordino-Yang & Damasio, 2007; Immordino-Yang & Sylvan, 2010). Or, the learner lacks available working memory resources to process the information in the format in which it is presented (Sweller, Ayres, & Kalyuga, 2011). Inherent limitations of working memory impact learning in distinct ways when the nature of a task requires interpretation of multiple representations and sources of information. Successful comprehension requires successful execution of administrative duties such as remembering the location of items and patterns in a figure plus extracting structural organization while managing the demands of the cognitive processing loads.

In one study using a driving simulator, evidence was found to support the idea that workload may be unaffected by differing practice conditions, but retention may be positively impacted (de Groot, Ricote, & Winter, 2012). Workload has been found to be a more important factor than type of practice (specific or variable) in performance gains in elementary-aged children (Van Dan Tillaar & Marques, 2013). These findings suggest that as working memory resources decrease, workload becomes more crucial to learning.

Summary of Perception Research. While little investigation has accounted for the impact of multiple feedback sources within a single context, even fewer investigations examine the impact of varying feedback scheduling and strategies on learner perceptions. Research addressing perceived realism, self-efficacy, and workload provide insight to the multidimensional role of feedback and focuses empirical evidence on the relation of feedback to learner performance. Learner's perceptions of a training protocol's ability to mimic reality, their self-judgment of personal ability, and task demand have been found to directly impact retention. Future studies should be extended to address how the manipulation to the frequency of feedback strategies impacts learner perceptions. Findings may inform instructional designers on ways to create more efficient learning events.

Justification for Study

One of the major challenges in the field of instructional design is conducting empirically substantiated design recommendations for multimedia affordances. Empirically-based training protocols start with known themes of learner perceptions and feedback effects. Expert performance research, and, in particular, the theoretical framework of deliberate practice gives understanding of the principles and activities that are essential in order to excel in a domain (van Gog, Ericsson, Remy, 2005). Rather than dismiss the instructional design process, empirical studies should follow the natural progression of the field. In this case, empirical studies should address the design of multimedia for learning and seek empirical support for training protocols.

Research Questions and Hypotheses

The objective of this study is to provide empirical evidence for designing instruction afforded by multiple feedback capabilities of the VRTEX™360 or similar welding simulators with the following hypotheses and research questions. Research questions include the following:

1. How does feedback strategy (gradual increase, gradual decrease, consistently-single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainee performance as measured by initial learning, retention, near transfer, and far transfer?
2. How does feedback strategy (gradual increase, gradual decrease, consistently-single) and scheduling (relative and absolute) in a moderate

fidelity welding simulator impact trainees’ perceptions as measured by perceived realism, perceived self-efficacy, and workload?

The following hypotheses are anticipated:

1. Feedback strategies (gradual increase, gradual decrease, and consistently-single) and feedback scheduling (absolute) will facilitate initial learning but hinder near and far transfer.
2. Feedback scheduling (relative but not absolute) will facilitate near and far transfer but hinder initial learning.
3. Initial learning, perceived realism, and perceived self-efficacy will decrease as feedback complexity (scheduling and strategy) increases.

CHAPTER II

METHODS

The intent of this nested, mixed-methods study was to investigate the effects of feedback scheduling and strategies on initial learning, perceived realism, perceived self-efficacy, workload, near transfer, and far transfer. The VRTEX™360 was used to manipulate visual feedback strategy and scheduling. Dependent measures, initial learning and near transfer, were quantitatively assessed by the VTREX 360. Additional measures of perceived realism, perceived self-efficacy, and workload were explored by survey instruments, instructor observations, and group interviews.

Participants were recruited from a United States military training facility which incorporates VRTEX™360 simulator training into its curriculum. The facility conducts vocational training targeting the professional development needs of over 6,000 newly recruited Soldiers in the Ordnance Branch of the United States Army (specific to this study is the Army's occupational profession known as Allied Trades Specialists). Training at the facility takes place during an 8-hour training day. The facility annually trains approximately 550 Army Soldiers in the basic skills and foundational knowledge of an Allied Trade Specialist.

Training new Soldiers to perform the duties of the Allied Trades Specialist involves a 19-week program of instruction known as the Allied Trades Specialist Initial Entry Training. This instruction trains Army Soldiers (and Marines) in the basic skills and foundational knowledge of an Allied Trade Specialist. Initial training for the Allied Trades Specialist is 755 academic hours and taught in three phases.

The first two phases consist of training attended by Marines and Army students and focuses on machinist and welding training, respectively. The third phase is attended by Army students only. The final phase is a capstone module that involves role-play and teamwork. The weld phase of the course involves five modules (see Appendix A for course map of welding phase). This study will focus on module E that teaches introductory weld concepts (work angle, travel speed, travel angle, and contact-to-work-distance), weld symbols, shop drawings, and shop safety. The subsequent module, Module F, involves metal preparation procedures (i.e. metal cutting) and portable weld processes (i.e. oxy-fuel welding). Typically, modules H and I involve practice on the VRETX™360 simulator. To control for prior knowledge of welding and experience on actual weld equipment, practice on the VRETX™360 simulator occurred at the end of the introductory module and prior to modules F, G, H, and I. The experimental task involved welding a t-joint, fillet weld using the gas metal arc welding process in the horizontal and vertical positions (see Figure 1 for standard weld positions).

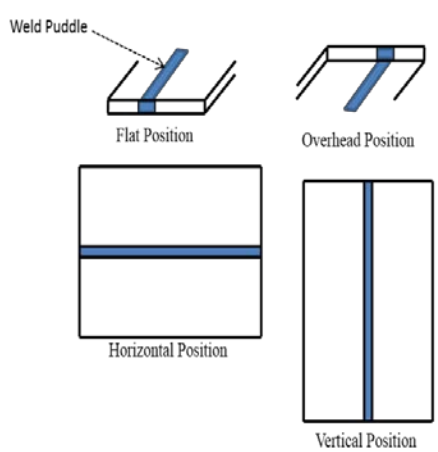


Figure 1. Standard weld positions recognized by American Welding Society.

The use of instructional time was not used to recruit subjects. Instead, time allocated for student registration was used to identify participants. This researcher is part of the cadre at the military facility. This researcher was the course manager at the facility and not an instructor with direct interaction with trainees in the course. Senior command leadership granted approval and appointed this researcher with an additional duty of research lead at the training facility. The study protocol was submitted and approved by the Darden College of Education of Human Subject Committee prior to recruitment or data collection under the project number, 860836-1.

Trainees attending the Allied Trades Specialist course are pre-selected by the military institution based on physical and aptitude measures. Weight restrictions follow Army doctrinal standards for height and age. Physical fitness requirements follow physical fitness readiness testing based on the Army's Field Manual 7-22. Aptitude, as measured by the military enlistment test known as the Armed Services Vocational Aptitude Battery (ASVAB), assesses verbal, math, science-technical, and spatial domains on 10 subtests. Scores from various subtests are combined to compute minimum eligibility line-scores for a military occupation. The average general technical (GT) minimum line-score for the welding course, which is comprised of arithmetic reasoning plus a verbal composite of word knowledge and paragraph comprehension, is 92.

As an order of preference, only active duty participants were recruited. Some classes of potential participants (i.e., Reserve and National Guard Soldiers) were eliminated as participants because of restricting military policies governing these specialized categories. Only Army trainees were included in the study. The course also trains Marines; however, Marine trainees were not recruited for the study because of restricting military policies governing inter-service training. In addition, Marine trainees must meet different pre-requisites than Army trainees. Including Marine trainees violates the homogenous assumption of convenience sampling.

Participants

The population of VRTEX™360 end-users includes organizations from community colleges, industry, military, high schools, and trade schools. An ideal sample of participants would include random representations from each of these 44 international and national organizations that use the VRTEX™360 simulator. For this study, one location, a nonprobability sample of convenience, was sought to explore preliminary findings without incurring the cost or time required to select a random sample. While the population is a nonprobability selection, the treatment assignments were random.

Participants for each treatment were randomly assigned from the students who completed Modules E of the welding phase of Allied Trades Specialist Initial Entry Training over the four months of data collection for this study. The course teaches welding skills; therefore, use of a sample from this population will inform the body of knowledge addressing the use of simulator training for welding skills. A total of 55 trainees, aged 18-34, enrolled in the Allied Trades Specialist course was recruited for the study. Participants were asked to self-report their age and years of welding experience. Of the participants who self-reported their age, 77% (n=41) the majority who self-reported their age were between 18 and 24. The average years of experience was 2.85 (see Table 1).

Table 1

Descriptive Statistics on Characteristics of Participants

		Frequency	Percent
Gender (*n*=55)	Male	51	93%
	Female	4	7%
Age	18-24	41	77%
	>24	12	*23%*
Welding Experience (*n*=49)	<0 yrs	39	*80%*
	1-2 yrs	3	*6%*
	>2 yrs	7	*14%*

Materials and Apparatus

Training Simulator

The VRTEX™360 is a virtual reality arc-welding simulator used in this study. This training system is designed to allow practice of welding techniques in a simulated mixed-reality environment (see Figure 2). The VRTEX™360 is a second generation to the VRS SimWelder. Practice with the simulator combines realistic puddle simulation and arc welding sounds with the welder wearing actual protective equipment (i.e., welding helmet) and using an actual welding gun for movements to provide a mixed-reality experience.

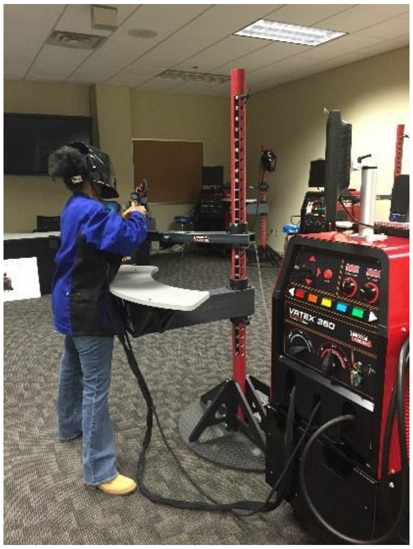


Figure 2. VRTEX™360 Virtual Reality Welding Simulator

Hardware

The VRTEX™360 was designed to replicate the actual hardware of an arc welding machine and its attachments. Hardware for the VRTEX™ 360 replicates haptic features such as touching the electrode to the base metal and require the learner to push the hand-held stinger, welding gun that holds the electrode. Hardware includes the weld machine, weld table, and welding helmet.

Weld machine. The weld machine on the VRTEX™360 replicates the similar locations for operator controls on an actual arc welding machine (see Figure 2). On the front panel of the weld machine, operator controls settings must be accurate. If settings are incorrect, the trainee is “locked –out” and unable to continue until setting are corrected. A 16” monitor, mounted on the top surface of the machine, allows the trainee to view setup selections. Several additional screen views are available on the monitor: (a) the student view, which shows the virtual view as seen under the helmet, (b) the instructor view, which shows the virtual weld in real time, and (c) the live action student evaluation report (LASER) view, which displays multiple representations of four sub-movements on a single display graph on a monitor outside the virtual welding environment.

A rod gun holder is mounted on the right side of the weld machine. One haptic feature of the weld gun is the torque of the trigger. The trigger adjusts to the squeeze of the trainee. The VRTEX™360 replicates haptic features such as touching the electrode to the base metal and, dragging the handheld welding stinger gun that holds the electrode. Typically, a weld gun will get stuck to the weld if the welder presses the gun too closely to the metal of the weld. This haptic feature is absent on the VRTEX™360. The weld gun is connected to the machine by a cable that allows extension from the weld machine to the weld table.

Weld table. A free-standing weld table with post (which houses the connecting cables) and swing arm accompanies each weld machine. The swing arm can be adjusted to replicate any weld position (see Figure 1 for weld positions). A weld coupon attaches to the swing arm and becomes the weld surface used for practice (see Figure 3).

Figure 3. Table on the VRTEX™360 Virtual Reality Welding Simulator.

Welding helmet. Learners wear a welding helmet designed to produce the virtual environment through 3D stereo eye and earpieces. When practicing using the

VRTEX™360, the 3D stereo and eyepieces allow participants to observe as the weld puddle formulate while also hearing welding sounds related to their movement. A welding helmet is connected to the weld machine by a cable. The weld helmet replicates the size and protective shield feature of the actual helmet used by expert welders. The addition of eye and earpieces makes the weld helmet slightly heavier than an actual helmet (see Figure 4). Each lens on the eyepiece can be adjusted to the left or right to align them parallel to the trainee's eye placement. Trainees enter the virtual environment by looking into the eyepiece of the helmet.

Figure 4. Weld Helmet for the VRTEX™360 Virtual Reality Welding Simulator.

Personal protective equipment. Trainees wear protective clothing, known as personal protective equipment, while using the VRTEX™360. Protective equipment includes steel toe boots, leather gloves, welding caps, and leather jackets. In an actual welding environment, welders wear protective equipment to prevent and reduce safety and health risks (e.g., burns from weld sparks). Although burning is not a risk, trainees are required to wear protective equipment at all times (see Figure 5). Use of personal protective equipment for the VTREX™360 training helps replicate actual weld conditions.

Figure 5. Personal Protective Clothing.

Instructional Interface

The VRTEX™360 simulator provides a mixed-reality experience. The simulator combines realistic puddle simulation and arc welding sounds with the welder wearing actual protective equipment (i.e., welding gloves, steel toe boots) and using an actual welding gun for movements. The environment can be set to any of the virtual worlds (i.e., construction site, desert location, or machine shop) and includes up-close views of the work materials. As the trainee welds, the VRTEX™360 simulates filler metal consumption and light from an electrical arc. The virtual environment is also visible on the 16" monitor during the student view mode.

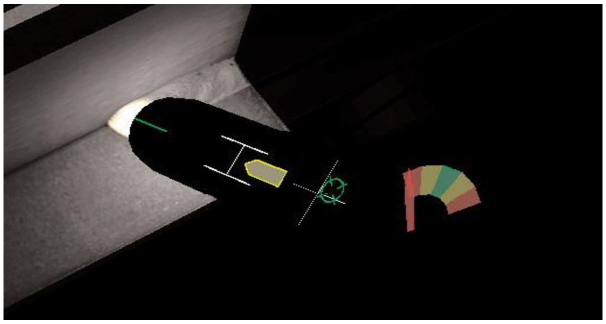


Figure 6. View from lens of VRTEX™360 helmet with all visual cues.

Visual cues can be added above the weld gun as dynamic, visual feedback of the trainees' performance (see Figure 6). The learner can view the cues, the weld gun, and coupon metal contiguously within the virtual interface of the simulator. Visual cues represent weld concepts which describe a subcomponent movement of the overall body mechanics required for a welding process. Each of the visual cues can be toggled on or off using setting controls of the VRTEX™360. Explanation of each weld concept represented by the visual cues can be found in Table 2.

Table 2

Weld Concepts Represented by Visual Cues

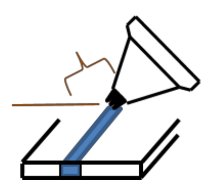
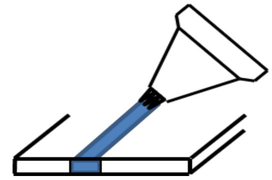
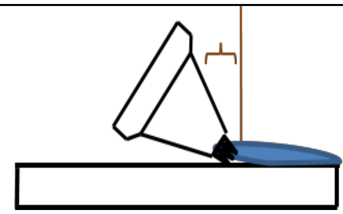
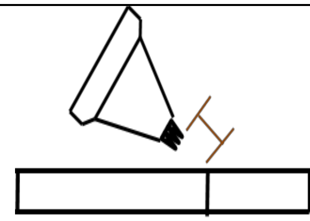
Weld Concept	Definition	Pictorial Representation
Work Angle	The angle comprising of the y-axis of the workpiece and electrode	

Table 2

Continued

Travel Speed	The rate of motion from beginning to end	
Travel Angle	The position held by the electrode and workpiece along the direction of travel	
Contact to Work Distance	The distance from the tip of the weld gun to the weld	

Simulator Training Context

Trainees learn to create a fillet weld, two pieces of mild steel joined at a 90 angle. This common type of weld is produced by filling the area where the two pieces join with a weld bead. The point where the two pieces of metal join may create a lap, corner or "T" joint. The strength of the joint is determined by the amount of penetration. The weld bead should penetrate both pieces of the joining metals in equal distribution. Failure to allow the welding rod to travel along the joint equally results in poor penetration. To do so, the welder must master the mechanics of several sub-movements. Several processes may be used to produce a weld bead. In this study, the trainees used the gas metal arc welding (GMAW) process to create the fillet weld (see Figure 7).

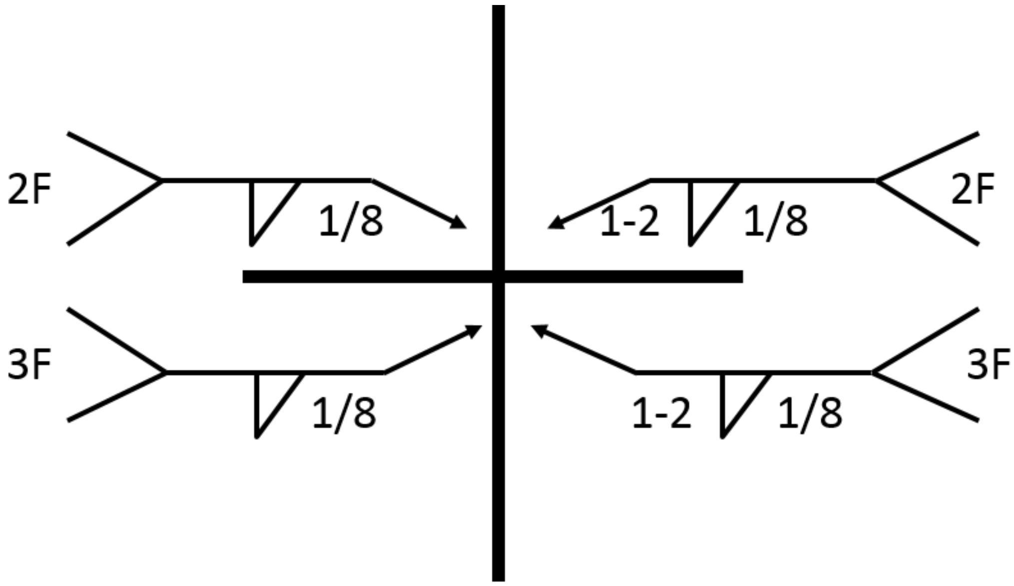
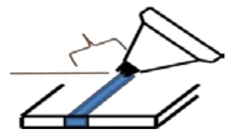
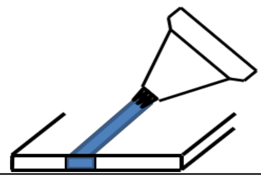
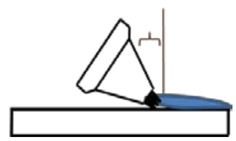
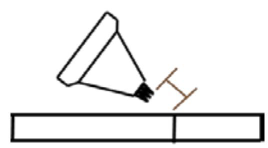


Figure 7. Print Drawing of the filet weld.

As trainees practice the GMAW process on the VRTEX™360, graphical representations provide performance feedback regarding subcomponents of movement (i.e., work angle, travel speed, travel angle, and work-to-contact distance). These graphical representations alert the trainee to deficiencies regarding movement. The trainee must attend to the performance feedback provided by each graphical representation while welding (see Figure 6). Feedback is given in real-time and follows a red-yellow-green color code. When a graphic indicates performance in the red color zone, the trainee's performance is poor for that subcomponent of movement and does not meet standard performance. When a graphic indicates performance in the yellow color zone, the subcomponent movement is fair and barely meets standard performance. When a graphic indicates performance in the green color zone, the subcomponent movement meets the standard performance. Table 3 compares the graphical representations afforded by the VRTEX™360 and its conventional pictorial representation.

Table 3

Comparison of Conventional Representation to VRTEX™360

Weld Concept	Conventional Representation	VRTEX™360 Representation
Work Angle		
Travel Speed		
Travel Angle		
Contact-to-Work Distance		

Control settings of the VRTEX™360 can be set to show one, some, or all graphical representations to the trainee during simulator practice.

Study Treatments

Prior to treatment, all participants received a 1-hour training session on weld concepts (see Appendix B for description of pre-training). The following paragraphs describe the 2 x 3 factorial design of the study.

Feedback Strategy. Feedback strategy described the number of visual cues available to the learner during each practice trial. On this level, the number of visual cues followed a feedback strategy that was operationally defined as either: (a) gradual decrease to the number of visual cues within the interface, (b) gradual increase by increments of one, or (c) a consistently-single cue at each trial. The consistently-single group where feedback highlighted the task from a different perspective followed the same single-representation practice variation as found in the motor learning literature (Lee & Carnahan, 1990; Shea, Lai, Wright, Immink, & Black, 2001). Evidence from contextual interference studies also suggest that the transient effects of feedback dissipate when feedback targets different perspectives of a task (Lee & Carnahan, 1990; Shea & Morgan, 1979).

The emphasis of this research is on the difficulty students, especially novices, may have translating or making connections when multiple perspectives are afforded simultaneously, however, little research examines practice conditions where multiple-representations are manipulated as a feedback strategy of a moderate fidelity simulator. Cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1992) suggests that switching between multiple perspectives of an ill-structured domain such as welding benefits transfer of knowledge and skills. The switching between perspectives provides feedback from different perspectives of the task. Since participants lack cognitive resources germane to the task, multiple perspectives were manipulated as a gradual increase or decrease and provided the instructional support critical for schema development in novice learners.

Feedback Scheduling. On another level, feedback scheduling described the availability of visual cues over practice. This level referred to the scheduling of cues over twelve trials of practice per session. Feedback was scheduled during each practice trial within a practice session, or absolute scheduling. Or, feedback was scheduled every third practice trial, or relative scheduling (see Appendix C for training protocol). Empirical evidence suggests that initial learning is usually transient and changes in behavior are rarely permanent; that is, the learner becomes dependent on the feedback source and change in motor performance usually dissipates once the feedback source is removed. To account for this guidance effect during initial learning, feedback scheduling was manipulated to impose deeper processing. Feedback guides the learner to the correct action, then repeating the movement without feedback at the goal position serves to strengthen the action and its recognition schema.

In summary, feedback scheduling is the number of trails receiving visual feedback and consists of two most commonly levels as found in the literature: relative (50% of trials) and absolute (100% of trials). Feedback strategy is the number of visual feedback cues available within the virtual environment and consist of three levels: gradual increase, gradual decease, and one only. Feedback scheduling and strategy will be factored, resulting in six treatment groups (see Table 4).

Table 4

Overview of Treatment Groups

	Relative Scheduling	Absolute Scheduling
Gradual Increase	terminal feedback, plus concurrent visual cues grad↑, relative 50% (12 trials total)	terminal feedback, plus concurrent visual cues grad↑, absolute 100% (12 trials total)

Table 4

Continued

	Relative Scheduling	Absolute Scheduling
Gradual Decrease	terminal feedback, plus concurrent visual cues grad↓, relative 50% (12 trials total)	terminal feedback, plus concurrent visual cues grad↓, absolute 100% (12 trials total)
Consistently-Single	terminal feedback plus concurrent visual cues consistently-single; relative 50% (12 trials total)	terminal feedback plus concurrent visual cues consistently-single; absolute 100% (12 trials total)

Dependent measures. Trainee performance was measured using quantitative and qualitative methodology at four data points (i.e., initial learning, retention, near transfer, and a far transfer session). Performance on each subcomponent of movement was collected and reported by the VRTEX™360 using a ratio scale ranging from 0-100 at initial learning, retention, and a near transfer practice session, respectively. A final session collected far transfer performance as measured on the actual weld equipment using a ratio scale ranging from 0-100.

Initial learning. As learners practiced welding in the flat position under a given treatment, the VRTEX™360 scored initial learning in four areas of subcomponent weld movement (i.e., work angle, travel speed, travel angle, contact-to-work distance). Initial learning described the learner's performance while completing the task for the first time under a feedback treatment. An overall score was also calculated by the VRETX™360 on a ratio scale ranging from 0-100. After each weld pass, participants removed their helmets and viewed their scores on the LASER view of the monitor (see Figure 8). Each participant recorded their scores on the Practical Exercise Form (see Appendix D). For example, the absolute-increase group began practice with one visual cue. The scheduling of visual cues increased by increments of one every third trial. Practice continued for a total of 12 trials. By the final three practice trials, all four visual cues were available to the learner (see Figure 5).

Figure 8. Sample live action student evaluation report (LASER) view.

Perceived realism and perceived self-efficacy. As measured by inventory and group interview with open-ended questions, perceived realism was collected at the end of Day Two (see Appendix E). A realism inventory was created based on task analysis of the simulator training context (see Appendix F). Reliability of the realism inventory was estimated post hoc with Cronbach's coefficient alpha during data analysis.

Academic self-efficacy is usually measured at task-specific levels. A questionnaire, adapted from the Self-Efficacy for Learning Form-Abridged (Zimmerman & Kitsantas, 2007) and based on guidance for constructing self-efficacy scales (Bandura, 2006), was specific to factors known to impact learning a motor skill (see Appendix G). The original abridged scale reports an internal stability of α=.97. In the present study, the adapted task-specific self-efficacy scale measured against levels of task demands that represent graduations of difficulty. Identified challenges built into the scale were derived from archival data of end-of-course critiques (see Appendix H) which asked students to rate components of the task that made it hard for them to perform well. The scale purports to measure perceived difficulty when producing a weld. Reliability of the adapted task-specific scale was estimated post hoc with Cronbach's coefficient alpha.

From a phenomenological approach, analysis of the VRTEX™360 training environment aimed at unfolding the essence of the designed training event for the participants. Open coding, considering the data in minute detail while developing initial themes of perceived realism and self-efficacy, captured learner interactions with the technological affordances of the VRTEX™360. Open coding identified any redundancy and other incidental (or irrelevant) expressions found in the data. Later, more selective coding of core concept(s) and theme(s) analyzed intentional dynamics between the trainee and the designed training. Frequency counting and descriptive statistics was conducted to give meaning to revealed themes.

Workload. In this study, the original NASA Task Load Index (NASA-TLX) as developed by Hart and Staveland (1988) measured dimensions of workload. As measured by NASA-TLX, workload collected during each practice session at initial learning, retention, near transfer, and far transfer. Workload is evaluated using six subscales (frustration level, effort, performance, temporal demand, physical demand, and mental demand) on a low (0) to high (100) rating (see Appendix H). The original NASA-TLX has a reliability of .83. The amount of invested mental effort (AIME) questionnaire is a four-item scale (Salomon, 1984) with a Cronbach’s alpha equaling .89. In this study, this scale combined with the original NASA Task Load Index (NASA TLX) will be used to measure additional dimensions of mental demand (see Appendix I).

Retention. Retention describes the learner's performance after practice under a given treatment condition and without the aid of feedback. After each practice session under a given treatment condition, the trainee will weld in the horizontal position absent of feedback afforded by the simulator. This session on the VRTEX™360, referred to as the retention, scored performance in four areas of subcomponent weld movement (i.e., work angle, travel speed, travel angle, contact-to-work distance). An overall score was also calculated by the VRETX™360 on a ratio scale ranging from 0-100. The score was collected from the LASER view on the monitor (see Figure 8) and recorded by each participant (see Appendix D).

Near transfer. Near transfer describes weld performance using actual equipment but in the same weld position as performed on the VRTEX™360. Near transfer is operationally defined as welding in the horizontal position on actual weld equipment. Participants performed two weld passes on a t-joint using a mild steel coupon which was then scored using a rubric scoring of performance on actual equipment (see Appendix J). Three instructors from a pool of eight instructors were selected to use the rubric score sheet two weeks before the study. All eight instructors were given three sample welds from students in the course but not participating in the study. Instructors were trained on the criteria of the rubric and provided samples of exemplary and undesirable welds. A consistency estimate of inter-rater reliability was calculated using Cronbach's Alpha coefficient. Those three instructors whose correlation coefficient is closest to one were recruited as raters.

Far transfer. Far transfer describes weld performance using actual equipment but in a different weld position than performed on the VRTEX™360. Far transfer was operationally defined as welding in the vertical position on actual weld equipment. Participants performed two vertical weld passes on a t-joint using a mild steel coupon which was then scored using a rubric scoring of performance on actual equipment (see Appendix K). The welded mild steel coupon was scored using a rubric scoring by the three recruited instructors.

Figure 9. Conventional Gas Metal Arc Welding Equipment.

Procedures

Each participant received a notification form as part of the in-processing brief at the beginning of the welding phase of the course (see Appendix K) and a fact sheet prior to treatment (see Appendix L). In a traditional classroom setting, participants received an envelope which included a fact sheet and color-coded data collection instruments. Next, participants received pre-training on weld concepts. Then, the participants will complete a pre-assessment of self-efficacy with Instructor One (see Appendix G). Demographic data (to include name, age, ASVAB scores) was also collected. As participants completed the self-efficacy pre-assessment, they returned the assessment to the envelope and formed a line in the back of the classroom.

Once all students completed the survey, Instructor Two escorted students to an adjacent simulator lab and randomly assign each participant to a designated simulator station in chronological fashion from the line. Treatments were randomly assigned to each stationed and treatment protocol per station was changed daily. Participants placed their envelope on a stool located at each simulator station and practiced twelve weld beads of gas metal arc welding under a random treatment condition.

Instructor two assign the first participant to simulator station one, designated for the gradual increase to feedback condition on a relative scheduling. The next participant was placed at station two, under a gradual decrease to feedback condition on absolute scheduling treatment. The next participant was placed at station three, designated as random display of only visual feedback. The next participant was place on station four as the control group and so on (see Appendix C). The control group received no manipulation of feedback and practiced absent of any visual cues. This procedure continued until all stations (a total of 10) were assigned. Soldier names, rank, or company name will not be permitted to generate any lists for data collection or research purposes. All survey instruments had generic titles and were kept in a folder labeled “For Office Use Only” at the simulator station. Data collected by the simulator was recorded on the VRTEX™360 Practical Exercise Form by the participant and kept in the participant’s folder (see Appendix D). All data was recorded using a color-coded paper system which was only known by the researcher.

After each practice trial, a NASA-TLX was administered to all randomly grouped participants (see Appendices F and H). One day following treatment, participants will perform welding task on the VRTEX™360 without any feedback manipulation. Then, near transfer performance of gas metal arc welding task in the horizontal position was be measured on actual equipment (see Appendix J). Then, far transfer of gas metal arc welding task was measured on actual equipment in the vertical positions (see Appendix J). Data was collected over a 4-month period (see Table 5).

Table 5

Overview of Study Procedures

Day One: Prep Phase of 1 hour block of classroom instruction						
Perceived self-efficacy Inventory						
terminal feedback, plus concurrent visual cues grad↑ relative 50% (12 trials of RelInc)	terminal feedback, plus concurrent visual cues grad↑ absolute 100% (12 trials of AbsInc)	terminal feedback, plus concurrent visual cues grad↓ relative 50% (12 trials of RelDec)	terminal feedback, plus concurrent visual cues grad↓ absolute 100% (12 trials of AbsDec)	terminal feedback plus concurrent visual cues consistently-single; relative 50% (12 trials of RelCon)	terminal feedback plus concurrent visual cues consistently-single; absolute 100% (12 trials of AbsCon)	**Control Group** (12 trials of AbsOff)
Instructor Observation Notes in simulator lab						
NASA-TLX/AIME Inventory after trial 1, 6, and 12						
Perceived Self-Efficacy Inventory						
Instructor Observation Notes in simulator lab						
Day Two: Retention Test on VRTEX-horizontal position/T-joint- no feedback						
Perceived Self-Efficacy Inventory/Realism Inventory						
Near Transfer Test on actual equipment - horizontal position						
Far Transfer Test actual equipment –vertical position						
Instructor Observation Notes in shop area						
Group Interview						

Overall, participants completed twelve practice trials of welding under a feedback manipulation; then, participants complete twelve practice trials of welding without it. Lastly, participants performed the weld task on actual equipment in the shop area. Participants self-reported basic demographic data. Self-efficacy was self-reported before treatment, at three data points during treatment (trial one, six, and twelve), and the end of day two. Workload was reported at three data points during treatment (trial one, six, and twelve) and at the end of Day Two. Instructors completed observational notes in the simulator lab and shop areas (see Appendix N). A final group interview was conducted by the researcher (see Appendix O).

Data Analysis

Data were analyzed to determine the distributional properties (e.g. homoscedasticity, normality, etc.). Quantitative and qualitative data from the nested 2 x 3 factorial design were analyzed. Qualitative data were analyzed at the interpretation phase of statistical analysis and will involve identifying themes and creating codes. Any students self-reporting some or very experienced on prior knowledge were eliminated from data analysis. Raw data were cleaned to meet testing assumptions for parametric analysis. As the Friedman test does not assume normality in ordinal data and is much less sensitive to outliers, it was used to investigate whether a statistical difference exist in self-efficacy, workload, and realism with participants based on feedback strategy prior to treatment (see Table 6).

Table 6

Breakdown of Research Questions

Research Question	***Dependent Measure***	***Data Collection***	***Analysis***
How does feedback strategy (gradual increase, gradual decrease, consistently single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainee performance as measured by initial learning, retention, near transfer, and far transfer?	Initial Learning	**Day One:** VRTEX™360 Performance Metrics (Work Angle, Travel Speed Travel Angle, Contact-to-Work Distance)	One-way ANOVA (between subjects-group; within subjects-practice trials)

Table 6

Continued

Research Question	***Dependent Measure***	***Data Collection***	***Analysis***
	Retention	**Day Two:** VRTEX™360 Performance Metrics (Work Angle, Travel Speed Travel Angle, Contact-to-Work Distance)	One-way ANOVA (between subjects-group; within subjects-practice trials)
	Near Transfer, Far Transfer	Adapted from Instructors' Rubric Rating	One-way ANOVA (between-subjects-group)
How does feedback strategy (gradual increase, gradual decrease, consistently single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainees' perceptions as measured by perceived realism, perceived self-efficacy, and workload?	Perceived self-efficacy	**Day One:** Adapted Self-Efficacy for Learning Form-Abridged Inventory	One-way ANOVA (between subjects-group); Friedman Test (related, within-subjects)
	Workload	NASA-TLX	One-way ANOVA (between subjects-group); Wilcoxon Signed Ranks (related, within-subjects)
	Workload	**Day Two:** NASA-TLX/AIME	One-way ANOVA (between subjects-group)
	Perceived Realism	10-point rating from "not at all" to "very, very high"	Post-positivist Qualitative Analysis
Feedback strategies (gradual increase, gradual decrease, and consistently single) and feedback scheduling (absolute) will facilitate initial learning but hinder near and far transfer.	Initial learning	VRTEX™360 Performance Metrics	One-Way ANOVA (between subjects-group)
	Near Transfer	Adapted from Instructors' Rubric Rating	
	Far Transfer	Adapted from Instructors' Rubric Rating	

Table 6

Continued

Feedback scheduling (relative but not absolute) will facilitate near and far transfer but hinder initial learning.	Initial learning Near Transfer Far Transfer	VRTEX™360 Performance Metrics Rubric Rating Rubric Rating	One-Way ANOVA (between subjects-group)
Initial learning, perceived realism, and perceived self-efficacy will decrease as feedback complexity (scheduling and strategy) increases.	Initial Learning Perceived Realism Perceived Self-efficacy	VRTEX™360 Performance Metrics 10-point rating from “not at all” to “very, very high” Adapted Self-Efficacy for Learning Form-Abridged	One-Way ANOVA (between subjects-group); One-Way ANOVA (between subjects-group); Post-positivist Qualitative Analysis

Limitations

The scope of this study was limited to motor learning of a welding task using a simulator. The results of the study are only generalized to simulator training. Additional limitations include treatment fidelity as measured by the simulator and the possibility of threats to internal validity of the questionnaires. Reliability and validity data of the dependent measures collected by the simulator were not available at the time of the study. However, reliability of the adapted task-specific self-efficacy scale and the combined mental effort scale was estimated post hoc with Cronbach’s coefficient alpha during data analysis.

The level of statistical significance (i.e., $p < .05$) approximates absolute truth. False positive and false negative results can never be avoided, but large sample sizes reduce the likelihood by increasing the power of study. Because of the sample size of the treatment groups, this study is subject to Type II error, also known as a "false negative."

Measures of realism, workload, and self-efficacy have been collected through self-reporting surveys at the ordinal level. As such, it may not be feasible to expect outcomes to be consistent with a normal distribution given the sample size and data level. The additional use of nonparametric measures captures trends in data of the small sample size of ordinal data. Effect sizes are reported with confidence intervals as a possible indication whether any non-significant findings could be due to small sample sizes.

Specific to the phenomenological perspective of qualitative research, this study relies upon qualitative measures of the participants to construct theoretical truth based on individual perceptions. The assumptions and philosophical paradigm of qualitative methods point to an exceptional fallacy when group conclusions are made based solely from individual observations. Individual biases are unavoidable, but objectivity is approached by triangulation of multiple fallible sources. Although sampling procedures of this inquiry adhere to purposefully selection rather than deviant cases, threats to external validity may create ethical dilemma.

Special care was taken to maintain anonymity and the right to withdraw. The researcher was a formerly employed as a course manager at the facility. Therefore, adherence to voluntary consent was especially important. Because the inquiry sought observation of a commercial simulator, not proprietary military equipment, an ethical issue violating military research protocol was avoided.

CHAPTER III

RESULTS

The intent of this nested, mixed-methods study investigated two research questions and three hypotheses. The reported results for first research question and the first two hypotheses were obtained using quantitative analyses. The second research question and final hypothesis were explored using quantitative and qualitative analyses.

Research Question One

The first research question explored how feedback strategy (gradual increase, gradual decrease, consistently single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainee performance as measured by initial learning, retention, near transfer, and far transfer?

A one-way analysis of variance (ANOVA) was conducted to examine the impact (i.e., the mean differences in initial learning, retention, near transfer, and far transfer) of treatment manipulation across treatment groups. Where levels of the dependent variable (i.e., initial learning and retention) was measured over time, the one-way repeated measures ANOVA was used. All participants underwent scheduling and strategy manipulation which resulted in six unrelated treatment groups and one control group.

Table 7

Summary of ANOVA on Overall Initial Learning, Retention, Near & Far Transfer

<table>
<tr><th></th><th>df</th><th>F</th><th>p</th><th>partial η^2</th><th>M</th><th>SD</th><th colspan="2">Cohen’s d</th></tr>
<tr><td>Initial Learning (n=54)</td><td>6</td><td>.22</td><td>.97</td><td>.03</td><td>72.83</td><td>9.90</td><td rowspan="2">-0.45</td><td rowspan="4">1.74</td></tr>
<tr><td>Retention (n=52)</td><td>7</td><td>.60</td><td>.75</td><td>.09</td><td>77.05</td><td>8.92</td></tr>
<tr><td>Near Transfer (n=52)</td><td>7</td><td>1.83</td><td>.11</td><td>.23</td><td>57.56</td><td>12.71</td><td rowspan="2">0.31</td></tr>
<tr><td>Far Transfer (n=50)</td><td>7</td><td>1.25</td><td>.30</td><td>.17</td><td>53.77</td><td>11.86</td></tr>
</table>

The one-way ANOVA indicated no statistically significant difference across treatment groups in terms of initial learning, retention, near transfer and far transfer. Because sample sizes of treatment groups were small and unequal, a Cohen's d was computed for initial learning and far transfer; a large effect size (*d* = 1.74) was found (see Table 7). This means that if 100 students practice with the VRTEX™360 under one of the treatment protocols, 60 would have a favorable outcome in terms of far transfer compared to if they received the control treatment (i.e., practice without visual cues available). With the Cohen's *d* of 1.7, ninety-six percent of the treatment group will be above the mean of the control group; 40% of the two groups will overlap.

A graphically look at mean scores by group indicated that all treatment groups experienced a numerical improvement during the retention trials. The control group who experienced no treatment manipulation showed a flatline performance at retention. During the near transfer task, both the control and treatment groups showed a large decrease in performance. The absolute-decrease treatment was the only group who showed an increase during far transfer task (see Figure 10).

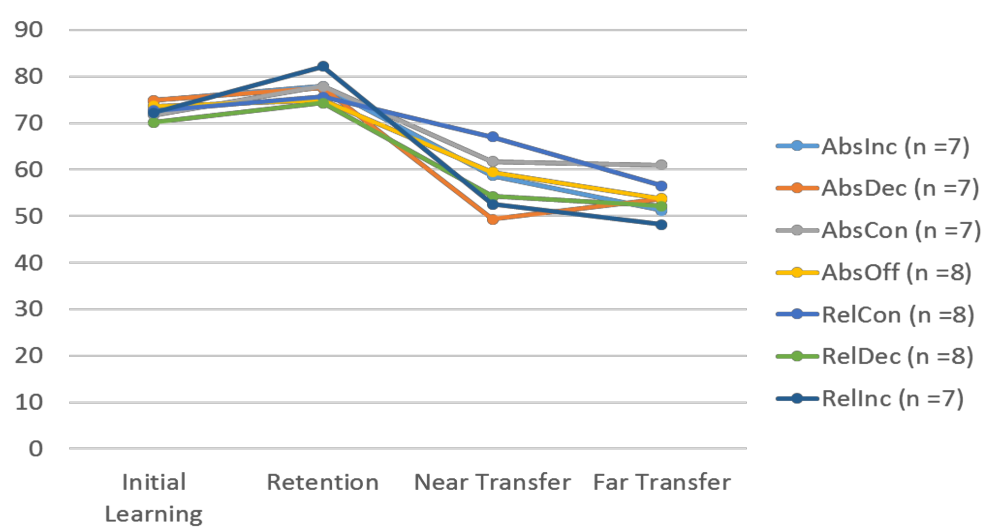


Figure 10. Estimated marginal means of trainee performance by treatment group.

A post-hoc two-way mixed design analysis of variance (ANOVA) was used to examine the main effects of scheduling and strategy between treatment groups, where the dependent variable trainee performance was measure over time (i.e., initial learning, retention, near transfer, and far transfer). Box's Test of Equality of Covariances Matrices indicted that the covariance matrices of trainee performance were equal across group ($p > .616$). Mauchly's test of Sphericity was statistically significant, $\chi(5)= 24.82$, $p =.000$, indicating the need for a Greenhouse-Geisser adjustment (€=.69). Trainee performance and treatment group interaction effect was not statistically significant, $F(12, 80) = 1.260$, $p < .257$, indicating that scheduling and strategy do not interact or vary across treatment.

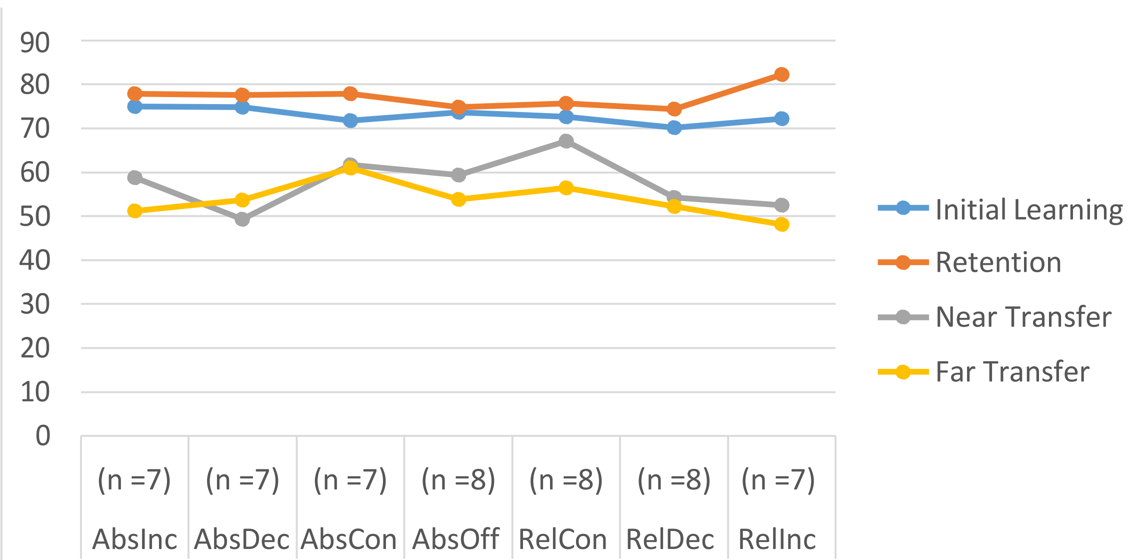


Figure 11. Estimated marginal mean differences of trainee performance at (1) initial learning, (2) retention, (3) near transfer, and (4) far transfer.

Analysis showed no statistically significant main effect of trainee performance across treatment groups, $F(24, 126) = .939$, $p = .549$; Wilk's $\Lambda = 0.565$, partial $\eta^2 = .133$. However, the within-subjects main effect was statistically significant, $F(2, 80) = 68.428$, $p = .000$. partial $\eta^2 = .637$. Nearly 64% of the within-subjects variability is accounted for by treatment group. When treatment was not factored, results showed that initial learning

(*M*=72.67, *SE*=1.53), retention (*M*=77.17, *SE*= 1.40), near transfer (*M*= 57.13, *SE* = 1.734) performance means all differed significantly from one another (see Table 8). Although, far transfer (*M*=53.64, *SE* = 1.67) was not significantly different from near transfer; far transfer was significantly different from initial learning and retention. A one-way trend analysis was performed relating the number of practice trials to trainee performance. Analysis of the linear components of trend $F(1, 39) = 89.323$, $p < .000$, partial $\eta^2 = .696$ indicated statistical significance, accounting for nearly 70% of the variance of within-subjects trainee performance (see Figure 10).

Table 8

Pairwise Comparison of Within-Subjects Trainee Performance

		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
Initial Learning	Retention	-4.50*	1.55	.036	-8.80	-0.20
	Near Transfer	15.54*	2.22	.000	9.37	21.71
	Far Transfer	19.03*	2.24	.000	12.81	25.26
Retention	Initial Learning	4.50*	1.55	.036	0.20	8.80
	Near Transfer	20.04*	2.06	.000	14.30	25.77
	Far Transfer	23.53*	2.22	.000	17.36	29.70
Near Transfer	Initial Learning	-15.54*	2.22	.000	-21.71	-9.37
	Retention	-20.04*	2.06	.000	-25.77	-14.30
	Far Transfer	3.49	1.32	.069	-0.17	7.15
Far transfer	Initial Learning	-19.03*	2.24	.000	-25.26	-12.81
	Retention	-23.53*	2.22	.000	-29.70	-17.36
	Near Transfer	-3.49	1.32	.069	-7.15	0.17

In terms of initial learning, Mauchly's test indicated that the sphericity assumption of the repeated measures ANOVA had been violated, $\chi^2(65)= 193.71$, $p=.000$, therefore degrees of freedom was corrected using Greenhouse-Geisser correction estimates of sphericity (€=.52). The results show that mean initial learning differed statistically significantly over the twelve practice trials $F(6, 304) = 19.26$, $p = .000$, partial $\eta^2 = .267$. Post hoc tests revealed that initial learning show statistically significant difference from practice trial one to practice trial six (62.65 ± 2.25 vs 72.91 ± 1.78, respectively). Statistically significant improvement was noted from trial six to the end of the initial learning task, or trial 12 (see Table 9). Therefore, we can conclude that a minimum of six practice trials elicits a statistically significant improvement in initial learning, but not less than six trials of practice.

Table 9

Mean Differences of Initial Learning during Practice Trials

Practice Trial		Mean Difference (I-J)	Std. Error	Sig.[b]
1	2	-3.30	1.95	1.000
	3	-6.76	2.10	.146
	4	-7.54	2.18	.071
	5	-7.13	2.50	.410
	6	-10.26*	2.17	.001
	7	-12.35*	2.16	.000
	8	-12.17*	2.17	.000
	9	-13.20*	2.30	.000
	10	-16.50*	2.63	.000
	11	-16.83*	2.15	.000
	12	-16.19*	2.69	.000

In terms of retention, Mauchly's test indicated that the sphericity assumption of the repeated measures ANOVA had been violated, $\chi^2(65)= 137.77$, $p=.000$, therefore degrees of freedom was corrected using the Greenhouse-Geisser correction estimates of sphericity (€=.64). The results show that mean retention differed statistically significantly over the twelve practice trials $F(5, 349) = 4.57$, p = .000, partial $\eta^2 = .08$. Post hoc tests revealed that retention show statistically significant difference between practice trial one and practice trial twelve only (72.63 ± 1.91 vs 80.26 ± 1.67, respectively). Therefore, we can conclude that a minimum of twelve practice trials elicits a statistically significant improvement in retention, but not less than twelve trials of practice (see Table 10 for mean retention and initial learning practice scores).

Table 10

Mean of Initial Learning and Retention during Practice Trials

		Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Initial Learning	1	62.65	2.25	58.13	67.17
	2	65.94	1.88	62.17	69.72
	3	69.41	1.86	65.67	73.14
	4	70.19	1.90	66.38	74.00
	5	69.78	2.25	65.26	74.29
	6	72.91	1.78	69.33	76.48
	7	75.00	1.71	71.56	78.44
	8	74.82	1.46	71.90	77.73
	9	75.85	1.53	72.78	78.93
	10	79.15	1.56	76.03	82.27
	11	79.48	1.27	76.93	82.03
	12	78.83	1.70	75.44	82.23
Retention	1	72.63	1.91	68.80	76.46
	2	75.14	1.60	71.93	78.35
	3	74.82	1.71	71.33	78.32
	4	75.33	1.82	71.69	78.98
	5	78.12	1.50	75.11	81.13
	6	77.63	1.60	74.41	80.84
	7	77.57	1.62	74.32	80.82
	8	79.08	1.47	76.13	82.02

Table 10

Continued

	Mean	Std. Error	95% Confidence Interval	
			Lower	Bound
9	76.88	1.70	73.47	80.29
10	79.43	1.40	76.62	82.24
11	79.49	1.38	76.71	82.27
12	80.26	1.67	76.89	83.62

Research Question Two

The second research question explored how feedback strategy (gradual increase, gradual decrease, consistently single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainees' perceptions as measured by perceived realism, perceived self-efficacy, and workload.

The one-way between subjects ANOVA was used to examine the impact (i.e., mean differences are the same) between the six treatment groups and one control group where the dependent variable, perceived realism, was measured at the end of Day Two. Analysis failed to yield statistically significant difference for overall realism in more than two treatment groups after Day Two, $F(6, 45) = 0.533$, $p = .780$. Based on the sample data, overall perceptions of realism did not differ across treatment in terms of scheduling and strategy.

At the end of Day One, fifty-two of the 55 participants rated realism perceptions of the weld gun, helmet, sound, and sparks, on a 10-point Likert scale, ranging from zero (not at all) to nine (very, very high). Most respondents perceived realism of the weld gun and helmet with a median (or likeliest response) as rather high; sound was perceived as neither high or low. Realism of sparks was perceived as low. Fifty-one of the 55 participants rated heat, striking an arc, travel/work angle of the weld gun on a scale of 0 to 100. Most respondents perceived heat as not real at all. Striking the arc was perceived mostly as rather high. The positioning of the weld gun (travel/work angel) was perceived as high.

At the end of Day Two, twenty out of the 55 surveyed rated overall perceptions of realism on a scale of 0 to 100, found to have an approximately normal distribution, W = 0.986, p = .812, with skewness of .010 and kurtosis of .298. Overall perceptions of realism were rated highest by the relative-decrease group (see Figure 12).

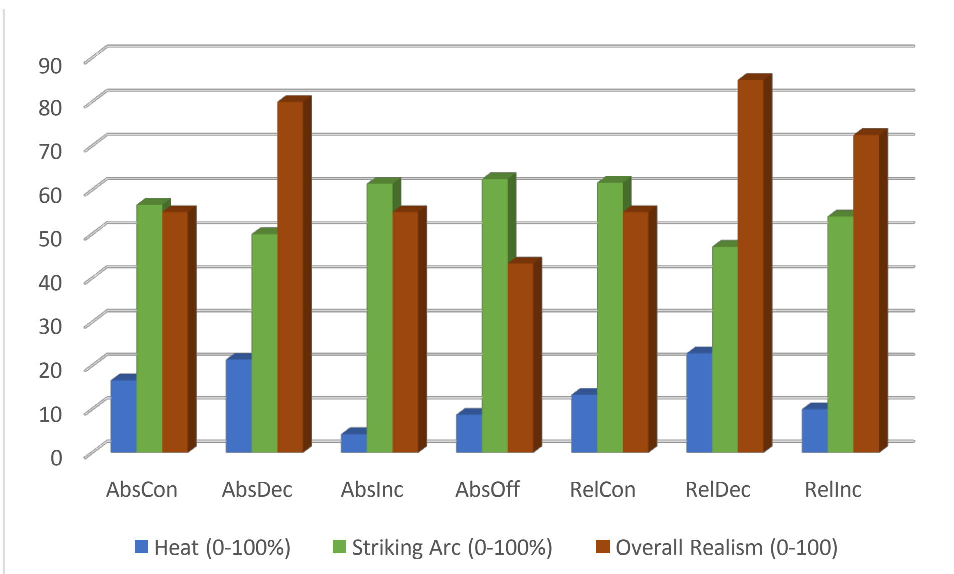


Figure 12. Mean Perceptions of Realism at Day Two.

To further describe learner perceptions of realism, findings from self-reporting and unobtrusive observations were examined. A phenomenological methodology of qualitative research identified emergent meanings and coded themes from the ordinary knowledge and perceptions of participants. The arrival at truth focuses on the idea that all observations are theory-laden. The way multiple individuals tell the truth commensurate a basic objectivistic assumption as inductively retold by the researcher. This truth was approximated by a collection of subjective meanings of instructors and participants located at the military training facility.

When asked about similarities and differences between welding on the virtual welder and the actual equipment, themes emerged regarding fidelity and procedural knowledge (See Appendix P). Twelve of the 39 participants (31%) reported that fidelity differences regarding the live sparks and heat from the conventional machines were exceptionally different than the virtual experience (see Appendix P). Five participants identified low depth perception on the simulator compared to welding on actual equipment. One participant wrote, “[the] virtual welder wasn’t scary because I knew it was fake, but [using] the actual one, I could see the sparks so [I] was a little scared.” Instructors noted that participants had an elevated, but false sense of their abilities once they left the virtual lab.

When asked about similarities between the simulator and actual equipment, themes emerged regarding fidelity and procedural knowledge. Of the 35 participants who responded, 15 participants (43%) identified similarities in the mechanics needed to weld. Eleven participants (31%) identified fidelity similarities in the hardware such as the helmet and weld gun. Sound was also noted as a similarity.

The one-way analysis of variance (ANOVA) was used to examine the impact (i.e., mean differences are the same) of the six treatment groups and one control group on each dependent variable, perceived workload and self-efficacy. All participants underwent both treatments (scheduling and strategy) to examine if there were mean differences in perceived self-efficacy and workload (see Table 5). Results indicate no statistically significant differences across groups at the end of day one, *F*(6,52) = .639, *p*=.73 or day two, *F*(6, 46) = .351, *p*= .88, in terms of perceived self-efficacy.

Table 11 shows summary of ANOVA for perceived workload and self-efficacy regardless of treatment. Results indicated that workload was not significantly different at the beginning, middle, or end of day one (i.e., practical trial one, six, and twelve). Although the non-parametric Friedman test indicated that mean ranks of perceived workload was not statistically significantly different, $\chi^2(2) = .533$, $p = .766$, the mean ranks showed the same order as the order of data collection. The Wilcoxon Signed Ranks tests indicated that for 41 of the 53 participants, their perceived self-efficacy was greater at the end of Day One than at the onset of practice. Two participants showed tied ranks, or the same level of perceived self-efficacy. Based on the negative ranks, *z*= -4.729, results indicate that when practicing on the weld simulator under one of the treatment protocols, there was a significant increase in the observed differences in perceived self-efficacy, *p*= .000.

Table 11

Summary of ANOVA on Perceived Workload and Self-efficacy at Beginning, Middle, and End of Treatment.

	df	*F*	*p*	partial η^2	Md	Min	Max	Cohen's d
Self-efficacy-PE1 (*n*=53)	6	1.52	.12	.20	56.67	25.00	100.00	
Self-efficacy-PE6 (*n*=53)	6	1.59	.15	.19	66.67	20.00	100.00	0.157
Self-efficacy-PE12 (*n*=53)	6	.64	.73	.08	75.00	11.11	100.00	-0.165
Self-efficacy-D2 (*n*=53)	6	.35	.88	.05	68.39	33.23	98.06	

Table 11

Continued

	df	*F*	*p*	partial η^2	Md	Min	Max	Cohen's d	
Workload-PE1 (*n*=51)	6	.87	.59	.11	8.17	2.67	14.17		
Workload-PE6 (*n*=51)	6	.42	.84	.06	8.17	2.50	14.83	-0.655	
Workload-PE12 (*n*=50)	6	.46	.77	.08	9.00	2.17	18.67		-0.467
Workload-D2 (*n*=53)	6	.98	.74	.08	9.50	2.50	17.33		

Because sample sizes of treatment groups were small and unequal, a Cohen's *d* was computed for perceived self-efficacy; a small effect size was found (see Table 11) when perceived self-efficacy was compared during day one. This means that if 100 students practice with the VRTEX™360 under one of the treatment protocols, six participants would have a favorable perceived self-efficacy compared to if they received the control treatment (i.e., practice without visual cues available). With the Cohen's *d* of 0.1, fifty-eight percent of the treatment group will be above the mean of the control group; 92% of the two groups will overlap. Similar results were found between the onset of day one and the end of day two.

Measures of central tendency indicated that overall median perceptions of workload remained numerically the same from trial one to practice trial six (*Md* = 8.167), but increased numerically by the last practice trial (*Md* = 9.000). A numerical median increase was noted after Day 2 as well (*Md* = 9.500). When data were examined by group, all groups showed either a numerical increase (AbsInc, AbsOff, RelInc) or decrease (AbsCon, AbsDec, RelCon, RelDec) from trial one to trial six. The control group showed a numerical increase in perceptions during Day One (After trial 1, 6, and 12), but a numerical decrease after Day Two. The control group (absolute off), absolute consistently-single, relative-increase, and the absolute-increase groups reported lower perceptions of workload than the overall median. Based on the sample data, the absolute-increase group reported the lowest median perception of workload (*Md* = 6.333). Three of the seven groups (AbsDec, AbsOff, RelDec) reported a decrease of perceptions of workload between Day One and Day Two (see Table 12).

Table 12

Descriptive Statistics of Perceived Workload

		WLPE1	WLPE6	WLPE12	WL_D2
AbsCon	Mean	8.92	8.33	8.81	9.21
	N	8	8	8	7
	Minimum	5.50	6.67	3.83	6.33
	Maximum	13.67	14.00	15.00	12.00
	Median	8.08	7.75	8.83	9.50
AbsDec	Mean	9.60	9.17	9.97	7.86
	N	5	6	5	7
	Minimum	7.83	6.17	7.33	5.67
	Maximum	11.00	11.17	13.67	10.83
	Median	10.33	9.75	10.33	7.83
AbsInc	Mean	6.62	7.71	7.25	8.25
	N	7	7	6	8
	Minimum	3.00	2.50	2.17	4.50
	Maximum	12.50	14.33	15.33	15.83
	Median	6.33	7.50	5.92	6.75
AbsOff	Mean	8.17	9.29	9.33	7.46
	N	8	7	8	9
	Minimum	3.33	4.67	4.00	2.50
	Maximum	14.17	14.67	18.67	12.33
	Median	7.50	9.20	9.50	7.00
RelCon	Mean	8.29	7.52	8.44	9.15
	N	8	8	8	8
	Minimum	2.67	3.67	3.67	4.17
	Maximum	13.00	11.67	12.83	12.00

Table 12

Continued

		WLPE1	WLPE6	WLPE12	WL_D2
	Median	8.50	6.50	7.58	9.75
RelDec	Mean	9.50	9.21	10.35	10.52
	N	8	8	8	8
	Minimum	4.67	4.17	4.17	6.33
	Maximum	12.67	14.83	15.83	17.33
	Median	10.2500	9.1667	10.8333	9.9167
RelInc	Mean	7.5952	8.8571	8.9286	10.0000
	N	7	7	7	6
	Minimum	5.17	5.33	5.17	5.17
	Maximum	10.50	14.33	15.00	13.33
	Median	8.0000	8.6667	9.0000	9.8333
Total	Mean	8.3627	8.5595	9.0267	8.8679
	N	51	51	50	53
	Minimum	2.67	2.50	2.17	2.50
	Maximum	14.17	14.83	18.67	17.33
	Median	8.1667	8.1667	9.0000	9.5000

Additional perceptions of workload were reported using the AIME rating scale after Day Two. Of the 55 participants, most participants rated their amount of invested mental effort as low. Post hoc internal consistency analysis yielded a low coefficient of reliability, α=.447. One participant from the absolute-decease treatment noted, “They are very similar to each other but the VR is much easier to work.” A student from the relative-increase treatment wrote, “The virtual welding was easier then the live welding because in the virtual welder. Things were easier to take advantage of.”

Participants were administered a self-efficacy Likert-style questionnaire, ranging from zero (cannot do at all) to 100 (highly certain can do). A Friedman Rank test indicated a statistically significant difference during day one, $\chi^2(2) = 29.36$, $p = .000$. When considering the total score of self-efficacy, learners mostly likely rated their self-efficacy as moderate (*Md* =56.67), with a skewness of -0.059. Perceptions increased during practice on the VRTEX™360 with most participants reporting their perceived self-efficacy beyond moderate (*Md* = 75.00) by the end of Day One. Results indicated that the control group (AbsOff) was the only group that displayed a statistically significant decrease in self-efficacy at the end of Day One. Perceptions of self-efficacy numerically decreased after Day Two practice session on the conventional weld machine (*Md* = 68.38), but remained numerically higher than at the onset of treatment (see Table 13). Post hoc internal consistency analysis yielded a high coefficient of reliability, α=.920.

A Cohen's *d* was computed for perceived self-efficacy; a slightly moderate effect size was found (see Table 11) when perceived self-efficacy was compared during day one. This means that if 100 students practice with the VRTEX™360 under one of the treatment protocols, 13 participants would have a more favorable perceived self-efficacy compared to if they received the control treatment (i.e., practice without visual cues available). With the Cohen's *d* of 0.4, sixty-six percent of the treatment group will be above the mean of the control group; 84% of the two groups will overlap.

Table 13

Descriptive Statistics of Perceived Self-efficacy

		SEPE1	SEPE6	SEPE12	SE_D2
AbsCon	Mean	61.39	74.17	79.86	68.44
	N	8	8	8	7
	Minimum	25.56	57.78	61.11	47.24
	Maximum	77.78	84.44	100.00	85.16
	Median	66.67	76.11	82.78	67.10
AbsDec	Mean	43.61	60.32	69.54	65.98
	N	6	7	6	7
	Minimum	25.00	36.67	50.00	42.26

Table 13

Continued

		SEPE1	SEPE6	SEPE12	SE_D2
	Maximum	61.11	85.56	100.00	81.94
	Median	43.33	55.56	64.17	72.58
AbsInc	Mean	49.97	61.11	70.40	70.83
	N	7	7	7	8
	Minimum	27.78	54.44	53.33	34.67
	Maximum	77.78	77.78	84.44	91.29
	Median	51.11	58.89	73.34	69.35
AbsOff	Mean	69.51	78.61	74.94	67.47
	N	9	8	9	9
	Minimum	52.22	54.44	35.56	47.10
	Maximum	100.00	100.00	100.00	93.87
	Median	70.00	87.22	88.89	70.97
RelCon	Mean	64.17	72.22	74.86	70.75
	N	8	8	8	8
	Minimum	26.67	41.11	52.22	47.33
	Maximum	88.89	92.22	93.33	98.06
	Median	62.78	77.78	78.89	65.00
RelDec	Mean	60.28	61.18	62.50	61.70
	N	8	8	8	8
	Minimum	30.00	20.00	11.11	33.23
	Maximum	91.11	90.00	100.00	82.26
	Median	53.33	65.56	66.67	65.34
RelInc	Mean	63.02	61.59	73.02	70.86
	N	7	7	7	6
	Minimum	27.78	44.44	51.67	58.39
	Maximum	97.78	97.78	97.78	81.29
	Median	56.67	58.33	74.44	73.87
Total	Mean	59.71	67.37	72.33	67.92
	N	53	53	53	53
	Minimum	25.00	20.00	11.11	33.23
	Maximum	100.00	100.00	100.00	98.06
	Median	56.67	66.67	75.00	68.39

Based on written responses of the participants, learners left the virtual lab with high self-efficacy, but their perceived confidence in their ability to weld quickly dissipated after one weld pass attempt on the actual equipment. Of 23 respondents, ten

(43%) self-reported themes of decreased self-efficacy when comparing practicing on the simulator to actual equipment. Nine participants self-reported themes of increased high self-efficacy. One instructor noted,

> "The students ….are always excited about going in…VR. I think more so than after they have been on the floor. It kinda changes a little bit. They'd rather go on the floor to weld something. But when they first enter the welding phase, they don't want to go on the floor right away, they want to go and play on the virtual reality…I've also noticed that the ones that don't seem to pick up on it as quickly, they lose that motivation real quick and then they, most of them, you will see where they're trying and their scores will slowly start to coming up and then they just drop off."

Hypothesis One

The first hypothesis predicted that feedback strategies (gradual increase, gradual decrease, and consistently-single) and feedback scheduling (absolute) will facilitate initial learning but hinder near and far transfer. Results supported the hypothesis that initial learning was facilitated but near and far transfer was hindered (see Table 14). Overall performance within-subjects statistically significant improvement from initial performance to retention (*MD* = - 4.50). A significant decrease was noted from retention to near (*MD* = 15.54) and far transfer (*MD* =19.03), although near and far were not significantly different from one another (*MD* = -3.493). The absolute consistently-single group showed the greatest numerical gain in near transfer. The absolute-increase group showed the least numerical difference between near and far transfer.

Table 14

Comparison of Study Participants at Initial Learning and Transfer

	AbsInc (*n* = 7)	AbsDec (*n* = 6)	AbsCon (*n* = 8)
Initial Learning	74.91	74.86	71.71
Near Transfer	58.71	49.33	61.71
Far Transfer	51.21	53.69	61.00

Hypothesis Two

The second hypothesis predicted that feedback scheduling (relative but not absolute) will facilitate near and far transfer but hinder initial learning. Results showed that hypothesis was not supported (see Table 15). Initial learning of all groups was numerically higher than near and far transfer. The absolute-decrease treatment showed numerically greater far transfer than near transfer.

Table 15

Descriptive Statistics of Trainee Performance by Treatment

	AbsInc (*n* =7)	AbsDec (*n* =7)	AbsCon (*n* =7)	AbsOff (*n* =8)	RelCon (*n* =8)	RelDec (*n* =8)	RelInc (*n* =7)
Initial Learning	74.91	74.86	71.71	73.64	72.69	70.14	72.25
Retention	77.90	77.56	77.95	74.88	75.68	74.33	82.19
Near Transfer	58.71	49.33	61.71	59.42	67.05	54.21	52.52
Far Transfer	51.21	53.69	61.00	53.813	56.50	52.17	48.17

Hypothesis Three

The third hypothesis predicted that initial learning, perceived realism, and perceived self-efficacy will decrease as feedback complexity (scheduling and strategy) increases. When asked to rate the overall realism of the VRTEX™360, twenty of the 52 respondents categorized realism as rather high (*Md* = 60). Initial learning, perceived realism, and perceived self-efficacy did not follow the hypothesized pattern (see Table 16).

Table 16

Comparison of Initial Learning, Perceived Realism, and Perceived Efficacy by Least Complex to Most Complex Treatment Group

	AbsOff	AbsDec	AbsInc	AbsCon	RelCon	RelInc	RelDec
Initial Learning	73.64	74.86	71.91	71.71	72.69	72.25	70.14
Perceived Realism	Rather low (40)	Very High (80)	Neither High or Low (55)	Low (30)	Neither High or Low (55)	Very High (80)	Very High (80)
Perceived Efficacy	70.97	72.58	69.35	67.97	65.00	73.87	65.34

Instructor observations were also reported as participant-observers and captured learner perceptions within the context of a portion of their personal world, simulator training. Instructor observations were an unobtrusive method of recording learners' nonverbal cues which may indicate any unconscious perceptions, thoughts, and interpretations. Coding from all qualitative data sources identified anticipated themes, emerging themes, and perceptions of learners (see Appendix P).

Episodes of learners investing practice with ease were recorded and operationally defined as high self-efficacy. Observations were noted of the number times students asked questions or walked away from their assigned simulator to query another student to capture deviant cases of high self-efficacy. The final codebook describes the resulting themes revealed as defined by salient points from the data sources (see Appendix P).

Participants from the control group (i.e., no manipulation of visual feedback) appeared to want more instructional support that addressed how to make corrections, not whether their movements were accurate. When feedback was manipulated, cueing provided by the visual feedback appeared to promote metacognitive self-assessments for the participant by cueing them to the accuracy of the movements. In turn, participants began making inferences of reasons why those movements were accurate. The simulator was unable to provide any additional instructional support outside of “right” and “wrong.”

As practice progressed on the simulator, participants of the control group (i.e., practice without manipulation of visual feedback) seemed less motivated to continue practicing and experienced more frustration as evidenced by emergent themes. When aggregated by treatment group, more participants in the absolute-increase group reported themes of high self-efficacy when practicing on the simulator than any other group. The relative-decrease group noted the greatest amount of self-efficacy when welding on actual equipment.

To describe perceived realism, findings from self-reporting and unobtrusive observations were examined. Based on the definition of fidelity as described by Alessi (1988), perceived realism was operationally defined as learner perceptions of the realism of interaction and duplication of the actual task situation. Perceived realism was discovered as themes in the written responses of all participants regardless of treatment. Written statements describing differences between the simulator and the actual equipment included: (a) “you could feel the wire pushing against the metal on the real equipment,” (b) “The huge difference was the fact that when using an actual welding equipment, the lens of the helmet gets really dark at the point I couldn’t see much of what I was doing,” and (c) “You have no depth perception on the VR which is frustrating but in real life it almost came natural." When learner perceptions were corroborated by instructor observations, both negative and positive perceptions of realism were discovered as themes.

Summary. All treatment groups reacted positively to the scheduling and strategy of feedback in which they were introduced (see Figure 10). Participants in the control group responded to the virtual experience with a flatline retention rate and lowest amount of perceived workload after Day Two. The absolute consistently-single treatment showed decreases in perceived workload during Day One and the greatest numerical near transfer performance. The absolute increase treatment showed the least difference from near to far transfer performance and the greatest amount of both perceived self-efficacy and workload at Day One. The relative consistently-single treatment was the only group who showed increases in self-efficacy after welding on actual equipment. Participants' written responses during final interview also suggest that their beliefs in their ability to weld decreased after welding on the conventional equipment when compared to the virtual environment. Based on written responses of the participants, learners focus more on the visual icons than the accuracy of the movements required to maintain the "green" status of the visual icon. Student #8 self-reported, "I feel the virtual training was good, but I feel the instructors and demos are definitely better, for not only learning but retraining the knowledge." Overall, the participants had a positive experience with the mixed-reality simulator as evidenced by written responses. When asked about what stands out from the training, themes of metacognition, fidelity, and satisfaction emerged (see Appendix P).

Instructor observations also suggest that participants spend more time learning the affordances of the simulator than learning the conceptual knowledge and mechanical skills of welding at the onset of training. As training continued, learners directed more attention to their scores and mechanical skills of welding. Participants in the treatment groups pointed out that they learned travel speed and travel angle while practicing on the virtual welder. Themes emerged that suggest that the participants perceived the virtual experience as authentic, but lacked enough realism to prepare them for the live sparks and amount of heat when welding on the conventional equipment.

CHAPTER IV

DISCUSSION AND CONCLUSIONS

The intent of this nested, mixed-methods study was to investigate the effects of feedback scheduling and strategies on trainee performance and learner perceptions by focusing on quantitative results, but also, relying on qualitative findings to help interpret those results. Conducted from a phenomenological tradition, qualitative findings of the study began the look at the whole system, in this case simulator training in the military context, by revealing learner perceptions as a function of feedback strategy and scheduling afforded by simulator training. In this study, the overall goal of learner behavior was to achieve a score of 80 in both the virtual and actual welding environments. The discussion will look at each research question alongside its associated hypotheses where appropriate.

Impact on Trainee Performance

When considering how feedback strategy (gradual increase, gradual decrease, consistently-single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainee performance alongside the first two hypotheses of this study, no treatment group showed statistically superior performance over the other as defined by initial learning, retention, near transfer, and far transfer. However, each treatment group showed moderate numerical variation. One can conclude that the rejection of the null hypothesis only suggests that the sample means do not reflect a similar difference between population means. The purposeful sampling technique alongside the unique military context limits generalizability. The military training system, like any system, is a complex synergy of human capital, their resources, and their layers of meanings. One explanation for the lack of significance may be found in the uniqueness and small size of the grouped sample.

Another conclusion for the lack of statistical difference among treatments can be explained by the idea that each manipulated scheduling and strategy was empirically supported. It would be unethical to introduce instruction that is empirically known as poor. For example, absolute feedback has been found to hinder retention (Anderson, Magill, & Sekiya, 2001; Salmoni et al., 1984; Schmidt et al., 1989; Young & Schmidt, 1992). In this study, absolute feedback was coupled with a scheduling variation as suggested by cognitive flexibility theory (Spiro, Feltovich, Jacobson, & Coulson, 1991). A lack of statistical difference suggests that variations of the scheduling produced similar results on learning and their impact was comparable. Because all manipulations were supported by empirical evidence, within-subjects comparisons would be expected to have significance unless some unknown variable was unaccounted and not controlled.

Findings of this study show that a combined scheduling and strategy protocol of feedback accounts for 70% of the learning within groups. A key premise of schema theory of motor learning is the use of variable practice conditions without consideration of the order in which the conditions were arranged (Sherwood & Lee, 2003). Based on the findings of this study, it is reasonable to predict that learning would not be statistically affected by order.

It is also reasonable to infer that the guidance effect of feedback found with absolute scheduling dissipates when strategy (gradual increase, gradual decrease, consistently-single) is also manipulated. As found in contextual-interference studies, the transient effects of feedback dissipate when feedback targets different perspectives of a task (Lee & Carnahan, 1990; Shea & Morgan, 1979). The contextual-interference of increasing, decreasing, or changing feedback counteracts its guidance effect. As found in this study and replicated by other empirical findings, a variability of practice paradigm promotes retention and transfer (Lee & Carnahan, 1990; Shea & Morgan, 1979; Salmoni, Schmidt, Walter, 1984). It is important to note that initial learning of this study was not hindered as found in most contextual interference studies and those where a distinction between initial learning and retention is made. Findings of this study suggest that a minimum of six practice trials while learning within the context of multiple perspectives strengthens knowledge and skill, not only beyond initial learning, but during initial learning as well.

A closer look at initial learning within each group of this study shows spikes and falls over the 12 practice trials (see Figure 10). This graphical pattern suggests the development of internal representations, or schema, needed in motor learning (Schmidt, 1975) and may represent a closed feedback loop as the learner self-corrects movement. The spikes and falls over the practice sessions suggests that learners are self-assessing while switching among various subcomponents of movement. Results give insight for the disparities found in feedback studies by suggesting that motor learning is not a mechanistic process. Motor learning benefits from mental practice and feedback that promotes cognitive effort. Even so, random mental practice can increase cognitive effort and active processing of a motor skill.

Findings of this study also echoes the importance of distinguishing between initial learning and retention. For retention to have occurred, feedback effects during practice must persist when instructional supports are absent. In this study, statistical improvement in retention was found at trial 12 of the retention task. During the initial learning task, participants experienced statistical improvement in their scores at trial six. Findings suggest empirical support for training protocols that begin with variable feedback conditions but conclude with longer practice times without feedback support.

Impact on Learner Perceptions

When considering how feedback strategy (gradual increase, gradual decrease, consistently-single) and scheduling (relative and absolute) in a moderate fidelity welding simulator impact trainees' perceptions as measured by perceived realism, perceived self-efficacy, and workload, the absolute-decrease treatment who showed numerically greater far transfer than near transfer among the groups rated workload as high (*Md*=7.8). One explanation for the high rating of workload alongside the greatest numerical increase in far transfer is that the participants in the absolute-decrease treatment experienced their zone of proximal development (Bruning, Schraw, Norby, & Ronning, 2004) within the simulated context of the task. In other words, providing the novice learners with visual feedback afforded by the simulator at the onset of practice, then decreasing that feedback allows welding skill development in the horizontal position that can be transferred to welding in the vertical position. Thus, one may conclude that the absolute-decrease group produced the best learning because of its ability to produce greater far transfer than near transfer.

Most participants in the absolute consistently-single (AbsCon) group rated their workload as very, very high (*Md*=9.5), but produced the greatest gain in near transfer. The absolute-increase group perceived the lowest workload. These participants most likely rated their workload as rather high (*Md*=6.7) and showed the least difference between near and far transfer. Findings support the premise proposed by Ennis & Chen (2011) that motor learning of a skill such as welding is a problem-solving process. As such, cognitive effort is needed alongside the mechanistic patterns of behavior during practice. Training protocols that target both cognitive and motor skills yield the best transfer of learning.

Participants in the absolute-off, absolute-decrease, and relative-decrease groups showed a steady decline, or numerical decrease, in perceptions of workload during initial learning. Except for the absolute-off treatment, each of these groups showed an increase in performance when practicing without feedback. Performance flatlined in the absolute-off treatment. Results suggest that the absolute-off treatment was the least effective. The absolute-decrease, and relative-decrease treatment groups also represented the least variable practice but most complex conditions in terms of the number of visual cues displayed at the onset of practice. When practicing without feedback, these same participants had greater workload because needed instructional support was unavailable.

Participants in the absolute-off, or control group, behaved similarly to participants in the complex conditions although no feedback manipulation was present. Novice learners lack germane resources and, as is the case of this study, lacked the instructional support needed to perform the task. The lack of instructional support needed to navigate the task produced greater perceptions of workload.

When learner perceptions were corroborated by written responses, both positive and negative perceptions of realism were discovered as themes. At the end of day two, most learners perceived realism as very low. Results provide empirical evidence for Alessi & Trollip's (2001) hypothesized relationship which suggests that novice learners perceive simulator fidelity as high, however, results suggest that these perceptions may dissipate as the learner practices. The rate of learning impacts perceptions of fidelity. The idea that low perceptions of fidelity remains throughout training protocols for novice learners only holds true at the onset of training. Novice learners quickly develop reactions to fidelity much like experienced learners.

It was hypothesized that initial learning, perceived realism, and perceived self-efficacy would decrease as feedback complexity (scheduling and strategy) increases. In terms of feedback complexity, those feedback manipulations that involved the greatest number of cues at the onset of practice or had cues available at every other trial are anticipated as most complex. Since learners determine sensory sources early in practice, the most appropriate instructional method is one that embraces opportunities for students to practice both declarative and procedural knowledge.

At the time of this study, initial learning approximately followed the hypothesized inverse relationship to strategy and scheduling complexity. However, perceived self-efficacy and realism patterns did not. No linear pattern was noted. It can be concluded that novice learners relied so heavily on the cues because of the complexity of the motor task that perceptions of self-efficacy and realism became overly exaggerated. The instructional support for the high cognitive skills and conceptual knowledge needed by the task was adequate for learning, but a detriment to self-efficacy.

Novice learners may have perceived the task as real because cues needed to process the complex task were available. Given experienced learners who would perform those cognitive demands of the task independently of any cues, the training experience would have been perceived as less authentic. The visual cues would have been extraneous for the experienced learner and detrimental to perceptions of realism. A possible interpretation of the results of this study support prior research (Dahlstrom, Dekker, van Winsen, & Nyce, 2009) suggesting that learning is determined more by the extent to which the simulator acknowledges and reacts to the participant than by the fidelity alone.

Recommendations & Future Research

Simulator training is an active experience. Once the instructor completes all directives, the training event continues under the locus of control of the simulator. As suggested by the interactive, two-feedback loop (ITFL) model (Narciss, 2007) for computer-based instruction, a learning task involves regulation of any discrepancies between the actual value provided by external representations and internal representation values of the learner. As a delimitation of this research, the VRTEX® 360 simulator serves as the instructional medium providing the external representations to learners within the controlled process of welding. Feedback should be presented to the learner in such a way that it promotes internal representations of natural sources of intrinsic feedback. Research should be extended to discovering effective training conditions where feedback is interactive and can be manipulated by the learner during practice. Future studies may also revisit instructional efficiency and establish empirical support for connections between the theoretical frameworks of cognitive load and deliberate practice (Van Gog & Paas, 2008).

Previous studies found little evidence that novice students trained with a high-fidelity simulator are more able to transfer skills to actual tasks (de Giovanni, Roberts, & Norman, 2009). Participants of this study were given two transfer trials each of near transfer task (i.e., horizontal filet weld) and far transfer task (i.e., vertical filet weld).

Instructor ratings showed that weld samples from the transfer tasks (i.e., welding using conventional equipment) had very little splatter. Participants were noted as displaying high conceptual knowledge during transfer sessions as evidenced by their conversational use of welding concepts and the types of questions that were being asked. Because a statistical significance was not found between the groups in terms of near and far transfer, one may conclude that the number of transfer trials were only enough to measure the technique and not render skill mastery. Given a greater number of practice trials, an improvement in skill transfer may occur and be evident in the rubric ratings. Future studies should include transfer tasks as well as initial learning and retention tests. The number of practice trials for transfer and retention tasks should equal in the number.

Future research should continue to explore the distinction between initial learning, retention, and transfer (Kantak & Winstein, 2012). Research should seek empirical evidence for a new theory of motor learning that incorporates the benefits of mental practice as a component of variable practice. More research is needed to describe what happens during simulator training protocols that aim to teach complex motor skills. Future examination is needed in terms of the interaction between the learner and the simulator, as well as the role of learner perceptions and metacognition when learning complex motor skills. One of the major challenges in the field of instructional design is the empirically substantiated design recommendations for multimedia affordances. Fundamental questions which warrant additional inquiry include: (a) How can designers facilitate the acquisition of expert knowledge during multimedia instruction? (b) When instruction is designed for the learner who possesses expertise in the specific domain, what are the most effective ways (and conditions) to design multimedia? (c) How can knowledge of the characteristics of expertise be applied heuristically to the design process? (d) How do learner perceptions impact conditions of practice? (e) Do multimedia principles apply to learning in the psychomotor domain as in concept learning? (f) Should training protocols for multimedia be based on a multi-dimensional view of feedback? (g) How should instructional designers most effectively make the learning goals and success criteria transparent to students and maximize the effects of multimedia? (h) How do we structure simulator training and computer-based simulations for procedural tasks to enhance initial performance, learning, and transfer?

Summary

Variable practice protocols can be used to design instruction for higher levels of skills mastery. The heuristics for multimedia environments can be empirically-based. Findings of this study begin the discussion of complex, dynamic feedback such as those afforded by moderate fidelity simulators and extends that discussion to a multi-dimensional view of feedback. Additional considerations should be noted such as: (a) learner motivation may decrease if mistakes are perceived as design errors, (b) give directions when first needed then allow learners to control the retrieval of directions, (c) feedback should incorporate a variable protocol during skill acquisition for novice learners, (d) novice learners become aware when they make mistakes very quickly, but this awareness does not necessarily extend to knowing why the mistake occurred, and (e) when simulators are targeting whole task of a motor skill, novice learner become aware of fidelity early in practice.

Learning outcomes are varied and based upon many factors including the nature of the learning environment, nature of the learner, and the nature of what is to be learned.

Heuristics provide criteria and offer guidelines to desired results within the dynamics of its application. Instructional designers gain insight from empirical data which examine training protocols. Results from such research can be useful when creating progressively more challenging instructional activities beyond traditional lecture protocols.

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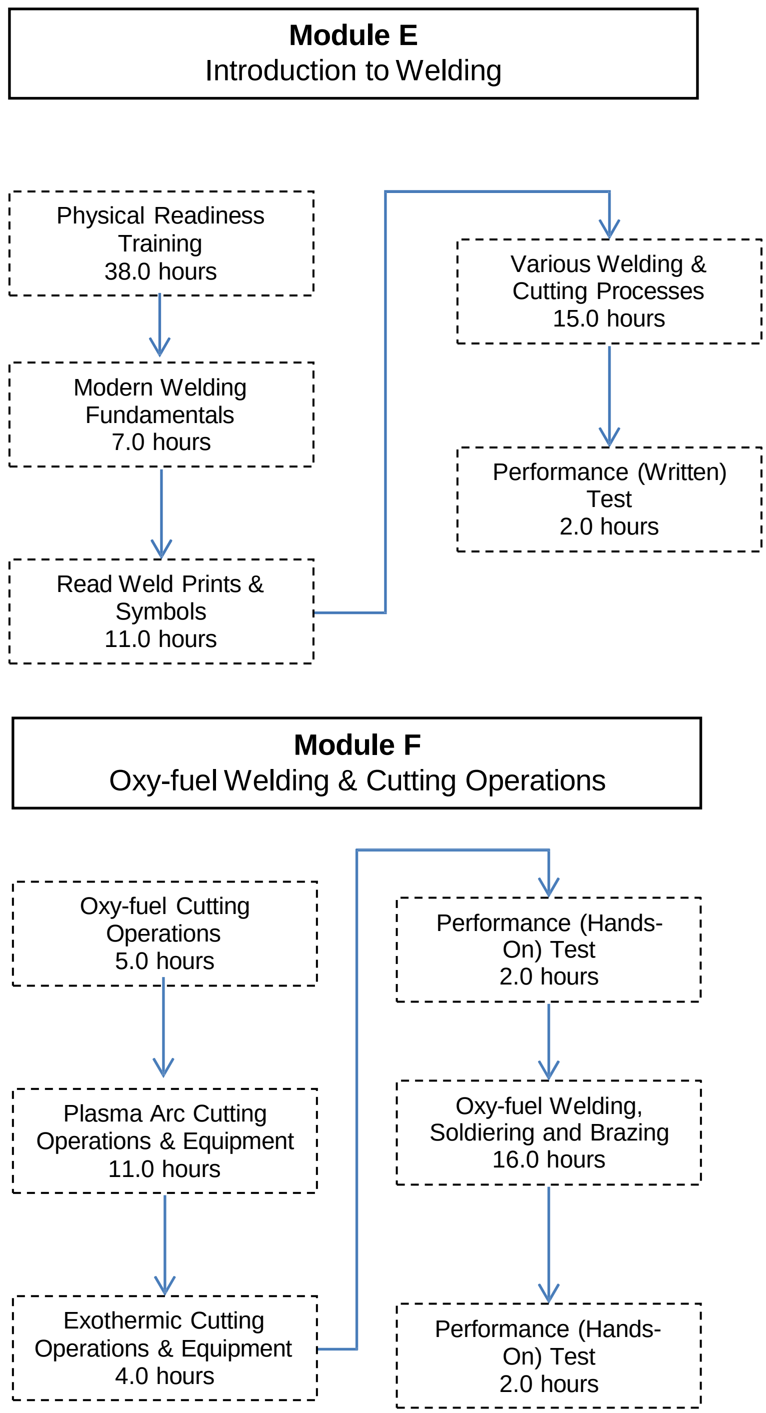
Appendix A

COURSE MAP OF WELDING PHASE FOR THE ALLIED TRADES SPECIALIST COURSE



Module G
Gas Tungsten Arc Welding (GTAW) Operations

Gas Tungsten Arc Welding (GTAW) Operations
47.3 hours

↓

Performance (Hands-On) Test
6.7 hours

Module H
Gas Metal Arc Welding (GMAW) Operations

91E10H01
Gas Metal Arc Welding (GMAW) Operations
64.3 hours

↓

91E10H02
Performance (Hands-On) Test
6.7 hours

Module I
Shielded Metal Arc Welding (SMAW) Operations

Shielded Metal Arc Welding (SMAW) Operations
90.3 hours

↓

Performance (Hands-On) Test
7.7 hours

Appendix B

TASK ANALYSIS OF SIMULATOR TASK

Tee Joint Horizontal Position:

Note: The instructor will use a demonstrator for this exercise.

Note: Instructor will inform student that when welding with the Welding Simulator, only 3 string beads are used. When welding with the Miller Welding Machine, six string beads will be used. Explain graph window and how the cues helped the welder.

Tee Joint Vertical Position:

Note: All beads will be run from the bottom of the metal plates toward the top. Forehand technique gun positioned 90° to the work and 5-10° away from the direction of travel.

1. Enter name, using the joy stick.
2. Press continue
3. Select metal, ¼", using the joy stick.
4. Select process, GMAW short arc.
5. Select polarity, DC+
6. Set and enter table height.
7. Set and enter arm height.
8. Enter arm rotation, A, B or C.
9. Enter coupon rotation
10. Press continue
11. Select environment
12. Select gas flow, 30
13. Continue
14. Set wire Speed, 275
15. Set voltage at 18
16. Adjust helmet
17. Adjust eye pieces in helmet
18. Run string bead, using no cues, Forehand technique gun positioned 90° to the work and 5 to 10° away from the direction of travel.
19. Press "END PASS" once.
20. Press "NEXT" to see the graft window, score and discontinuities.
21. Explain the graft window.
22. Press "NEXT" to return to the welders view.

Note: Before welding the second bead,(weave) trim the wire and add cues.

23. The second bead will cover the first bead.
24. Press "END PASS" pass once.
25. Press "NEXT" to see the graft window, score and discontinuities.
26. Explain graft window and how the cues helped the welder.
27. Press next to return to the welders view.

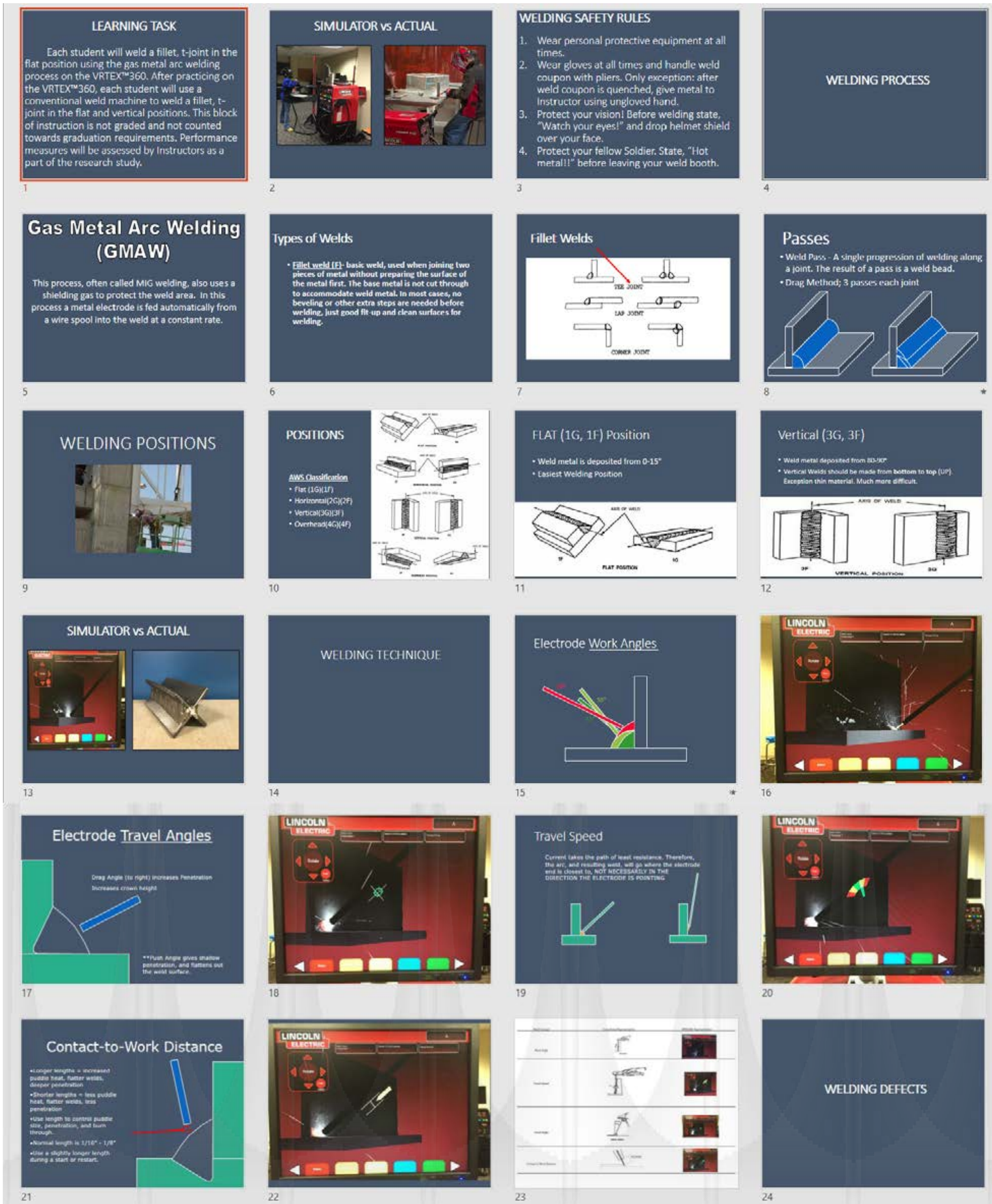
Note: Before welding the third bead, trim the wire and add cues.

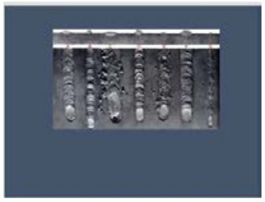
28. The third and final bead will cover the second weave bead, tying into the second bead.
29. Press “END PASS”
30. Press “NEXT” to see the graft window, score and discontinuities.

Note: Explain graft window and how the cues helped the welder.

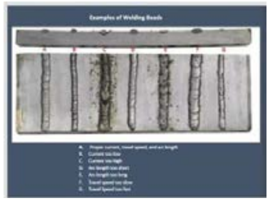
Appendix C

SCREENSHOT OF PRE-TRAINING FROM MODULE E





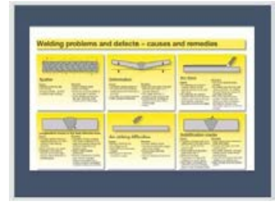
25


Examples of Welding Beads
A. Proper current, travel speed, and arc length
B. Current too low
C. Current too high
D. Arc length too short
E. Arc length too long
F. Travel speed too slow
G. Travel speed too fast

26


BACKUP SLIDES

27

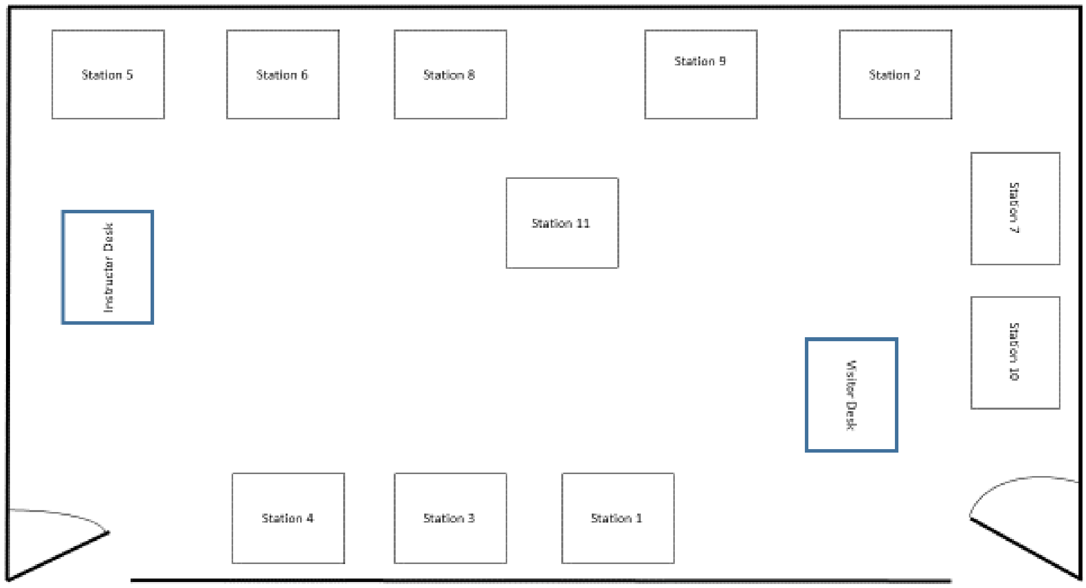

Welding problems and defects – causes and remedies

28

29

Appendix D

TRAINING PROTOCOL WITH FLOOR MAP LEGEND



The below table of random numbers was produced according to the following specifications: (a) numbers were randomly selected from within the range of one to seven because seven is the maximum number of treatment groups, (b) duplicate numbers were not allowed since only one participant will be allowed per station, (c) random numbers were selected based on statistical algorithm used by http://stattrek.com and retrieved October 13, 2015.

terminal feedback, plus concurrent visual cues grad↑ relative 50% (12 trials)	terminal feedback, plus concurrent visual cues grad↑ absolute 100% (12 trials)	terminal feedback, plus concurrent visual cues grad↓ relative 50% (12 trials)	terminal feedback, plus concurrent visual cues grad↓ absolute 100% (12trials)	terminal feedback plus concurrent visual cues consistently single; relative 50%(12 trials)	terminal feedback plus concurrent visual cues consistently single; absolute 100% (12 trials)	**Control Group**
1= Actual Station #5	2=Actual Station #6	3=Actual Station #8	4=Actual Station #9	5=Actual Station #2	6=Actual Station #7	7=Actual Station #10
4	**1**	**2**	**6**	**7**	**5**	**3**
3	**4**	**6**	**2**	**5**	**1**	**7**

Continued.

terminal feedback, plus concurrent visual cues grad↑ relative 50% (12 trials)	terminal feedback, plus concurrent visual cues grad↑ absolute 100% (12 trials)	terminal feedback, plus concurrent visual cues grad↓ relative 50% (12 trials)	terminal feedback, plus concurrent visual cues grad↓ absolute 100% (12trials)	terminal feedback plus concurrent visual cues consistently single; relative 50%(12 trials)	terminal feedback plus concurrent visual cues consistently single; absolute 100% (12 trials)	**Control Group**
1= Actual Station #5	2=Actual Station #6	3=Actual Station #8	4=Actual Station #9	5=Actual Station #2	6=Actual Station #7	7=Actual Station #10
5	**7**	**3**	**2**	**6**	**4**	**1**
6	**5**	**4**	**1**	**7**	**2**	**3**
7	**1**	**3**	**4**	**6**	**5**	**2**
3	**7**	**2**	**6**	**5**	**4**	**1**
5	**3**	**7**	**2**	**1**	**6**	**4**
7	**2**	**4**	**6**	**1**	**5**	**3**
2	**7**	**6**	**4**	**1**	**5**	**3**
6	**5**	**1**	**3**	**7**	**2**	**4**
5	**7**	**3**	**6**	**2**	**4**	**1**
4	**1**	**3**	**7**	**5**	**2**	**6**
7	**4**	**1**	**3**	**2**	**5**	**6**
1	**4**	**6**	**5**	**7**	**3**	**2**
4	**5**	**6**	**1**	**3**	**2**	**7**
7	**1**	**6**	**3**	**2**	**4**	**5**
5	**2**	**4**	**1**	**6**	**7**	**3**
6	**1**	**3**	**4**	**2**	**7**	**5**
1	**7**	**4**	**5**	**6**	**3**	**2**
3	**4**	**6**	**5**	**1**	**7**	**2**

Appendix E

VTREX™360 PRACTICAL EXERCISE FORM (RelDec)

Your scores will help us improve training with the virtual welder. Your recorded data **will not** compute as part of your grade in the Allied Trades Specialist Course. Your answers will remain completely anonymous. (X=work angle; Y=travel angle; Z=travel speed; W=CTWD)

DATA ENTRY CODE:______________________

PE 1: X	Score	****PE 2: OFF**	Score	**PE 3: X**	Score
Position		Position		Position	
CTWD		CTWD		CTWD	
Work Angle		Work Angle		Work Angle	
Travel Angle		Travel Angle		Travel Angle	
Travel Speed		Travel Speed		Travel Speed	
Overall Score		Overall Score		Overall Score	
PE 4: XY	Score	**PE 5: OFF**	Score	****PE 6: XY**	Score
Position		Position		Position	
CTWD		CTWD		CTWD	
Work Angle		Work Angle		Work Angle	
Travel Angle		Travel Angle		Travel Angle	
Travel Speed		Travel Speed		Travel Speed	
Overall Score		Overall Score		Overall Score	

PE 7: XYZ	Score	**PE 8: OFF**	Score	**PE 9: XYZ**	Score
Position		Position		Position	
CTWD		CTWD		CTWD	
Work Angle		Work Angle		Work Angle	
Travel Angle		Travel Angle		Travel Angle	
Travel Speed		Travel Speed		Travel Speed	
Overall Score		Overall Score		Overall Score	

PE 10: WXYZ	Score	**PE 11: OFF**	Score	**PE 12: WXYZ**	Score
Position		Position		Position	
CTWD		CTWD		CTWD	
Work Angle		Work Angle		Work Angle	
Travel Angle		Travel Angle		Travel Angle	
Travel Speed		Travel Speed		Travel Speed	
Overall Score		Overall Score		Overall Score	

Appendix F

REALISM QUESTIONNAIRE

This survey has nothing to do with the end of course critique or your grade in the course. Answers will be used only to improve training.

Please rate the level of realism by placing an "X" in the box that best describes your experience while you trained on the VRTEX welding simulator. **Realism** describes how closely the simulator represents the actual task.

Remember: There is no right or wrong answers. Your instructors will not see your individual answers to this survey.

Strongly Disagree		Disagree		Slightly Disagree	Neither Agree, nor Disagree	Slightly Agree		Agree		Strongly Agree
0	10	20	30	40	50	60	70	80	90	100
How certain are you that you can weld in the flat position using the virtual welder?										
How certain are you that you can weld in the flat position using the equipment in the arc lab?										
How certain are you that you can weld in the horizontal position using the virtual welder?										
How certain are you that you can weld in the horizontal position using the equipment in the arc lab?										
How certain are you that you can weld in the vertical position using the virtual welder?										
How certain are you that you can weld in the vertical position using the equipment in the arc lab?										
Choose a percentage from the above scale to indicate your answer										

Percentage of Time	0% | 10% | 20% | 30% | 40% | 50% | 60% | 70% | 80% | 90% | 100%	
1. ________________	1. When you feel moody or restless during training, can you focus your attention well enough to finish your assigned work?	
2. ________________	2. When you discover that your weld position for the weld is much harder than expected, can you make the needed adjustments to have your weld achieve a GO1?	
3. ________________	3. When your last test results are NO GO1, can you figure out potential ways to improve the next weld bead pass that will improve your weld greatly?	
Please answer the following…		
AGE ___________	ASVAB SCORE ________________	Gender __________________

Thank you for your honest opinion!

Appendix G

SELF-EFFICACY QUESTIONNAIRE

This survey has nothing to do with the end of course critique or your grade in the course. Answers will be used only to improve training. Please rate your degree of confidence by placing an "X" in the box that best describes your experience while you trained on the VRTEX welding simulator**. Remember: There is no right or wrong answers.** Your instructors will not see your individual answers to this survey.

	Cannot Do At All					**Moderately Can Do**					**Highly Certain Can Do**
	0	10	20	30	40	50	60	70	80	90	100
On the virtual welder, produce a good **weld** (academic self-efficacy) in the flat position.											
in the horizontal position.											
in the vertical position.											
no matter the position.											
on the actual equipment in the arc lab.											
On the virtual welder, (Self-regulatory efficacy)											
maintain adequate travel speed.											
maintain correct work angle.											
maintain correct travel angle.											
maintain CTWD.											
hear distorting sounds.											
On the virtual welder, learn to weld (academic self-efficacy) in the flat position.											
in the horizontal position.											
in the vertical position.											
in the most difficult position.											
without help from the simulator.											
On the virtual welder, (self-regulatory self-efficacy) use feedback to improve performance.											
concentrate while welding.											

	Cannot Do At All					Moderately Can Do					Highly Certain Can Do
	0	10	20	30	40	50	60	70	80	90	100
do the things to perform a good weld.											
perform a good weld without help.											
keep poor performance from getting you down.											
get rid of self-doubt.											
keep from being easily rattled.											
overcome discouragement when nothing you try seems to work.											
bounce back after you tried your best and failed.											

Choose a percentage from the below scale to indicate your answer.

	Definitely Cannot Do It			Probably Cannot		Maybe		Probably Can			Definitely Can Do It
Percentage	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1. ______________	1. When your practical exercise is very complex, can you associate new concepts with old ones sufficiently well to remember them?										
2. ______________	2. When a practical exercise is especially boring, can you motivate yourself to keep going?										
3. ______________	3. When you had trouble understanding, can you clarify the confusion before the next class meeting?										
4. ______________	4. When you feel moody or restless during training, can you focus your attention well enough to finish your assigned work?										
5. ______________	5. When you discover that your weld position for the weld is much harder than expected, can you make the needed adjustments to have your weld pass inspection?										
6. ______________	6. When your last test results were poor, can you figure out potential ways to improve the next weld bead pass that will improve your weld greatly?										
7. ______________	7. When you are struggling to remember technical details of a welding process, can you find a way to associate them together that will ensure recall?										
8. ______________	8. When you are feeling down about a forthcoming test, can you find a way to motivate yourself to do well?										
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

Your age____in years Gender - male/female ASVAB score ________

Thank you for your honest opinion!

Appendix H

END OF COURSE CRITIQUE

CP98-1481 (C3-F3) *U.S. GOVERNMENT PRINTING OFFICE: 1997-531-629

AIMS
STUDENT EVALUATION
(AIMS CONTRACT)

This form gives you the chance to rate the block of training you just completed. You are not required to put your name on the form so tell us what you really think about the training. Your responses will be used to improve the training for future soldiers.

DIRECTIONS

1. Use a No. 2 pencil only
2. Erase clearly if you make a change.
3. Do not fold form.
4. Fill circle with a dark mark.

Incorrect — ⊘ ○ ⊗ ○ ◒
Correct — ○ ● ○ ○ ○

5. Put written comments only in boxes provided.
6. Information for blocks to the right will be provided by your instructor.

Course No.	Class No. — Yr.	Sec	Block No.

EVENT IDS	EVENT IDS

1. USING THE RATING SCALE TO THE RIGHT, TELL US HOW OFTEN EACH OF THE FOLLOWING THINGS HAPPENED DURING THE BLOCK OF TRAINING YOU JUST COMPLETED.

1. = Always
2. = Usually
3. = Sometimes
4. = Seldom
5. = Never
NA = Does not apply

TRAINING OVERALL

1. Objectives were presented at the beginning of training. ① ② ③ ④ ⑤ NA
2. The training was well organized. ① ② ③ ④ ⑤ NA
3. The training was interesting. ① ② ③ ④ ⑤ NA
4. The training was challenging. ① ② ③ ④ ⑤ NA

INSTRUCTORS

5. The instructor(s) knew the subjects well. ① ② ③ ④ ⑤ NA
6. The instructor(s) presented the training well. ① ② ③ ④ ⑤ NA
7. The instructor(s) were easy to understand. ① ② ③ ④ ⑤ NA

WRITTEN MATERIAL

8. The written material was easy to read and understand. ① ② ③ ④ ⑤ NA
9. The written material helped me learn the subjects. ① ② ③ ④ ⑤ NA
10. The written material required was made available to me. ① ② ③ ④ ⑤ NA

TRAINING AREAS/EQUIPMENT

11. The training areas (classrooms, bays, field areas) were good. ① ② ③ ④ ⑤ NA
12. The equipment used in hands-on training worked well. ① ② ③ ④ ⑤ NA
13. There was enough equipment for everyone to practice on. ① ② ③ ④ ⑤ NA

EXAM(S)

14. The exam(s) covered the materials presented in class. ① ② ③ ④ ⑤ NA
15. The exam(s) questions were easy to understand. ① ② ③ ④ ⑤ NA

SCHEDULING

16. Classes were completed during the time scheduled. ① ② ③ ④ ⑤ NA

COMMENTS: DO NOT WRITE OUTSIDE BOX

TRADCO FORM 559, SEP 90

TURN PAGE OVER

Appendix I

ADAPTED AIME & NASA-TLX (WORKLOAD)

Your answers to these questions will help us improve training with the virtual welder. **Do not put your name on the survey**. Your answers will remain completely anonymous.

Mental Effort is defined as the mental energy (thinking) needed when you train on a task.

Rate yourself on each of the following statements. Using the scale below, place an "X" in the box that best describes your experience while you trained on the VRTEX™360, the virtual welder. **There are no right or wrong answers.** Your instructors will not use this survey to assess your performance.

	Not at all	**Very, Very little**	**Very low**	**Low**	**Rather low**	**Neither low or high**	**Rather high**	**High**	**Very high**	**Very, Very high**
1. How hard did you try to understand the task? [AIME]										
2. How hard did you try to understand compared to other students in the room? [AIME]										
3. How much concentration was needed while training on the VRTEX welding simulator? [AIME]										
4. How easy to understand was the VRTEX welding simulator? [AIME]										
5. How much mental effort was needed while training on the VRTEX welding simulator? [AIME]										
6. How hard to understand was the VRTEX welding simulator? [AIME]										
Choose a percentage from the below scale to indicate your answer.										
Percentage	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%
1. ___________	1. How hard did you have to work on the virtual welder to accomplish your level of performance? *(Mental Effort)*									
2. ___________	2. How much mental and perceptual activity was required (e.g. thinking, deciding, calculating, remembering, looking, searching, etc.)? *(Mental Demand)*									
3. ___________	3. Was the learning task easy? *(Mental Demand)*									
4. ___________	4. How successful do you think you were in performing this welding process in this position? *(Performance)*									
5. ___________	5. How satisfied were you with your performance in									

	accomplishing the task in this position? *(Performance)*
6. ___________	6. How frustrated were you during this task in this position? *(Frustration level)*
7. ___________	7. How much physical activity was required (e.g. pushing, pulling, controlling, steadiness)? *(Physical demand)*
8. ___________	8. Was the task restful? *(Physical demand)*
9. ___________	9. Was the task demanding? *(Mental demand)*
10. __________	10. How much time pressure did you feel due to the rate or pace at which the task or task elements occur? *(Temporal demand)*

Circle the number that shows your overall level of mental effort.	0	10	20	30	40	50	60	70	80	90	100

Mental Demand--How mentally demanding was the task?

Very Low Very High

Physical Demand--How physically demanding was the task?

Very Low Very High

Temporal Demand--How hurried or rushed was the pace of the task?

Very Low Very High

Performance--How successful were you in accomplishing what you were asked to do?

Perfect Failure

Effort--How hard did you have to work to accomplish your level of performance?

Very Low Very High

Frustration--How insecure, discouraged, irritated, stressed, and annoyed were you?

Very Low Very High

Appendix J

TRANSFER RUBRIC

____________________ ____________________ __________/__________/__________

Student's PRINTED Name | Class Number | Date/Start Time/End Time

Item	Performance Measures	Max Points	Horizontal Evaluation Criteria			Student Assessment	Instructor Assessment	
			deduct 10 points	*deduct 15 points*	*deduct 20 points*		1st Attempt	2nd Attempt
Penetration	Fillet weld is aligned 90° Weld penetration of less than 3/4 of the base (Contact-Work Distance)	20	Incomplete flush less than 1" of total weld length. No obvious penetration markings on the underside of base metal.	Penetration of less than 1/4 the base. Incomplete flush exceeding 1" of total weld length but less than 5" Markings on the underside but they are not well defined	Completely unflushed (full separation totaling the 6" length of the weld). Well-defined and consistent penetration markings on the underside			
Bead Height	String bead reinforcement of the butt joint equals 1/16" high. String bead/root pass is smooth and consistent. (Travel Speed)	20	Bead has one of the following problems: (a) equals 3/32" height or (b) varied consistence/not uniform	Bead has both of the following: (a) equals 3/32" height and (b) varied consistence/not uniform	Bead has both of the following: (a) Less than 3/32" and (b) inconsistent			
Bead Width	String bead reinforcement of the butt joint equals 1/8" to 3/16" wide. String bead/root pass may not exceed 5/16" in width (Travel Speed)	20	String bead measures greater than 1/8" but less than ¼" in width. Bead width equals the width of two electrodies used.	String bead measures between ¼" and 5/16" in width.	String bead exceeds 5/16" in width. Bead narrower or wider than width og two electrodes used.			
Splatter	Minimal droplets of molten material that are generated at or near the welding arc (Travel Angle)	10	Spatter is present on 51-100% of the weld.	Spatter is presenter on 25-50% of the weld.	Spatter is present on less than 25% of the weld.			
			deduct 10 points	*deduct 30 points*	*deduct 30 points*			
Weld Appearance	Bead has none of any of the following inconsistent weld bead pattern: cracks, overlap, burn through, weld ripples are pointed/long, porosity, separation on any of the 4 joint areas.	30	Indications of inconsistent weld bead patterns exist and measures less than ¼" of the total weld length.	Indications of inconsistent weld bead patterns exist and measures greater than ¼" but less than 5/16" of the total weld length.	Indications of inconsistent weld bead patterns exist and measures greater than 5/16" of the total weld length.			
	MAXIMUM POINTS	100	TOTAL POINTS (minimum = 80 points)					

<u>This test is not a graduation requirement.</u> All appropriate safety precautions followed. Performed pre-inspection to ensure equipment is in good operating conditions. Students must refer to 502 weld drawing for project specifications. Instructor shall examine the weldment for weld defects and acceptable appearance. Visual examination is the minimum criterion for acceptance,however all weldments are subject to examination using a 6" rule graduated in 32nds. Any safety violation will result in the student's test being IMMEDIATELY STOPPED. At that point, the student will be retrained on safety before restarting.

ANNOTATE SAFETY VIOLATION HERE:

Today's Date:	**Instructor's Name and Signature**	**GO1 / NO-GO**
Today's Date:	**Instructor's Name and Signature**	**GO2 / NO-GO2**

Updated 26 June 2015

Appendix K

IN-PROCESSING NOTIFICATION LETTER

Date:____________

ATSD-DTD-M

SUBJECT: Research Study – Varying Feedback Strategy and Scheduling in Simulator Training: Effects on Learner Perceptions, Initial Learning, and Transfer

1. Background. As you know, I am the course manager for your military occupational specialty (MOS 91E). I am also a doctoral student at Old Dominion University and am collecting information about ways to use feedback during technology-facilitated training. I need your feedback to improve how we train with the virtual welder. You are asked to train on the virtual welder and complete a questionnaire about your perceptions regarding the training. If you decide to participate, then you will join a study of 90 Army Soldiers from the Metalworking Services Division, United States Army Ordnance School. Your participation will take place a part of phase 1B of the 702-91E10 course, but will not be considered as part of your evaluation in the course.

2. Action. The potential benefit of your participation is improvement in the way we train your fellow Soldiers. Initial Entry Soldiers, other Non-commissioned Officers, and Warrant Officers in your MOS may also benefit by these changes. Risks are minimal, but there is a risk that you may be identified. The researchers will maintain strict confidentiality unless required by law. We will reduce the risk by removing all linking identifiers for all participants. We are recording scores obtained while training on the virtual welder, but only project researchers at ODU will have access to these scores. We will strongly urge the other participants to maintain confidentiality but cannot guarantee that they will do so. The results of this study may be used in reports, presentations and publications, but the researcher will not identify you.

3. Comments. It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away from your participation in the study at any time. Your decision will not affect your relationship with Old Dominion University or your chain of command, or otherwise cause a loss of benefits to which you might otherwise be entitled. By the time you read this, I should have answered any questions you may have had about the study.

4. Further information may be obtained by contacting the undersigned at 804-765-9014 or sonya.blandwilliams@us.army.mil. If at any time, you have any questions about your rights as a participant, then you should contact the Old Dominion University Office of Research, at 757-683-3460 or George Maihafer, Institutional review Board Chair, at 757-683-4520.Thank you very much for your consideration.

SONYA BLAND-WILLIAMS
Course Manager, MSD

Appendix L

NOTIFICATION FACTS SHEET TO PARTICIPANTS

INTRODUCTION
The purpose of this form is to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. Project Virtual Welder will be conducted using the VRTEX™360.

RESEARCHERS
Sonya Bland-Williams, Doctoral Student, sblon001@odu.edu, (804) 765-1136
Old Dominion University, College of Education, STEM & Professional Studies, Norfolk, VA

Ginger Watson, Ph.D., Associate Professor, gwatson@odu.edu, (757) 683-3246
Old Dominion University, College of Education, STEM & Professional Studies, Norfolk, VA

DESCRIPTION OF RESEARCH STUDY
This study focuses on the effects of feedback strategy when learning a motor skill during simulator training.

INCLUSIONARY CRITERIA
To be eligible for this study you must be at least 18 years of age or older and a 91E10 student at Metalworking Services Division.

RISKS AND BENEFITS
The researchers do not see any risk for participating in this study. Benefits include learning more about your own reactions to feedback and simulator training.

COSTS AND PAYMENTS
There is no cost to participate. There will be no payments given to participants.

NEW INFORMATION
If the researchers find new information during this study that would reasonably change your decision about participating, then they will make this available to you.

CONFIDENTIALITY
All information obtained in this study is strictly confidential. The researchers will take reasonable steps to keep private information, such as surveys and demographic data, confidential. The researcher will remove identifiers from the information. The results of this study may be used in reports, presentations and publications, but the researcher will not identify you.

WITHDRAW PRIVILEGE
It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdrawal from the study - at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might

otherwise be entitled. The researchers reserve the right to withdraw your participation in this study, at any time, if they observe potential problems with your continued participation.

VOLUNTARY PARTICIPATION

By participating in this research study, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied and you understand this form, the research study, and its risks and benefits. If you have any questions later, please contact the researchers.

Appendix M

TASK ANALYSIS: ACTUAL EQUIPMENT, HORIZONTAL POSITION

Fillet Weld in the Horizontal Position 1/16 and 1/8 Mild Steel,

1. Turn Machine on
2. Set Volts 16-22, page 240, figure 9-11
3. Set Gas Flow to -25-30 cfh
4. Set Wire Speed to 128-304
5. Wire brush the metal to prepare it for welding.
6. Tack weld the metal in three places.
7. Place work piece in jig for horizontal position welding.
8. The centerline of the electrode should be held at about 45° o the edge and metal surface.
9. Angle the gun 5-15° in direction of travel.
10. Use a weaving motion to improve bead appearance.
11. Travel evenly to keep leg dimensions equal.
12. Stay on leading edge of puddle to avoid incomplete fusion (cold lap).
13. Deposit bead at root (center) of joint.
14. Turn off the machine.
15. Wire brush and quench metal in water until it is cool to the touch.

    Note: The instructor will answer any questions pertaining to this demonstration.

    Fillet Weld in the Vertical position on 1/16th and 1/8" Mild Steel, P 258, 9.10

1. Turn Machine on
2. Set Volts 16-22, page 240, figure 9-11
3. Set Gas Flow to 30 cfh

4. Set Wire Speed to 128-304
5. Wire brush the metal to prepare it for welding.
6. Place work piece in jig for horizontal position welding.
7. Tack weld the metal.
8. The centerline of the electrode should be held at about 45° to each surface.
9. Point more toward the surface if the edge melts too quickly.
10. Travel smoothly and evenly to completely fill joint.
11. Deposit bead at root (center) of joint.

    Note: The electrode or gun should tip about 5-15° push in the in the direction of travel. A C-shaped weld pool will indicate good fusion is occurring.
12. Travel at speed to produce a 5/16” wide bead face.
13. Travel evenly to keep leg dimensions equal.
14. Leg dimensions should be equal.
15. Run the Bead. Stay on leading edge of puddle to avoid incomplete fusion (cold lap).
16. Deposit bead at root (center) of joint.
17. Wire brush the joint.
18. Turn Machine off
19. Quench the metal so that it is cool to the touch.
20. Task Analysis: Actual Equipment, Vertical Position
21. Fillet Weld in the Vertical position on 1/16th and 1/8" Mild Steel, P 258, 9.10
22. Turn on Welding Machine
23. Set Volts to 16-22 page 240, figure 9-11
24. Set Gas Flow to 35-45

25. Set Wire speed to 128-304
26. Wire brush metal for preparation of welding.

    NOTE: Bead sequence, the first weld will be made on the left side of the project in the vertical position, the second weld will be made on the right side of the project in the vertical position, the third weld will be made at the top of the project in the horizontal position and the final weld will be made at the bottom of the project in the overhead position. These four welds will complete one bead, this project consist of three beads. TC 9-237 page 12-44 figure 11-22
27. Tack weld the project, and clean tack weld using a wire brush.
28. Place work piece in the jig. Do not rotate project, raising and lowering the project is permitted.

    NOTE: The patch will be welded to the outside of the damage armor.
29. Lay first weld at the left side of the project in the vertical position. Angle the gun 5°-15° direction of travel.
30. The centerline of the electrode should be about 45 to the edge of the flat surface.
31. Deposit first weld at root (center) of joint.
32. Wire brush the bead.
33. Lay the second weld at the right side of the project in the vertical position. Angle the gun 5°-15° direction of travel.
34. The centerline of the electrode should be about 45 to the edge of the flat surface.
35. Deposit second weld at root (center) of joint.
36. Wire brush the bead.
37. Lay third weld at the top of the project in the horizontal position.

38. Angle the gun 5°-15° direction of travel.
39. The centerline of the electrode should be about 45 to the edge of the flat surface.
40. Deposit third weld at root (center) of joint.
41. Wire brush the bead.
42. Lay forth weld at the bottom of the project in the overhead position. Angle the gun 5°-15° direction of travel.

    NOTE: These four welds make one complete bead around the project. Follow the same weld sequence for the next two beads.

43. Lay second weld across the bottom half of the first bead with its bottom toe fused into the lower base plate.
44. Wire brush the completed bead.
45. Lay the third and final bead across the top toe of the second bead with its top toe fused into the upper base plate.
46. Wire brush the completed beads.
47. Turn off the machine.
48. Quench the completed project, until it is cool to the touch.

Appendix N

INSTRUCTOR NOTES AND OBSERVATIONS FORM

LOCATION: ____ DATE: ________________

Descriptive Notes	Reflective Notes
Use this space to list any questions asked by participants, accounts of unique or noteworthy events, description of the training	Use this space for personal thoughts, feelings, speculations, or hunches

Appendix O

INTERVIEW QUESTIONS DURING FOCUS GROUP

Opening Statement

Thank you for your willingness to discuss your experience as you trained on the virtual welder. We are here to give you an opportunity to share additional information about your training experience. At no time will your instructor or chain of command be able to identify you with any comments made today. I will take notes, but not record any names. I am obligated to keep all identities and personally identifiable information anonymous. This interview will last no longer than one hour. During this time, I have several questions that I would like to cover and may push ahead to complete all questions.

Introduction
As I ask questions, any person may answer. Feel free to give any information that describes your reaction to the training, your thoughts about the welding training that you have had so far.

Key Reaction Questions:

1. What stands out in your mind most about the training?

    a. Probe: What did you like most?

    b. Probe: What did you like least?

2. Describe your feelings and/or thoughts during the first time you welded in the welding bay.

    a. Probe: What emotions did you experience?

    b. Probe: Describe any concerns you had about welding?

    c. Probe: Tell me about any questions that you may have asked yourself? Your instructor?

3. What did you learn while practicing on the virtual welder?

    a. Probe: What were you told you would learn?

    b. Probe: Describe your level of confidence after welding on the virtual welder. On the actual equipment?

4. What were some differences, if any, between welding on the virtual welder and the actual equipment that you noticed?

    a. Probe: What were any similarities, if any?

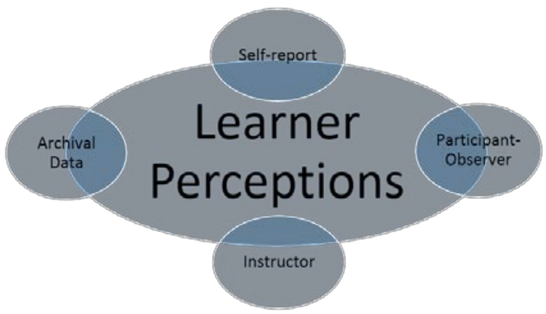
Probe: What could have been done differently?

Appendix P

Audit Trail with Field Notes

5 May 2016 Initial Field Notes

This project will look at the perceptions of novice learners who train using a mixed-reality simulator. My role as the researcher is that of an observer. I am a former employee of the department and understand that I may be viewed by the participants as a participant-observer. I understand that my bias is that teaching should involve interactions among the students as well as between the teacher and student with opportunities for interaction between the content and the student. My sample questions are written from a phenomenological perspective. The learner is aware of how they learn and able to describe the ways they experience the learning event.



6 May 2016 Meet with Gatekeeper

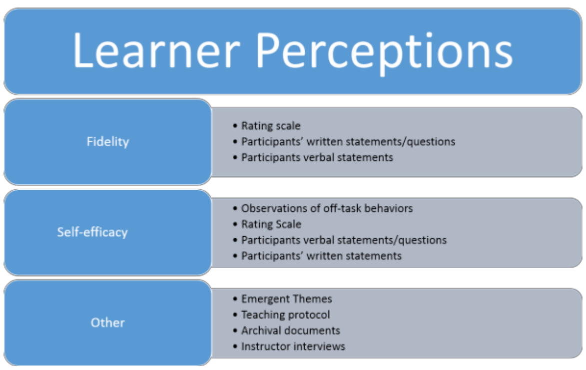
The gatekeeper is interested in the finding out the performance trends of students who train with the simulator. The gatekeeper believes that students learn faster on simulators than conventional machines. The gatekeeper has the authority to purchase any additional supplies that may be needed by the instructors. The gatekeeper is interested in discovering what additional supplies and equipment are needed.

27 June 2016 Field Notes from Instructors

Conducted two instructor interviews. Safety is an emergent theme to instruction. A personal responsibility is noted. Instructors appear to take sole responsibility for learning. Yet, students are expected to take sole responsibility for safety. Instructors focused on safety protocol during responses. Instructors appeared reluctant to mention negative comments towards training. Instructors focused on their role during training instead of the students as the locus of control.

29 June 2016 Initial Brainstorming of Themes

Reviewed Field and Instructor Notes. Safety continues to emerge as theme to instruction. A personal responsibility is noted as before. Consistent teaching protocol noted. After interview ended, instructor stated that some of the motivation decreases after students get some time in the virtual lab. Instructor attributed that decrease in motivation to a lack of simulator fidelity (specifically, some blurriness that students perceive after training on the simulator).
Anticipated Themes
-negative aspects of realism/low fidelity
-positive aspects of realism/high fidelity
Anticipated Learner Perceptions
-positive/moderate fidelity prior to conventional welding
-negative/low fidelity perceptions after conventional welding
-high self-efficacy



7 July 2016 Classroom Observation

Observed students within the virtual lab. The observation gave insight to the teacher-student relationship. This relationship appears to take precedence over the student-content relationship. I noted the high level of respect for rank and structure. Students were attentive to cadre personnel.

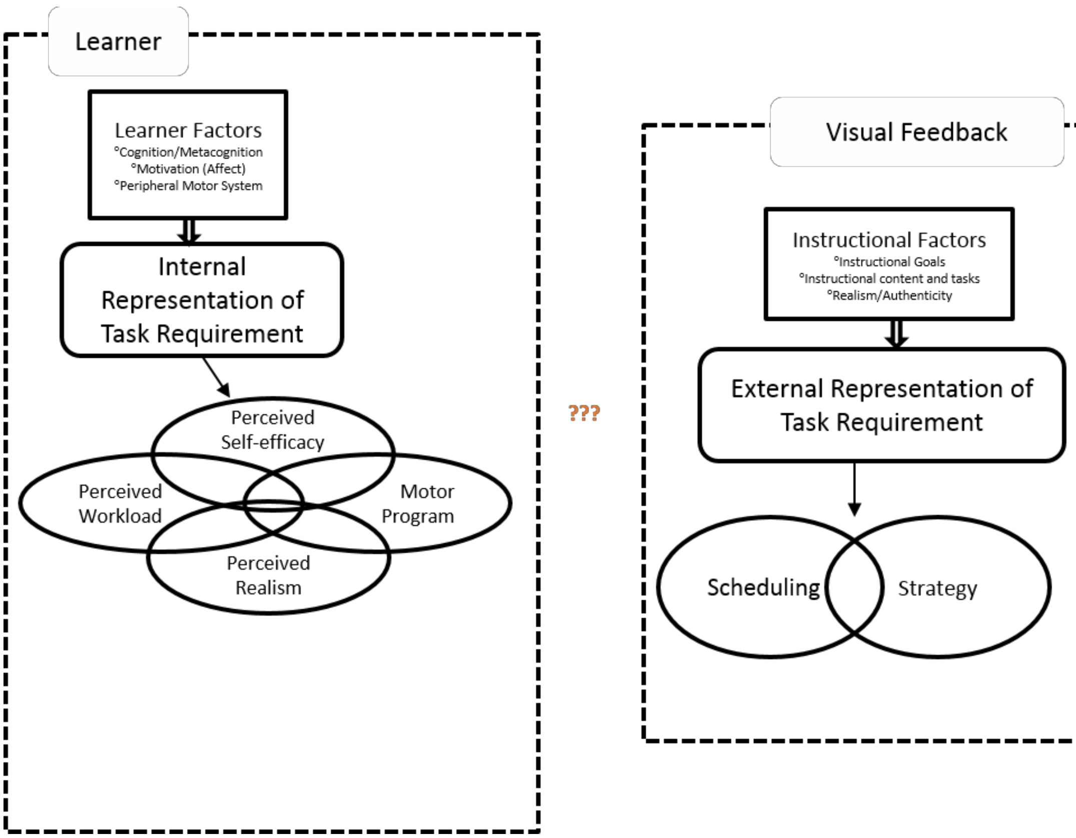
Classroom observation lasted 20 minutes to collect quantitative data on student behaviors such as questions, interactions with other students/simulator, unconscious behaviors, teaching strategies employed by instructors, etc. Scheduled afternoon interview with the instructor ID#103AEOB.
Student initiated question -1x
Sidebar conversations for peer help -6x
Instructor give individual help -4x
Self-assessment by students -2x
Student nonverbal gestures of confusion -1x
Student use of welding concepts -8x (work angle, travel angle, travel speed, arc length)
Practice with ease

Theme	Descriptive Notes	Reflective Notes
Perceptions of realism (positive)	Students wearing welding jackets and welding cap. Students hearing sounds of welding.	None

	Mixed reality with hardware weld gun, helmet, weld machine. Simulation of image of welding available to students through googles	
Perceptions of realism (negative)	Students noted making several adjustments to googles before during and after welding.	None
Teaching protocol	-Whole group instruction given during demonstration. Not all students asked questions 2 out of the total number of students noted. -All technical support was the responsibility of the instructor during the lesson Events of instruction noted: -Objective stated to students to score at least 80 -“motivator” stated that students will use simulator to prepare for live welding (gain attention) -demonstration by instructor -learner guidance available by simulator -elicit practice on simulator -feedback given to students’ questions and two references to unsafe practices -assessing performance -a total of 5 students working individually on simulator - one student =2 passes before reach 80 score -two students =6 passes before reach 80 score -1 student =12 passes before reach 80 score -1 student =9 passes before reach 80 score	Interesting that instructors do not encourage collaboration among students during lesson, yet, still occurs
Student Questions	“How do I know my work angle is good?” Instructor self-reported “some of the motivation decreases once they get in here.” Instructor attributes decreased motivation on blurriness of the goggles.	Students appeared at eased using conceptual terms to ask questions and talk among themselves. Little talking in the beginning in comparison to the end of practice session.

8 Aug 2016 Literature Search/Review-Concept Map

Literature suggests a hypothesized relationship between fidelity and learning. What impact, if any, is there on the learner's internal representation of task requirements when visual feedback is manipulated?



11 Aug 2016 After-action Interview

Conducted one instructor interview. More emphasis on the fidelity of the simulator. Instructor gave shorter responses than previous interviews. Instructor appeared least pleased with the simulator than other instructors. This instructor had most experience as a welder.

Welding as a skill that requires deliberate practice. Students were very self-aware of their learning; possessed metacognitive strategies. Different perceptions related to years of prior welding experience. Evidence of an inverse relationship-high prior experience=low satisfaction with VR.

11 Aug 2016 Classroom Observation

Theme	Descriptive Notes	Reflective Notes
Perceptions of realism (positive)	Students wearing personal protective equipment (cap, jacket, gloves). Students hearing sounds of welding. Mixed reality with hardware weld gun, helmet, weld machine. Simulation of image of welding available to students through googles	None
Perceptions of realism (negative)	Student complaints “I can’t see my weld”.	One Machine noted not scoring weld after each pass. Student has to restart to receive a score (2x)
Teaching protocol	-Whole group instruction given during demonstration. One student assisted the instructor by serving as the demonstrator on the machine as the instructor pointed out the procedures. Students gathered around one machine during demo -All technical support was the responsibility of the instructor during the lesson Events of instruction noted: -Gained student attention by setting a competition of who reaches highest score gets new weld cap. -informed objective performance of score of 80 --demonstration of simulator to present skill --learner guidance given by instructor and available by visual cues	Little reliance on simulator feedback by instructor; students given the option to remove the cues if preferred.
Student Questions	“What is CTWD again?” “Is…[student A] too far from the workpiece?” Instructor self-reported that some students get dizzy from visual cues.	Rather than ask peer questions all questions were directed to instructor

14-18 Aug 2016 Analysis of Instructor Notes

Theme	Descriptive Notes	Reflective Notes
Perceptions of realism (positive)	Students wearing gloves, weld cap, weld jackets, leather splats. Students hearing sounds of welding. Mixed reality with hardware weld gun, helmet, weld machine. Simulation of image of welding available to students through googles. Visual sparks seen through google	Students looking at scores more than the visual picture of the completed weld.
Perceptions of realism (negative)	No heat from weld. Visual sparks seen but no heat felt from sparks.	Process appears must faster than live welding. Students appear to complete passes very quickly
Teaching protocol	-Whole group instruction given during demonstration. Instructor pointed out the procedures. Students at their machines working in pairs. -All technical support was the responsibility of the instructor during the lesson Events of instruction noted: -Gained student attention by setting a competition of who reaches highest score gets new weld cap. -informed objective performance of score of 80 -welding simulator available -learner guidance given by instructor and available by visual cues -student practice on simulator -provided feedback -assess performance by instructor and simulator	None
Student Questions	“when are we going into the bay to weld?”	Student appeared highly confident that they were welding “correctly” as evidenced by reference to go to the welding bay

18 Aug 2016 Post Data Collection Concept Map

Anticipated Themes found during interviews
- -negative aspects of realism/low fidelity (no heat source)
- -positive aspects of realism/high fidelity (weld helmet, weld gun)

Emergent Themes found during interviews
- -safety as major component to instruction
- -student complaints (headaches, motion sickness)

VITA

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PUBLICATIONS

Peer-reviewed Conferences

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