# Operational Neuroscience for Adaptive Training Solutions

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## ABSTRACT

There are a number of theoretical, practical, and technological challenges inherent in the design, development and implementation of adaptive training systems. Adapting training materials (e.g. content, feedback, etc.) for improved training outcomes requires innovative and systematic investigations into emerging concepts and technologies. As detailed by the National Research Council in Human Behavior in Military Contexts (2008), behavioral neurophysiology represents a promising area for research and development in military contexts; however a range of key elements must be addressed. For example, determining appropriate levels of analysis (or combinations) for accurate measurement and assessment of complex skills (e.g., situation awareness, intuitive decision making, intercultural competence, etc.) is key as training organizations transition findings from research to applied settings. Moreover, this transition requires focused front-end analysis to determine training tradeoffs associated with technical and technological integration for effectiveness and efficiency.

A brief historical overview is provided, along with a review of contemporary work and directions, leading to presentation of a technical framework for an adaptive training system that uses state of the art behavioral and neurophysiological technologies coupled with human performance engineering to optimize training effectiveness and efficiency. A summary of relevant concepts and applications is provided, indicating how they relate to each other. Finally, a range of open issues and future challenges is discussed.

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OVERVIEW

Multiple shortcomings exist in current training systems that constitute the potential for improvements, including 1) the inability to detect problems with cognitive "readiness" for training, 2) the inability to monitor implicit perceptual and cognitive processes that cannot be inferred from observable physical behaviors, and 3) the inability to accurately and reliably diagnose the quality of an error *(e.g., is the error part of an error pattern that indicates a higher-level problem, such as insufficient understanding or misinterpretation of the instructions)*. Furthermore, few training systems can provide these types of analyses in real-time, and thus have limited responsiveness in adapting training as needed to optimize learning effectiveness and efficiency. Tools are needed that support trainers and trainees in determining when errors occurred, what errors occurred and why these errors occurred to increase the diagnostic value of training assessment and can adaptively respond to enhance the training opportunity. Furthermore, such tools should be able to detect training effect saturation and identify opportunities in real-time for training acceleration or compression.

This paper summarizes advances in the design, development, and implementation of a technical framework that applies advanced adaptive training tools based on a blended instructional strategy. First, a review of training and learning literature is discussed to provide an overview of the principles that structured the design and development of the proposed training system. Traditional learning theories and principles guided the implementation of adaptive training tools within a virtual environment platform to demonstrate capabilities that sharpen post-action feedback and manage training content in real-time. Examples of post-action feedback and real-time adjustments produced by the prototype are provided. Extensions for future work are discussed, along with implications of future advancements.

Over the past 20 years, research in the field of neuroscience has expanded the scope of neurophysiology, allowing for new opportunities to utilize process measures from neural and physiological sensor suites to accelerate learning and improve both training effectiveness and efficiency. Advances across a range of fields (neuroscience, biochemistry, psychology, computational science, etc.) continue to unravel the complexities of the human brain and are allowing for a more detailed and comprehensive understanding of the processes that underlie human performance. From these advances opportunities to enhance training tools are emerging. Specifically, state of the art technologies capable of real-time data capture and analysis of neural activity are being used to measure and assess implicit mental processes.

### Neurophysiology and Human Performance Engineering

Human performance assessment is a cornerstone of the training process, as an accurate understanding of trainee state can guide future training experiences to target individualized deficits and inefficiencies. Capturing human performance data in real-time allows for near real-time understanding of human state and opens the possibility for adaptive training to target. However, capturing high performance human behavior in real-time is challenging as it is the outcome of mingled, often mangled determinants that operate across biological, behavioral, cognitive, and social processes. Knowledge of these processes and the relational structures across them represents the foundation for next generation human performance engineering. Decomposing behavioral, cognitive, and social processes to specific neurophysiological processes that are observable and measurable will allow for precision training that can be used to effectively, efficiently, and predictably engineer high performance human behavior.

Rapid advances in technology and neuroscience are making it possible to begin development on this frontier. Numerous neurophysiological methods have been developed to capture (1) electrical activity and (2) metabolic rate of brain activity. Those methods which use electrical activity are very good at telling researchers the timing of certain brain activities, but they are not good at localizing that activity. Conversely, those measurers which use blood flow are very good at localizing brain activity spatially, but are not good for temporal assessments of brain activity. The tradeoffs associated with these technologies represent critical differences and associated advantages and disadvantages must be carefully considered prior to application.

Because real-time closed loop systems are time-critical, incorporating neurophysiological sensors that capture brain activity with high temporal accuracy are highly valued. For the system developed under this effort, Electroencephalography (EEG) event-related potential (ERP) were incorporated as the sensors are relatively unobtrusive and inexpensive, and can time brain activity very precisely. For example, EEG has been used to assess cognitive state dimensions such as workload, (dis-)engagement, and (in-) attention by monitoring changes in EEG power band activity. These states are relatively easy to detect as they are clearly characterized by increased alpha power across many EEG sites. The more transient hazardous states of cognition, such as inattention or distraction, are manifested in more focal (frontal sites) increase in low frequency power (< 7 Hz).

Furthermore, other „unobservable" behavioral measures such as eye tracking can be utilized to understand where visual attention is focused throughout training, and ensure that trainees are focusing on key components relevant to the task. If non-optimal or erroneous scan patterns are observed, training mitigations can be instantiated to target this specific root cause of error, which provides more granularity regarding trainee state than can be captured via overt behavioral responses alone (e.g., trainee missed target – but there is no understanding of *why* target was missed with overt behavior alone).

As a result of improved sensor technologies, neurophysiology has emerged as a major area of research for applied study, and has been adapted into real-time closed loop systems such as Augmented Cognition systems designed to optimize human performance in highly complex, dynamic environments. Benefits of neurophysiological metrics research are substantial for training programs as such measures capture the biological underpinnings of higher order cognitive processes that can be used to diagnose and predict human performance at a root cause level (Carroll et al., 2010). Because training effectiveness is dependent on the accuracy and reliability of performance measurement, it is imperative that neurophysiological metric research is leveraged to advance training programs. An additional benefit of incorporating such advanced metrics includes the ability to continuously capture neurophysiological data to drive real-time understanding of trainee state without necessarily requiring overt actions by the trainee.

## Military Training

The United States military relies on effective training to teach and maintain warfighter readiness and ensure mission success. Ultimately, warfighter readiness is proven on the battlefield where they must be prepared to perform complex tasks under extreme stress. In such stressful situations, cognitive workload is high and can produce a hyper-stress state of instability where simple task performance becomes difficult and complex/high performance tasks may not be executed optimally.

Among other battlefield stressors, warfighters are overloaded by cognitive demands, such as cue recognition, planning, and decision making (Cooke, Salas, Kiekel, and Bell, 2004). This degraded state of cognitive performance is often brought about by sleep deprivation, high degrees of physical and psychological activity, extended periods of vigilance, and an overwhelming sense of danger (Hancock & Hoffman, 1997). Training techniques dedicated to reducing overall cognitive load placed on warfighters are likely to raise the value of that training and improve training effectiveness and transfer. Training tools and platforms that might be useful in monitoring and managing cognitive load during training are emerging from developments in simulation-based training.

## Simulation-Based Training

Simulation-based training has garnered significant attention and is widely regarded as a robust training methodology because of the flexibility and control it provides. The instructional designer has control over most of the characteristics of the training environment in simulation-based training. This is especially useful for military training because it allows warfighters to engage in the dynamic elements (i.e., social, behavioral, and cognitive) representative of modern Irregular Warfare.

Traditionally, military training programs target, assess, and evaluate human performance using metrics of behavioral processes and outcomes. Optimal performance can be achieved using feedback derived from behavioral observations of task performance when the task be trained is static, constant, and consistent. However, behavioral observations are not sufficient for performance measurement and assessment of complex cognitive skills required during military operations. Moreover, traditional performance assessments of task behaviors are inadequate for diagnosis of performance thresholds across human capabilities (e.g., stress, mental workload, attention) that impact mission outcomes.

**After Action Review (AAR)**

The after action review (AAR) process developed and introduced by the United States Army in the 1970"s has gained acceptance across many disciplines as an exploratory feedback session that immediately follows team actions/events. In the context of military training, the AAR is a post-action review of individual, and team, performance in which warfighters examine individual and team actions. U.S. Army leaders are considering new directions for the AAR process in response to the implementation of new training tools, such as VE simulations (Knerr, Breaux, & Goldberg, 2002) and advanced neurophysiological data capture technologies. While the AAR process represents one element of a training program, it is an interdependent element that will require tailoring as training platforms change. With VE simulations gaining popularity as a training tool, researchers should work to leverage the advantages afforded (flexibility and control) by this platform in combination with the improved diagnostics of neurophysiological measures to deliver targeted feedback. As it relates to the AAR process, a training system that captures and analyzes root cause data has significant utility when we consider:

> *AARs display the unit's plan (what was supposed to happen), identify "what happened" during the execution, and stimulate player discussions on "why it happened." During these discussions... players learn from their mistakes and benefit from the lessons learned by other players. The AAR, in effect, becomes the bridge between the completed training event and the next training event, providing post-exercise learning on "how to improve" that enables leaders to fix training weaknesses. (Brown, Nordyke, Gerlock, Begley, & Meliza, 1998, p. 12)*

Within our adaptive training system prototype we leveraged the neurophysiological data captured to measure and assess trainee performance. During the AAR process, this data is used to support the instructor/facilitator.

**Science of Learning**

Learning is a problem space for which a single model of learning will likely never be universally applicable, or acceptable. Many human factors contribute to how knowledge is acquired and applied. For starters, limits on human capabilities restrict how much information can be handled (Miller, 1956), and there are limitations on how much information can be processed dependent on sensory channel input (Baddeley & Hitch, 1974). Moreover, widely accepted theories of mental resource distribution suggest functioning that is bound by relative constraints. Mental resource theories have evolved from a single pool of resources (Kahneman, 1973) to a push and pull perspective of coordinated multiple resources (Wickens, 2002). In choosing a training tool, we must give serious consideration to how humans process information and choose techniques and technologies that facilitate learning.

**Cognitive Load**

Cognitive load refers to the "load", or amount of processing requirements, placed on working memory during instruction (Sweller & Paas, 1998). Working memory has capacity (Miller, 1956) and processing limitations (Baddeley & Hitch, 1974) that are well researched and are integral during learning.

According to cognitive load theory, learning is facilitated when the learner is focused on the learning task. The cognitive load theory states that learning is most effective when learners are not cognitively overwhelmed. Clark, Nguyen, and Sweller (2006) suggest that all learners, all content, and all instructional media are pertinent to cognitive load. In other words, cognitive load is mediated through multiple factors, and the amount of cognitive load placed on a trainee is dependent on each of those factors. Therefore, the choice of instructional strategy that monitors and manages cognitive load so that training time in over/underwhelmed state is minimized would result in more effective and efficient training.

**Measurement and Assessment**

Research on the science of learning is replete with theories and models describing how learning occurs. Typically, these theories are presented in a cyclical framework, as outlined by Menaker, et. al. (2007). This framework is as follows:

1. *Experience or interact with the environment*
2. *Observe behavior and reflect on experience.*
3. *Generalize or form abstract concepts based on reflection.*
4. *Experiment and add to or modify concepts based on new experiences.*

As outlined above, the role of reflection/feedback is relevant throughout the learning cycle. Providing warfighters with the accurate feedback is critical, and the technical framework below includes an advanced instructor support tool to ensure appropriate feedback for training improvement. Moreover, a real-time adaptive capability is implemented within the technical framework discussed below to manage cognitive load, so that the trainee‟s experience within the training environment is maximized.

Here we propose a framework that leverages advances in neurophysiological measurement technologies for delivery of an adaptive training system. The design and development of this framework is grounded in established training and learning theories.

## ADAPT-RT FRAMEWORK

The Auto Diagnostic Adaptive Precision Training – Real Time (ADAPT-RT) Framework is designed to identify in real time *when* training adaptations should be implemented, *what* part of the training or simulation should be modified, and *how* such adaptations should be implemented to target the specific skills in need of improvement (Fuchs et al., 2008). ADAPT-RT integrates an easyGaze™ eye tracker and B-Alert® EEG headset with traditional behavioral metrics to provide granular performance and state data evaluation including traditionally unobservable perceptual processes such as search and detection and inaccessible cognitive states such as workload, engagement and fatigue. ADAPT-RT‟s diagnostic engine then transforms this detailed performance and state data into information which can facilitate real time training including key performance and cognitive state deficiencies, and root causes of errors. Based on the diagnostic engine output, ADAPT-RT‟s adaptation engine identifies effective adaptation strategies and triggers real time scenario adjustments designed to target these deficiencies and accelerate learning. The adaptation engine also outputs After Action Review (AAR) displays including a clear summary of performance and state results, easily interpretable in terms of where issues lie and what can be done to address these.

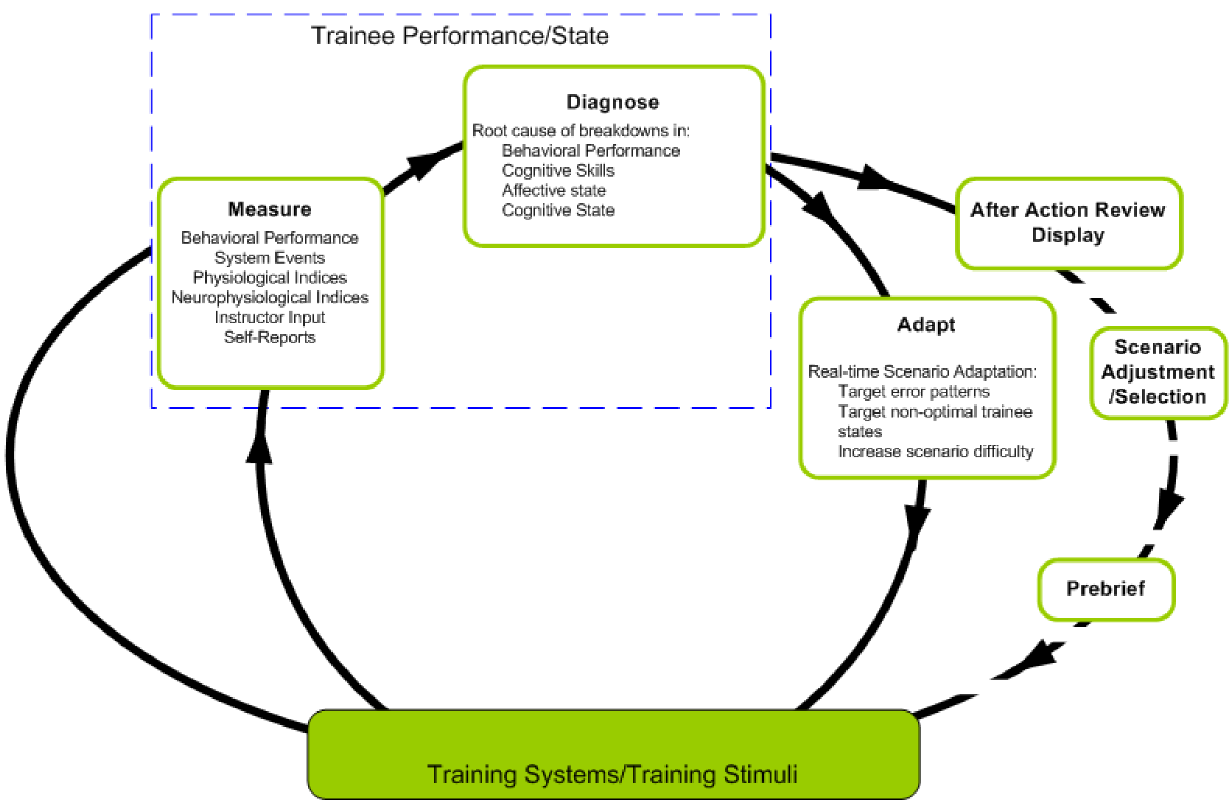

**Figure 1. ADAPT-RT Conceptual Model**

### Integrated ADAPT-RT Prototype System

ADAPT-RT was integrated into a blended training architecture across 3 training session for different instructional methods, 1) Instructor-led Training (ILT), 2) Computer Based Training (CBT), and 3) Mission Execution (ME) (Table 1). The following sections detail the implementation of ADAPT-RT in each of these scenes.

**Instructor Led Training (ILT).** Within this scene, ADAPT-RT measured trainee gaze data via eye tracking to determine if a trainee fixated on relevant information (i.e., specific areas of interest [AoIs] within slide content) while each slide was presented. ADAPT-RT also measured trainee cognitive state of workload, engagement, distraction and drowsiness using EEG indicators. Based on the measures above, ADAPT-RT identified two distinct conditions that may lead to adaptation (Table 2 outlines specific threshold values):

1. *Non-optimal visual attention allocation (evaluated for each slide): Trainee did not fixate on all defined AoIs on the presented slide by the time the Instructor completes his lecture for that slide.*

2. *Non-optimal cognitive state (evaluated for each slide): Trainee showed cognitive overload, increased levels of distraction, drowsiness, or low levels of engagement during slide presentation.*

Based on the problem states diagnosed above, ADAPT-RT can identify and trigger appropriate adaptation strategies as detailed in Table 2. While ADAPT-RT code is currently capable of diagnosing and triggering adaptations in real-time, adaptations for the current demonstration were scripted in, meaning that specific AoIs on two slides are „not viewed" and thus require adaptation 1, while adaptation 2 triggers the virtual classmate to ask a question regarding slide 3. This was done to simplify the number of potential slides created, as adaptations are currently instantiated into a predefined PowerPoint presentation, and to simplify navigation through slides (slide changes are hard coded).

**Computer Based Training (CBT).** ADAPT-RT was integrated at the end of CBT to complete a skill check of IED detection. Here, two separate images were shown in succession, and the trainee was asked to determine whether an IED was present in each image. ADAPT-RT measured trainee gaze data via eye tracking, and identified the occurrence of the following primary perceptual performance deficiencies:

1. *Scan Errors in which a trainee failed to scan relevant cues,*
2. *Recognition Errors in which trainee scanned a cue, but failed to allocate significant amount visual attention and indicate a threat is present, and*
3. *Attention Allocation Issues in which a trainee spent too much time scanning irrelevant areas in the scenarios.*

The parameters and thresholds for determining these problem states are detailed in Table 1. Based on the problem states diagnosed above, ADAPT-RT presented AAR displays to demonstrate summary trainee performance feedback. The current demonstration captured and diagnosed trainee performance in real-time, and drove selection of a subset of predefined AAR displays that included percentage of IED threats detected, illustration of trainee scan data with color coding to indicate fixations on relevant areas (green) and irrelevant areas (red), pie chart indicating percentage of time spent on irrelevant vs. relevant areas, and an indication of whether missed threats were due to search or detection error and elaborative information to aid in preventing this error in future scenarios. Figure 2 illustrates an example CBT AAR Display.

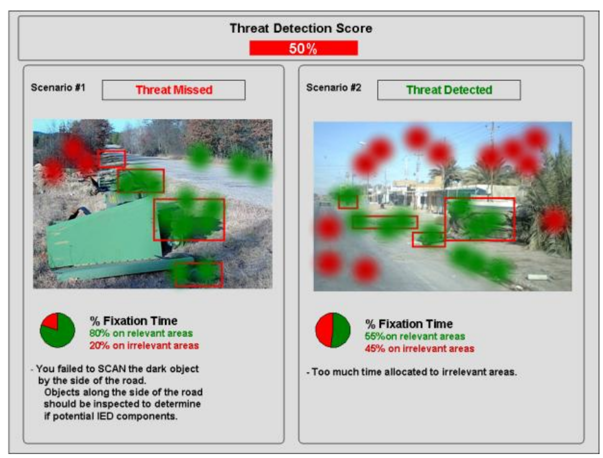


**Figure 2. CBT AAR Display Example**

**Mission Execution (ME).** During the mission execution scene, ADAPT-RT measured trainee gaze data via eye tracking to determine if trainee focused on relevant information (i.e., Mayor Ali"s eyes) or irrelevant information (i.e., elsewhere in the environment) throughout the scenario. ADAPT-RT also measured trainee cognitive state of workload, engagement, distraction and drowsiness via a continuous stream of EEG data throughout the scenario. Based on the measurement data collected,

**Table 1. ILT Problem State Diagnosis and Adaptations**

| Problem State | Diagnosis | | Adaptations |
|---|---|---|---|
| | **EEG** | **Eye Tracking Indicators** | |
| ***Instructor-Led Training*** | | | |
| Incorrect Visual attention allocation | | Trainee did not fixate on all defined AoIs on projection screen (i.e., slide) at end of instruction for that slide (i.e., when instructor is done talking). | Highlight missed AoIs on a given slide and provide elaborative information for why cue is important. |
| Disengaged | Workload AND probhigheng <.3 for 10 sec or more | | Have classmate ask clarifying question on one slide that was previously covered (e.g., „Can you review information on Slide 3?‟) |
| Distracted | Distracted Probdist > .5 for 5 sec or More | | |
| Overloaded | Workload > .75 for 10 sec or more | | |
| Fatigue | Fatigue Probdrowsy > .5 for 10 sec or more | | |
| ***Computer Based Training*** | | | |
| Scan Error | | Did not fixate on all critical cues | Presented AAR displays to demonstrate summary trainee performance feedback (see Figure 2 for example) |
| Recognition Error | | Fixate on AoI but did not recognize a threat in the image | |
| Attention allocation issue | | % time fixated on irrelevant AoIs > 20% | |
| ***Mission Execution*** | | | |
| Incorrect visual attention allocation | | Trainee not maintaining appropriate gaze on target areas | Presented AAR displays to demonstrate summary trainee performance feedback (see Figure 3 for example) |
| Disengaged | Workload AND probhigheng <.3 for 10 sec or more | | |
| Distracted | Probdist > .5 for 5 sec or more | | |
| Overloaded | Workload > .75 for 10 sec or more | | |
| Fatigue | Probdrowsy > .5 for 10 sec or more | | |

ADAPT-RT identified occurrence of 5 primary performance or state deficiencies (Table 1). Based on these diagnoses, ADAPT-RT presented AAR displays which summarized trainee performance throughout the scene. For the prototype demonstration, trainee data was collected and diagnosed in real-time, and used to select one of a pre-defined set of AAR displays. Figure 3 illustrates an example ME AAR Display.

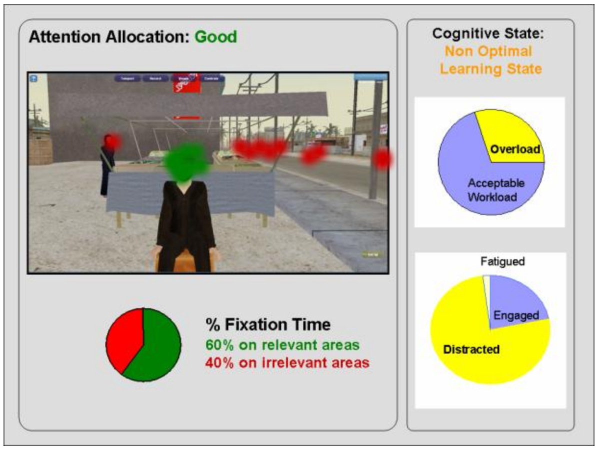


**Figure 3: Mission Execution AAR Display Example**

### Limitations of Prototype System

There were several areas within this prototype in which ADAPT-RT could have provided more effective adaptations; however, the limitations of the simulation prevented instantiation of these methods. Below is a list of limitations related to the current prototype:

- No real-time synchronization of eye fixations to objects in virtual world. One of the key innovations of ADAPT-RT is that, with support from the simulation, it has the ability to correlate eye tracking data with simulation objects near real-time. This allows ADAPT-RT to provide real-time assessment of trainee visual attention allocation on relevant areas of interest and drive appropriate adaptation. The current prototype‟s virtual world did not allow „picking‟, which would provide ADAPT-RT with knowledge of what was within the virtual world at specific locations in real-time. Thus, ADAPT-AAR in this prototype was limited in the level of diagnostics available regarding what specific virtual world components were fixated on.
- Display of AAR feedback not created from live trainee data. The current demonstration displayed feedback that was selected from a pre-defined representative set of feedback displays. This feedback was not based on actual trainee data because the capability to create a slide based on actual trainee data post-scenario and the ability to view the output of an AAR program that creates the display was not possible with the integrated virtual world.
- Identified problem states associated with only one single adaptation. ADAPT-RT has the framework to support multiple adaptations for a given problem state. Such adaptations could be increasingly intrusive, so that subtle adaptations are instantiated first, and if deemed unsuccessful, can be superseded by more direct adaptations. The goal with such a framework allows flexibility and individualized tailoring of feedback. With the short timeframe and goal of demonstrating a capability to provide closed-loop feedback based on neurophysiological data, the current demonstration included a single, prominent example of using neurophysiological data to drive adaptive training.

### Future Enhancements

There are many opportunities for extending ADAPT-RT over the next 3-5 years to advance the development of adaptive training solutions. The sections below outline short-term, mid-term, and long-term enhancements designed to integrate with emerging instructional platforms over the next 5 years.

**Near-term Enhancements.** Near-term enhancements focus on improvements required to realize a real-time closed-loop system that can be used for human subjects testing to provide a full representation of „state of the science‟ baseline of technology. This includes advancing ADAPT-RT and instructional technology to provide a more dynamic mission execution scenario that incorporates dynamic elements and shows increased flexibility and utility of neurophysiological measures in evaluating trainee state throughout a scenario as distractors/points of interest come and go (e.g., vehicles related to threat vehicle pass on street, new threat appears in scene). Furthermore, advancements are needed to transform the current demonstration into an effective training system. To realize this capability, the following enhancements are needed:

- Real-time synchrony must be developed between eye tracking output of fixation location and that location within the virtual world (i.e., „picking‟), which allows for real-time association between gaze points and virtual objects.
- A method for driving real-time adaptations and displaying AAR feedback within the virtual world is required that is based on live trainee

data from ADAPT-AR"s measurement and diagnostic suites.

- *ADAPT-RT has a program that generates an AAR interface. The optimal solution would be to identify a method for displaying that interface within the virtual world (e.g., showing display from a desktop running ADAPT-AAR interface?)*
- *Create the ability to display ADAPT-RT output in real-time within the virtual world, which would allow, for example, dynamic highlighting of missed AoIs based on trainee performance.*

**Mid-term Enhancements.** The enhancements listed in this section are anticipated to take 6 months to 2 years to fully realize a solution, and are designed to enhance future capabilities of the proposed demonstration.

- Providing an AAR summary that consolidates trainee performance across the blended learning scenes to highlight training success and future training recommendations based on skill deficiencies and instruction/training methodologies available within a virtual world (e.g., ILT, CBT, ME).
- Development of multiple adaptations for a variety of diagnosed training issues to more fully demonstrate the promise of adaptive precision training. To achieve this, the following steps are needed:
  - Design of adaptation methods and associated trigger points
  - Definition of exit strategies for each adaptation method
  - Transition schema for moving from one adaptation to another, and/or utilizing multiple adaptations at a time – ensuring one does not interfere with another
  - Interruption management strategies to ensure adaptations enhance training and do not distract/deter from training
- Enhance constructive models integrated into prototype demonstration by adding neurophysiological data
  - Current constructive modeling techniques utilized by the demonstration captured conscious knowledge of tasks through knowledge discovery methods
  - Neurophysiological data captures unobservable, potentially unconscious knowledge that can be integrated into constructive models to enhance complexity or subtlety of enemy avatar behavior
- Completion of a training effectiveness evaluation to validate the utility and benefits of real-time training adaptation based on neurophysiological indicators of trainee state

**Far-term Enhancements.** Enhancements listed in this section are section are anticipated to take 2 to 5 years to fully realize the solution, and are designed to enhance future capabilities of the prototype demonstration.

- Development of new hardware specifically focused on enhanced eye tracking systems.
  - Development of a portable eye tracker system that allows for real-time synchronization between eye fixations and world objects while the trainee is free to move about the environment. Such a training environment could be a fully immersive simulated trainer, a mixed reality trainer, or a live training environment.
  - Development of a low-cost eye tracker solution for desktop trainers, such as a webcam based solution.
- Development of additional neurophysiological measures to further characterize trainee state in real-time, thus providing a deeper understanding of training as it progresses and allowing for more precise adaptations. Such future measures may include:
  - Emotional state
  - Higher order cognitive states (e.g., decision making, situation awareness)
  - Novice to expert continuum measure
  - Readiness to learn measure
  - Individualized metrics that can be quickly calibrated
- Instantiation of real-time precision training for teams. This enhancement would require:
  - Diagnosis methods for identifying when and who in a team may require adaptation of training scenario
  - Development of adaptation strategies that effectively target individual and team needs within a team training environment. Some considerations may be impact of individual adaptation on team setting (e.g., slow down pace of training for one team member – how does that impact the team as a whole?)

## CONCLUSION AND FUTURE WORK

The initial demonstration of instantiation of the ADAPT-RT framework into a working prototype provided real-time trainee state evaluation using advanced neurophysiological measures which provide a more comprehensive understanding of trainee state compared to traditional observational and self report metrics. This more comprehensive understanding of

„non-observable" behaviors allows for more detailed training diagnoses (e.g., root causes of errors) that can then be used to drive training adaptations to provide precision training. The current demonstration successfully integrated ADAPT-RT and associated neurophysiological hardware into a virtual world blended learning scenario to provide real-time diagnosis of trainee state and precision feedback to optimize the training experience. To advance the current demonstration into a fully realized, next-generation training solution, this report summarized near-term, mid-term, and long-term future enhancements that should be considered.

Adaptive training should be used to maximize training effectiveness and efficiency throughout a training program for prescriptive training for post-action guidance and real-time adaptations. These adaptations could be leveraged at both the individual and team levels of analysis.

Technological advancements in neuroscience continue to push the envelope in the areas of measurement and assessment. In particular these advancements have demonstrated that higher order complex constructs of human performance (e.g., workload, engagement, distraction) can be measured and assessed. The next step forward is to transition these capabilities to training applications. While these technologies have yet to be perfected, many rich near-term opportunities are in sight for training applications. Neurophysiological technologies represent the most promising step forward in terms of precision training that promotes efficiency and ensures effectiveness.

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