Putting Live Firing Range Data to Work Using the xAPI

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ABSTRACT

The past decade has seen advances in instrumentation of live training ranges. For example, when combined, the Location of Hit and Miss (LOMAH) system and the Targetry Range Automated Control and Recording (TRACR) system send virtually immediate feedback on marksmanship performance to trainers, via a tablet computer. However, despite digital availability, the performance data are not used for individual feedback, analyzed, nor automatically shared with any other training management or readiness systems. A proof-of-principle prototype system was developed, which demonstrated how the use of the Experience Application Programming Interface (xAPI) could be used to collect valuable training data and support (1) individual feedback, (2) aggregated data views for trainers and range operations personnel, (3) flexible data views for training researchers, and (4) automated availability of qualification data to the Army Training Management System. The xAPI was developed to allow the collection of learner data from different types of learning experiences, and to make the data available to other applications. The LOMAH-TRACR data were converted to xAPI statements, which were sent via an encrypted wireless network to a Learning Record Store (LRS). Using a pin number, individual trainees could access a visualization of their own data on a mobile device, and be given a link to learning content, personalized by the software's analysis of their individual shot group pattern; however, no actual Soldier testing occurred as part of the project. Trainers and range operations personnel could also view data, and filter it according to their needs. An unanticipated benefit was the ability of range personnel to identify operational defects in LOMAH targets. A third "researcher" dashboard was created to allow for analysts to select data and export for further analysis. A future benefit will be the ability to integrate data from simulation and live training, in order to determine the most efficient and cost-effective combination to achieve desired levels of performance.

ABOUT THE AUTHORS

Paula J. Durlach received her Ph.D. in experimental psychology from Yale University in 1982. After working in both academia and industry, she joined the U. S. Army Research Institute for the Behavioral and Social Sciences in 2001. She was on assignment to the Advanced Distributed Learning (ADL) Initiative from April 2012 to July 2015, when the reported work was conducted. She now works at the Army Research Lab, Human Research and Engineering Directorate. She has published research in journals such as International Journal of Artificial Intelligence in Education, Military Psychology, Computers in Human Behavior, and Human-Computer Interaction.

Nick Washburn has a 20+ year career working with software companies and hi-tech entrepreneurs in distance learning and technology. Currently, Nick is Director of the Riptide Software Learning Division, bringing Riptide Elements® learning products to market. Elements core product development aligns with the goals of the ADL Initiative, and Nick is a member of the workgroup that created xAPI. Nick and the Elements team continue to research, develop and work within the standards for xAPI.

Damon Regan serves as a Technical Team Co-lead for the ADL Initiative. He served as a technical point of contact for the contract to produce a proof of principle for capturing live fire data using the Experience API and reporting on the data using role-specific dashboards.

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INTRODUCTION

The use of technology for training has become commonplace. Initially, digital technology was used to replicate classroom lectures; however, passive on-line learning has now been supplemented with interactive learning experiences such as training simulations and serious games. Moreover, mobile devices and environmental sensors have untethered the use of technology-based learning from the desk. Expansion of the environments in which learning can occur has created a problem for legacy learning and training management systems, however; the problem is how to manage learner records and keep track of training qualifications, when the learning occurs in multiple systems. One solution is to develop standards and specifications outlining how different systems can exchange and make use of one another's data.

Instructional designers, educators and trainers want to understand learning effectiveness and adapt the learning experience to produce better learning outcomes. Equally important, organizations want to quantify the time, costs, and materiel associated with education and training. A challenge in accomplishing this is that different technology-based systems, to the extent they collect and save student performance data at all, use idiosyncratic data capture, data storage, and data visualization methods. This makes analysis of the relative effectiveness and efficiency of different education or training methods difficult. Manual recoding and input of data into yet some other system is typically the solution; but one that can be error-prone and result in much loss of detail and potentially valuable information. For example, currently basic rifle marksmanship qualification is entered manually into the Army Training Management System (ATMS) as go or no-go, without any information about the details of how the qualification was obtained, or the resources used for training (e.g., how much ammunition was used, whether simulation served as a component). The good news is that the Department of Defense is moving increasingly to a net-centric software-as-a-service architecture, in which services provide a standards-based approach to information sharing (DOD CIO, 2007). Within this type of service-oriented architecture, web services allow different software systems to exchange data over the web, using application programming interfaces (APIs). APIs specify the inputs and outputs a software service can ingest or provide, without having to expose the inner workings of the software itself. As more education and training systems adopt this approach, automated data sharing will become more common place.

Another recent trend in the use of technology in education and training is personalization. It is well established that tailoring instruction or practice opportunities to the current skills and abilities of the learner is more effective and efficient than providing all learners with the same experience in lock-step (Bloom, 1984; Durlach & Spain, 2014). In order to personalize learning based on current mastery, it is necessary that (1) there is some record of learner mastery, (2) there are learning materials or opportunities that are appropriate to the recorded level of mastery, and (3) there are methods of matching these and delivering or at least recommending the personalized experience to the learner. Educational and training data are what allow number one, through representation of current skill and ability. It is therefore essential that learning enterprise systems moving toward a more learner-centric approach have the ability to capture and share these data with the multiple education and training delivery systems that members of their organization will be using.

This paper discusses the Experience API (xAPI) and how it could be used to support personalized education and training, as well as data sharing across multiple systems in a net-centric software-as-a-service enterprise environment. The discussion will center on a recent proof-of-principle project using xAPI, involving collection of data from an instrumented live marksmanship range. The work demonstrated how the xAPI could be used to support (1) individual feedback, (2) aggregated data views for trainers and range operations personnel, (3) flexible data views for training researchers, and (4) automated availability of qualification data to the Army Training Management System (ATMS).

EXPERIENCE API (xAPI)

Developed by the U. S. Department of Defense through the Advanced Distributed Learning Initiative (ADL), xAPI is a data standard for describing learning activities, and for allowing those data to be shared across systems. While technical standards exist to promote reusability and interoperability of learning content across Learning Management Systems (LMSs) in the form of the Sharable Content Object Reference Model (SCORM), SCORM does not address the issue of data sharing. Moreover, when SCORM was created, it was used to condense a series of learner interactions and inputs into a smaller and coarser set of data. Since that time, data transfer has become faster and memory has become cheaper, permitting larger amounts of data to be stored and shared. Consequently, xAPI provides the ability to track finer-grained data compared with SCORM. SCORM is still effective at what it does, and will not be completely phased out. xAPI and SCORM can both be used for the same content, and the addition of xAPI won't impact or interfere with the use of SCORM in any way.

The basic structure of xAPI mimics human language; but, is also machine readable, which means that either a human or computer can look at the data and decipher it. The technology used is JavaScript Object Notation (JSON). Technical information and resources on the xAPI can be found at http://www.adlnet.org/resources.html. The data structure is called a Statement and consists of at least three parts – an actor (e.g., Paula), a verb (e.g., passed), and an object (e.g., Defense Acquisition University course CLM222). Other parts of a Statement can allow additional contextual information to be captured, (e.g., Paula passed CLM222 in three hours on May 5, 2015). Statements can describe learning activities at different levels of granularity—that Paula passed a whole course, answered a specific assessment question correctly in that course, or spent 37 seconds on a particular screen in that course. It is up to the "activity provider," the system producing the statements, to determine what data it wants to publish; however, to the extent that there is concurrence about statements across different providers and consumers, the greater the ability to put the data to beneficial use. In order to accomplish this concurrence, ADL is supporting the formation of a number of communities of practice to establish controlled vocabularies (see http://www.adlnet.org/tla/experience-api/xapi-cop-directory/overview/index.html for more information). One of the original motivations for developing xAPI was to allow Learning Management Systems (LMSs) to ingest information about learning conducted on mobile devices; however, it can theoretically be used to transfer data among any software systems including automated training ranges, LMSs, simulations, games, training readiness, and training management systems.

xAPI is typically used in conjunction with a Learning Record Store (LRS; see http://www.adlnet.org/tla/lrs.html). An LRS stores the activity statements. It can be integrated with another system, such as an LMS, or stand alone. With the right permissions, systems besides the one that produced the statements can also write to and access data from the LRS, supporting the potential to integrate data from multiple types of training experiences. It is this ability that supports the potential for personalization. For example, the pattern of performance during a training simulation might be used to pick the most appropriate learning objectives and level of challenge for the next scenario or even a follow-on live training exercise.

PROOF OF PRINCIPLE PROJECT: USING xAPI ON AN INSTRUMENTED RIFLE RANGE

Instrumented rifle marksmanship training

Small arms live fire ranges provide individuals the opportunity to learn and practice their marksmanship. The U.S. Army, U.S. Marine Corps, Special Forces, Federal Law Enforcement Training Center (FLETC), Department of Homeland Security, and the Federal Bureau of Investigation utilize these ranges for training, testing, and formal qualification. Currently, there is no uniform mechanism for collecting the training results data from the live fire ranges. Some ranges are equipped with an acoustic sensor system, which can transmit the X-Y coordinate of target hits, either to a central control station or each firing lane. This sensor approach can also report location of misses near the target, and consequently is referred to as Location of Miss and Hit (LOMAH). Different LOMAH set-ups differ in the way they support shooters and trainers in visualizing shooter performance (the LOMAH raw data is numerical). For example, the Oscar 9 range at Fort Benning has been enhanced with Targetry Range Automated Control and Recording (TRACR), which supports selecting exercise requirements and displaying the pattern of hits and misses on target silhouettes on a tablet at each lane (Figure 1). Despite the availability of this detailed feedback, it is inaccessible once a new shooter occupies the lane. Trainees take away with them only their composite numerical score. Qualification credentials are entered manually into the Army Training Management System (ATMS).

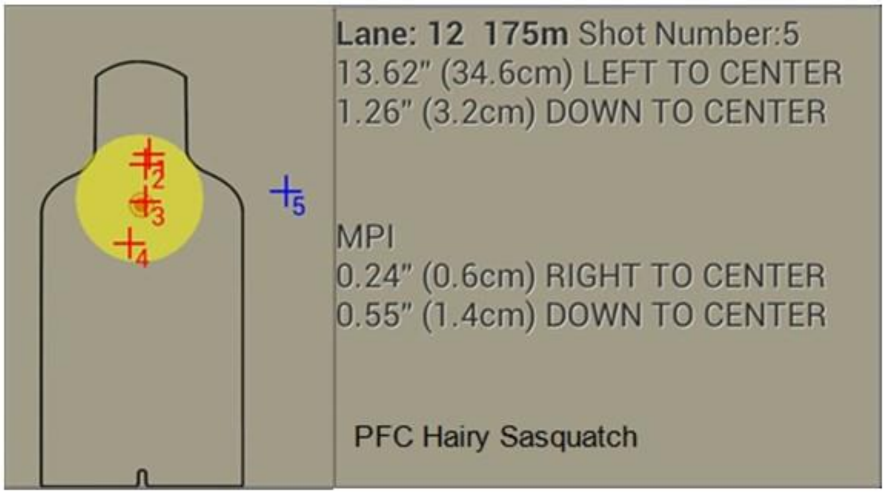

Figure 1. Tablet view of hits and misses from TRACR

Project Goals

The Army's training challenge is to optimize, synchronize and support training in schools, training in units, and self-development training to produce forces and leaders capable of responding across the range of military operations (TRADOC, 2014). The Army Training Management System (ATMS, previously known as the Digital Training Management System, DTMS) is a central repository for individual training records (ITRs), including diplomas, certificates of training, weapons qualification scorecards, physical fitness test scorecards, records of mandatory training, and other records. Every military unit commander is required to maintain ITRs to assist in Soldier readiness assessment and facilitate the electronic transfer of Soldier training records during reassignment. Today, the individual scorecard results from final qualification training at live fire training ranges are manually entered into ATMS. There is no uniform mechanism for collecting the data from the live ranges. Moreover, the data are typically aggregated to a single score for each individual, and thus do not capture the results required for personalized feedback and remediation, unit skills profiles, or higher level analysis (such as success of trainers, ammunition used, or range time required for qualification). The goals of this project were to capture the data from a live rifle marksmanship range instrumented with LOMAH-TRACR, in order to support such data use. In particular, the work focused on capturing the firing data using xAPI, for the purposes of providing (1) individual feedback and access to personalized remedial interactive multi-media content based on shot grouping patterns, (2) aggregated data views for trainers and range operations personnel, (3) flexible data views for training researchers and resource analytics, and (4) automated sharing of qualification data with ATMS.

Technical Solution

To meet the project goals, a concept of operations illustrated in Figure 2 was developed to track the flow of training data on the Oscar 9 range using the xAPI. The Oscar 9 range was selected in part because it is a LOMAH range where TRACR was already resident in the Range Operations Center (ROC) tower and controls the physical range devices using the FASIT (Future Army System of Integrated Targets) protocol. TRACR and LOMAH operated without changes. Government furnished data from the LOMAH-TRACR system was converted into xAPI statements captured in a local Learning Record Store (LRS) on the range. Since there was no internet connectivity at Oscar 9 (a common occurrence for Army live fire ranges), the ROC was outfitted with a commercial cellular data hot spot to provide connectivity to the central LRS housed at a secure facility. The connection between Oscar 9 and the central LRS used DoD approved hardware encryption to ensure Soldier privacy and data security.

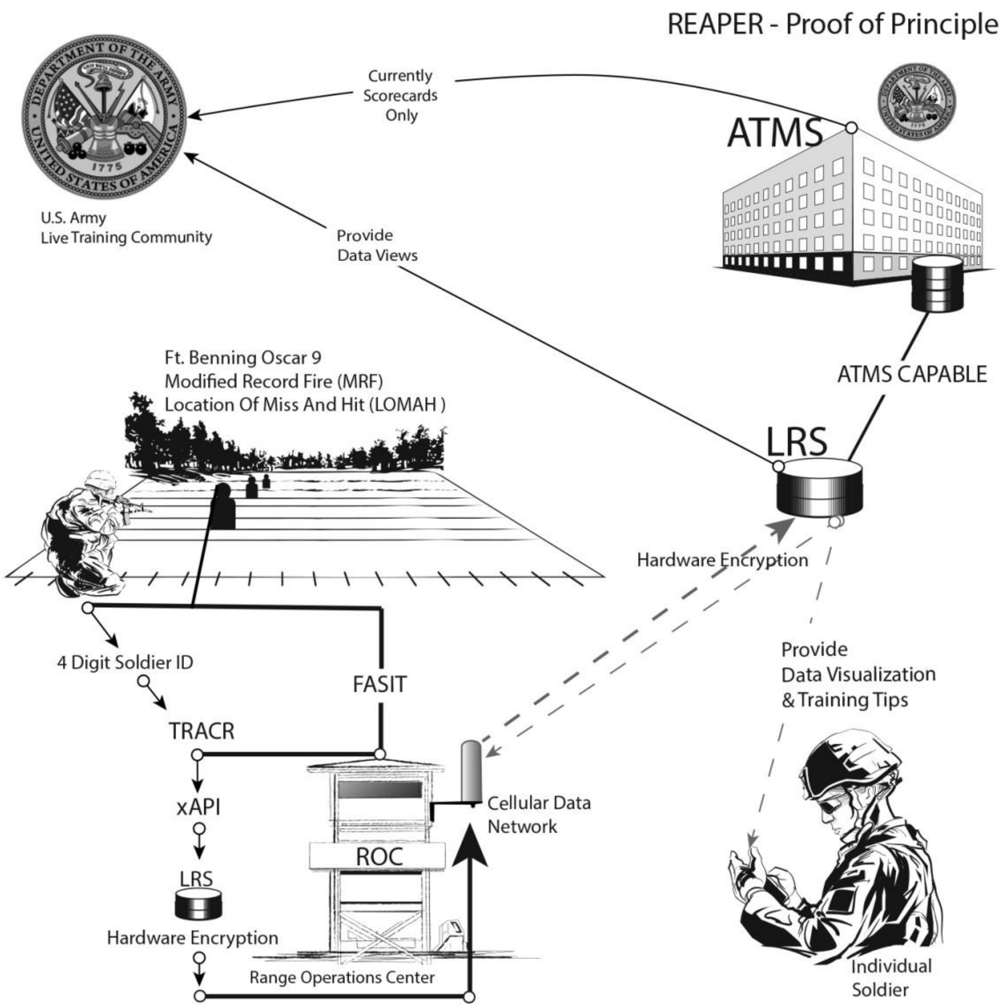

Figure 2. Proof of principle concept of operations diagram

Once the data was available at the central LRS, it could be exported to ATMS and/or accessed through a Web portal. The Web portal provided users with access to role-specific performance visualizations (individual, coach/commander, or researcher roles). These visualizations (or "dashboards") were accessible by secure password via mobile web-enabled devices. Each of the role-specific dashboards is described below. Besides viewing their own data, individuals could also access personalized training materials. In basic marksmanship there are four fundamentals that Soldiers must master: 1) establishing the steady position, 2) aiming, 3) breath control, and 4) trigger squeeze. Defects in these fundamentals can often be detected solely from the specific patterns in the resulting shot grouping. The developed system automatically detected those indicative shot patterns and, from the dashboard screen, would offer remedial interactive multimedia instruction (IMI) to assist in remedying their specific marksmanship defect. The IMI was taken directly from the Army field manual on rifle marksmanship (Department of the Army, 2008).

Individual Soldier View and Features

The individual Soldier dashboard allows the Soldier to choose the range location, date, and exercise or table (BRM5 or BRM6). Figure 3 illustrates the dashboard view, which shows an aggregate score and allows the Soldier to view per attempt details. The Soldier can also select a target view of each attempt (see Figure 4) and scrutinize precise placement of each shot. Functional Reactive Programing (FRP) techniques were used to "mine" the shot data as it was coming into the LRS to evaluate for deficiencies in the four fundamentals of marksmanship. The dashboard indicates any deficiencies that were automatically detected by turning the green buttons red. A user can select each of the 4 buttons to launch "just in time" training materials in mobile friendly view (see Figure 5).

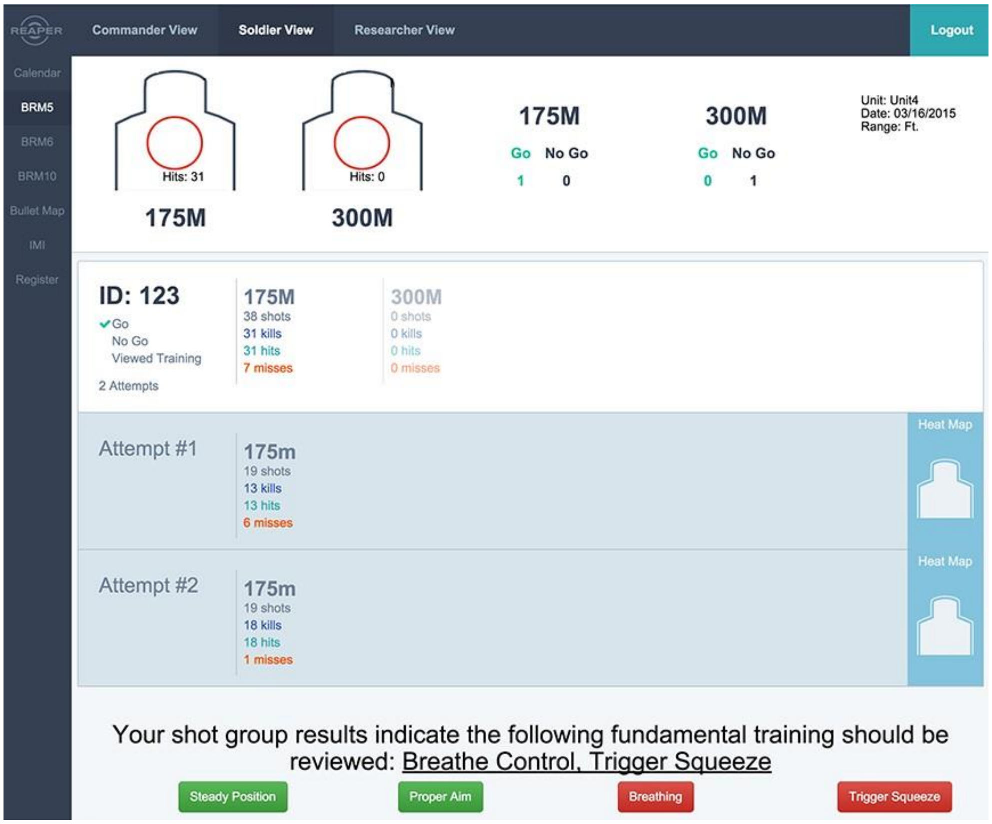

Figure 3. Individual Soldier View allows shooter to choose the date and exercise. The dashboard gives indications of deficiencies in the 4 fundamentals of BRM based on analysis of shot patterns. Soldier can select each of the 4 "buttons" to launch FM-9-22 data in mobile friendly view

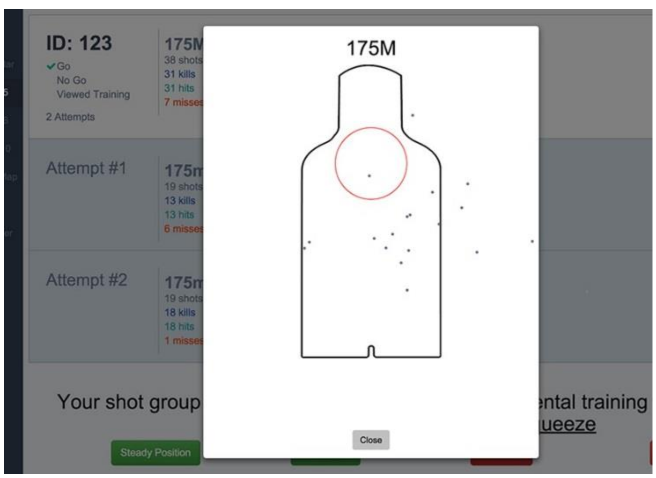

Figure 4. Soldier can view individual targets from each attempt

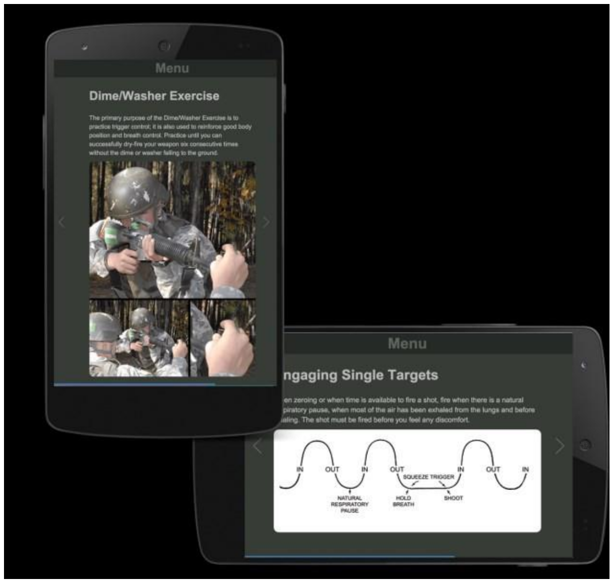

Figure 5. Individual Soldier mobile friendly view from the FM-22-9

Coach/Commander View and Features

The Coach/Commander can select exercise and date to view the total range performance for that day beginning with the calendar selector. The main coach's view (See Figure 6) is a list of all of individuals, Go/No Go, attempts and target views of each attempt.

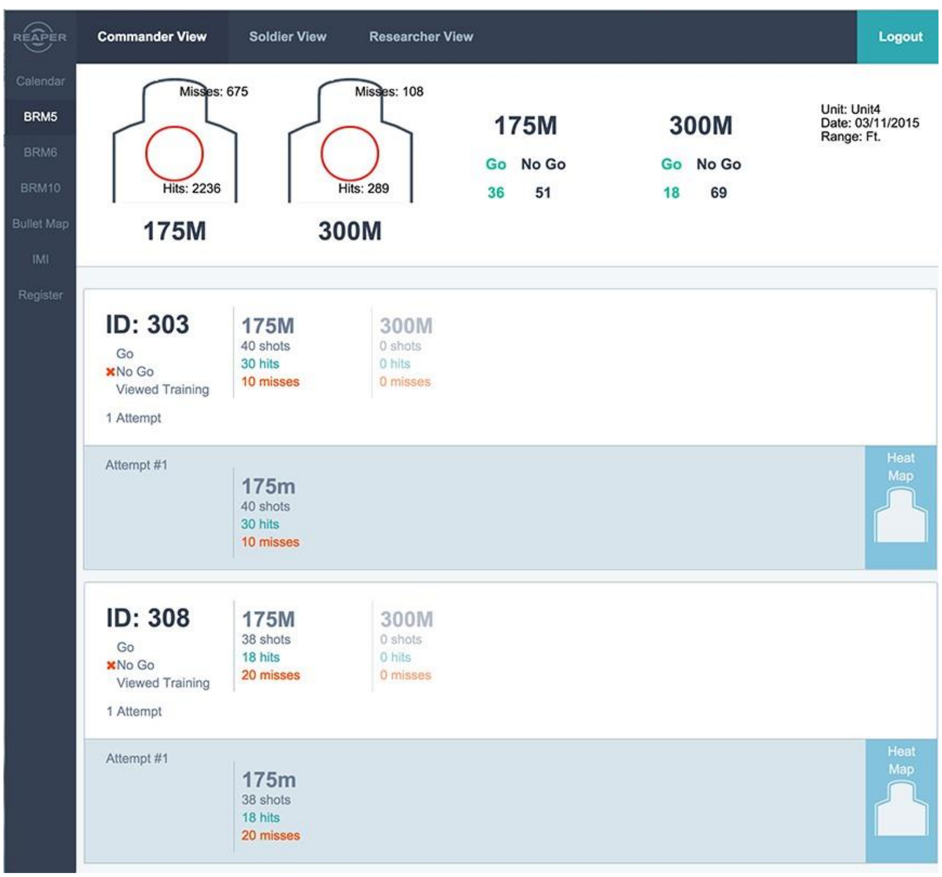

Figure 6. The coaches main view is a list view of each soldier's performance

The coach can also view a Bullet Map (see Figure 7) that aggregates the target types for the entire range. For instance, the total shots fired at the 175M targets, hits and misses. The coach can filter this view by individual and exercise. The coach can also see if the soldier was informed of deficiencies in the four fundamentals and if the Soldier viewed any remedial IMI to try and improve on their own.

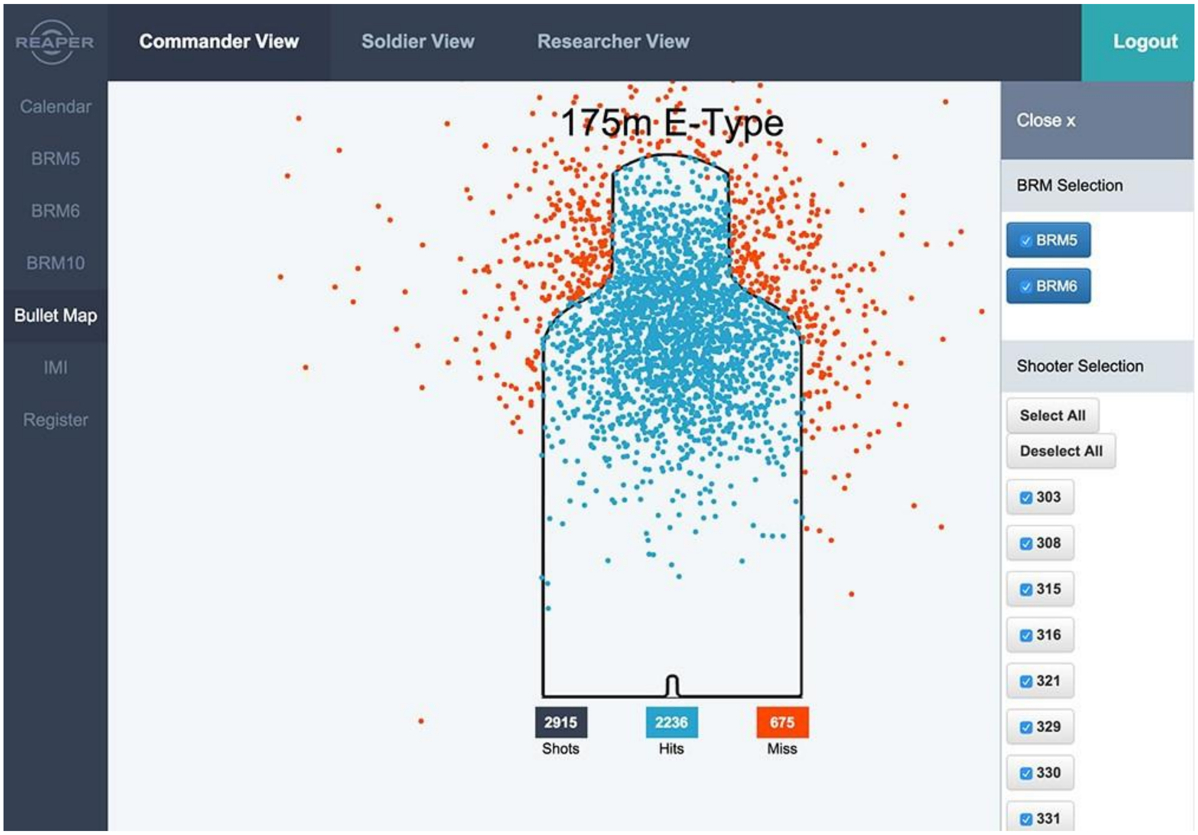

Figure 7. Coach/Commander can view bullet maps of performance and filter (menu on right) by groups, shooters and exercise. 175M target is shown in aggregate (all 175M targets on range) with total shots, hits and misses

Researcher View and Features

Currently, researchers and analysts must request data from range systems; the process to retrieve the data must be conducted manually by a TRACR expert. The Researcher dashboard developed in this project aimed to circumvent the need for this process. It allows researchers to filter and format the raw data, and to export it to a spreadsheet or statistical package, so that it may be further manipulated by their preferred tools and methods. The system's relational database was structured with a cross section of variables that had been requested by researchers from the TRACR system in the past. Figure 8 illustrates the initial researcher dashboard view, beginning with a total view of shots fired at the range. From this initial dashboard view the user is able to filter the data according to desired variables. The target heat maps react to these selections. The user can export the filtered data results to CSV format for further analysis.

The initial Soldier, Coach, and Researcher audience data views began as wireframes, then graphic user interface (GUI) designs were rendered. The dashboard "portals" went through three iterations of refinement based on feedback and direction from the TRACR project manager, a SFC U. S. Army trainer at Fort Benning, U. S. Army Research Institute researchers, the ADL, and comments from individuals available during the fielding and installation of REAPER at the Training Range.

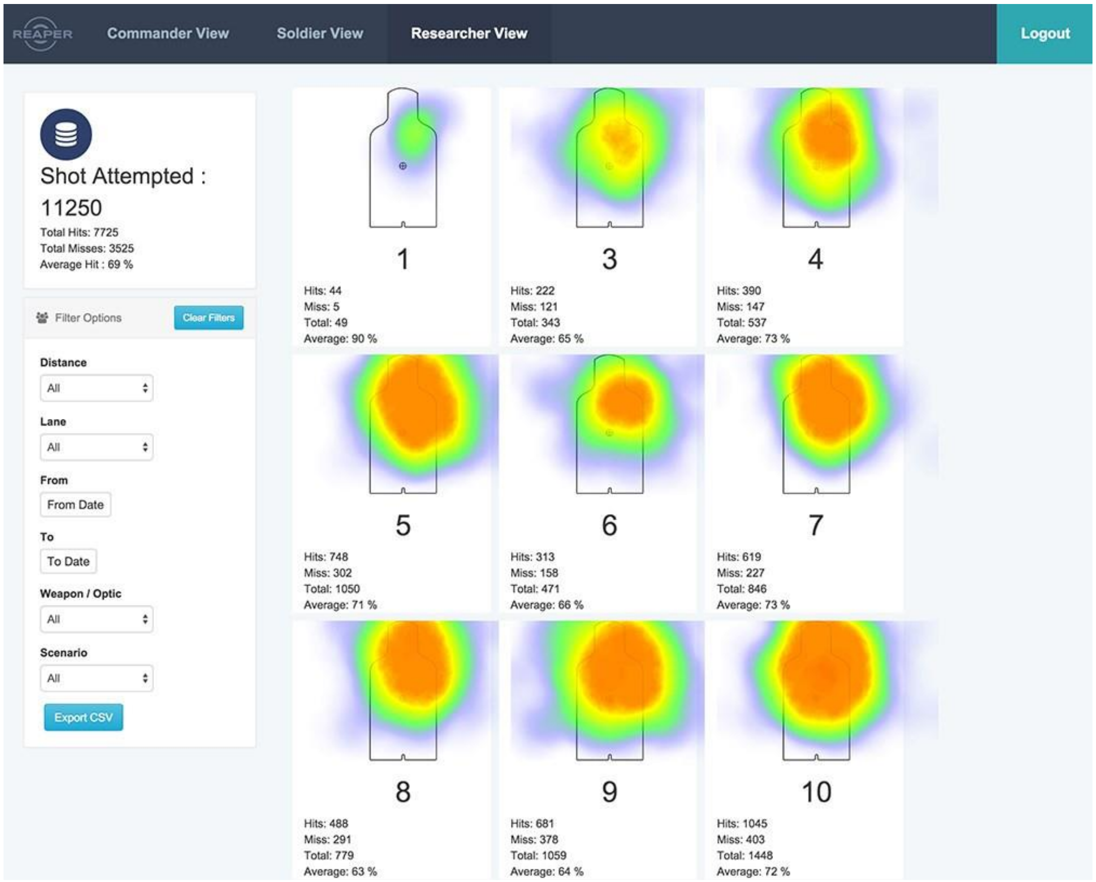

Figure 8. Researcher can filter and export data beginning with a "total shots" range view

Army Training Management System

It is part of the stated mission of the ATMS to be ready to receive scorecard results and performance data. Significant progress was made to accomplish the task of automating scorecard results. The project team had regular contact with and the cooperation of ATMS personnel during the span of this research project. While the work of the project team succeeded in putting the qualification data into the format requested by ATMS personnel, by the end of the project, ATMS had not completed the API required to receive it. Moreover, the current project was unable to capture Soldier's Electronic Data Interchange Personal Information (EDI PI) at the range, because the range did not provide the facilities to capture this information from Soldier's Common Access Card (CAC). This issue is discussed further below.

Lessons Learned

When we originally began this project, we had hoped to capture EDI PI along with an individual's data. CAC chip readers are available, and could be, but currently are not integrated with the LOMAH-TRACR set up. If they were, data from a CAC chip reader could be recorded in association with marksmanship performance results. We did not have the ability to change normal range procedures or the existing hardware in the current project; however, under these restrictions, we were able to uniquely identify an individual's results if the exercise date, time, and temporary lane id were known. Also, we were hoping to evaluate Soldiers' reactions to the Soldier dashboard and personalized IMI; however, as we had range access on a "non-interference" basis, we were not able to interact with personnel undergoing actual training; nor did the range schedule permit us to hold an experimental session with non-trainees. Thus future work should secure agreements from the local command regarding access to hardware and Soldiers. In fact, once the results of this project were demonstrated, the local command was keen (given funding) to establish an "experimental range" to conduct future development and evaluation.

While we did not have the opportunity to test our dashboards with individual Soldiers, we did have a chance to show them to range operations personnel; and, in so doing discovered that they represent a fourth interested user of the data. Range operations personnel are concerned with the proper functioning of the range equipment, and they were excited to see that our heat maps allowed them to identify problem targets quickly and easily. For example, when they saw the heat map shown in Figure 9, a problem with the target was identified immediately. Specifically, Figure 9 suggests an obstruction of the 175M target on lane six. By comparison Figure 10 illustrates an unobstructed 175M target on lane ten. Thus, the LRS captures range operations data to support identification of favored lanes and targets, target life cycle data, required maintenance, etc.

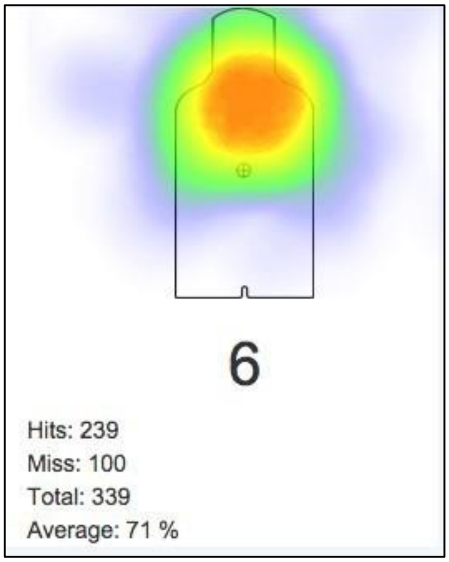

Figure 9. Obstructed target on lane 6

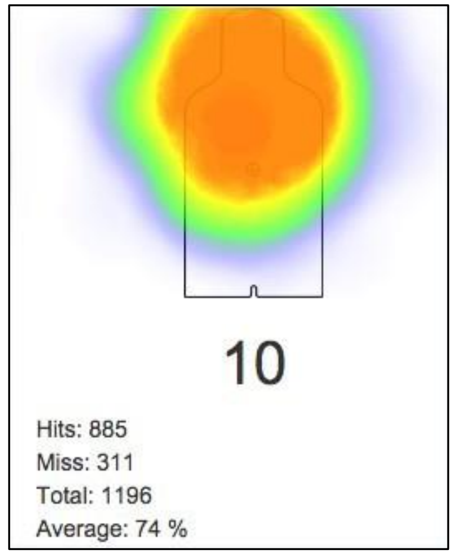

Figure 10. Fully exposed target on lane 10

We also conducted discussions with coaches. They voiced their desire to use the commander dashboard to plan the next day's training, for cases in which the same group trains on multiple consecutive days. The data would allow them to view the current day's performance and determine what to focus on the next day. The coaches also indicated that they thought giving individual Soldiers their own results and feedback would be helpful. A big challenge for coaches conducting training is that there is little time for personalized coaching. Coaches tend to focus most of their time on the weakest students, and let others fend for themselves (Dyer, et al., 2011). The present system could mitigate this problem by providing a higher level of individual feedback and guidance than students normally receive. In addition, if the detailed data were retained and passed on to a Soldier's new unit, it could also help guide how to structure refresher training (e.g., which Soldiers need practice only on distant targets, and which need practice at all distances).

FUTURE DEVELOPMENT

The described project demonstrated that the xAPI can be used to capture live marksmanship data for use in personalizing training, informing trainers and range operations personnel, performing data analytics, and training management record keeping. Even more potential could be garnered from the use of the xAPI as a standard for capturing marksmanship data if it were used generally across instrumented ranges and to collect other sources of marksmanship training data. In particular, simulations are used for rifle marksmanship training (Murphy, et al., 2015), as well as other forms of gunnery training (Hruska, et al., 2014). Potentially, simulation training can be used to reduce the time needed on live training ranges, and also reduce the materiel resources consumed (e.g., ammunition, targetry). The optimal mix of simulation and live training is currently difficult to establish. The different simulation systems that could be used (e.g., Engagement Skills Trainer [EST] or Indoor Simulated Marksmanship Trainer [ISMT]) collect different measures of performance (see summary presented by Murphy, et al., 2015), and are not designed to share the data with other systems. In addition, live instrumented ranges differ in data accessibility and transportability. Therefore analysis of the impact of simulation training on live performance requires labor-intensive effort to retrieve, recode, and integrate the data from different systems and ranges. Modifying all these systems with the ability to "speak the same language" in terms of the performance metrics they collect and with the ability to send their data to a common store would greatly increase the ease of conducting training effectiveness assessments and determining the optimal mix of simulation and live training. The xAPI and LRS is a proposed method of accomplishing this, as discussed here and by Hruska, et al., 2014 and Murphy et al., 2015. The xAPI provides flexibility for encoding data in various ways. Therefore true interoperability will not be achieved merely from using xAPI; it will also require establishing a "community of practice" to define a common vocabulary for that encoding. ADL is already supporting a number of communities of practice to develop controlled vocabularies for various applications of xAPI (see http://www.adlnet.org/tla/experience-api/xapi-cop-directory/overview/index.html). These communities are focused around either media types or domains. For example, with respect to media type, the videos community of practice is creating a controlled vocabulary to standardize video interactions that can be tracked, such as how to express when a user starts, pauses, or fast forwards a video. With respect to a domain, the healthcare education community of practice is creating a controlled vocabulary to standardize health care actions that can be tracked, such as actions that can be taken on a human patient mannequin (e.g., see Scott, et al., 2015). ADL has been discussing the formation of a rifle marksmanship community of practice with the Army Research Lab Simulation and Training Technology Center (STTC), the Army Program Manager for Training Devices, the Marine Corps Program Manager for Training Systems, the FLETC, and interested industry participants. In addition, STTC is conducting work to establish the required common metrics (Murphy, et al., 2015).

One challenge for the use of xAPI remains associating EDI-PI or identifying information with an individual student's data. This is easily accomplished when the data are generated by any system the student must login to with a user name and password, or other methods such as a CAC card. However, training simulations such as human patient mannequins, serious games (such as VBS3), and live instrumented ranges typically don't have such login procedures. ADL is currently examining alternative methods of associating xAPI data with individuals and/or teams in such situations, such as using IP or sensor addresses, and software wrappers.

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