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**An Initial Evaluation of the D2P/MTT, a Computer-Based,
Declarative to Procedural (D2P) Theory Driven Moving Target Tutor**

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Abstract

In this report, we describe a computer-based training tutor, the D2P/Moving Target Tutor (MTT) and our experience and results of running an experimental study using undergraduate students (N=27) to evaluate the effectiveness of D2P/MTT. D2P/MTT is designed and created to train users to judge point of aim quickly to shoot a moving target. The structure of the tutor is based on the Declarative to Procedural (D2P) learning theory that prescribes how repetitive practice can lead to declarative knowledge being proceduralized and how proceduralized skills can be retrieved quicker and less prone to forgetting. We analyzed our results and found that the accuracy rate on judging point of aim of a moving object improved from 20% (standard deviation = 15%) to 47% (standard deviation = 18%). This was a reliable difference, despite lost data. We also describe the possible reason for high data loss rate (63%) for future improvements in running studies like this.

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Jonathan H. Morgan created instructional materials for MTT and Jeremiah Hiam programmed parts of MTT. Amy DeGroft and Livia G. Soibelman helped run the experiment.

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1 INTRODUCTION

The Applied Cognitive Science Lab at the Pennsylvania State University derived a learning theory named Declarative to Procedure (D2P) from a series of studies related to learning and training under different situations and schedules(Kim, Ritter, & Koubek, in press). A detail explanation of one of the learning theories used in the summary theory, in particular the declarative and procedural stages can be found, for example, in Anderson's paper (Anderson, 1982). The D2P theory, in short, describes the relationship between cognitive knowledge and training schedule; it also describes knowledge retention after its acquisition.

This manuscript is the result of an experiment on a computer-based learning tutor called the D2P/Moving Target Tutor (MTT) that is created based on D2P to train users to retrieve knowledge quickly. We show the effectiveness of learning declarative knowledge after using MTT for approximately five hours with no other instructional interventions.

The structure of the report is organized as the following. First we briefly describe the theory behind D2P/MTT and the structure of MTT. We then describe the experiment including the participants, the apparatus, and the research design and procedure. In the results section, we present how the students learned and note that the results are significant and reliable. In the end we discuss our experience and present our conclusions including suggestions for improving studies like this.

2 THE D2P/MOVING TARGET TUTOR (MTT)

D2P/MTT is a computer-based tutor that teaches learners to retrieve the Point of Aim (POA) for a moving object. POA is the result of combining the range, speed, and angle of a moving object related to the observer. Judging POA is an important skill for any shooter, especially men and women in the military, who are often firing at moving targets. MTT contains roughly four to five hours of learning materials, including text, still images, audios, videos, and quizzes. The ultimate goal of MTT is so that a learner would be able to retrieve POA quickly after MTT training without having to retrieve each factor (range, speed, and angel) individually. That is, learners will use D2P/MTT to practice and eventually transform factual knowledge that later become part of their procedural knowledge, moving knowledge from declarative knowledge to procedural knowledge.

MTT is created in the ACS Lab at Penn State using the Java programming language. The instruction portion of MTT is constructed in eXtensible Markup Language (XML) format to separate the tutor program/interpreter from the instructional materials. This approach allows programmers and instructional designers to work separately and concurrently, and to make it easier to create tutors. This separation makes it possible and easier to extend the type of instructional pages supported by MTT without changing the previous tutors. It also allows us, if it arises in the future, to change the tutor interpreter but reuse the instructional materials. Details about the type of pages and their specification are covered in a separate report (Hiam, 2012).

The main function of the D2P tutor interpreter is to read the XML page file that defines the tutor's pages and to render them. The D2P engine handles page layout and switching between pages. In addition, the interpreter attempts to connect to a server to log user data, which will be used to create user models later. When there is no Internet connection available, the D2P engine will save user data locally that can be sent through email when the tutor is reconnected to the Internet.

On the instructional material part, D2P/MTT currently has six sections: pre-qualification exercise, moving target assessment, POA technique, moving target engagement techniques, qualification exam, and practice module (see Figure 1 left) and users can see sections as sub sections (Figure 1 right). Users will go through a series of training, from simple to complex. Training pages may contain text, still images, audio and video clips, and quizzes, and D2P/MTT uses all of these. Figure 2 shows an example of an exercise where the user has to answer about range (distance), angle, speed, and POA. Exercises can be configured with and without time constrain.

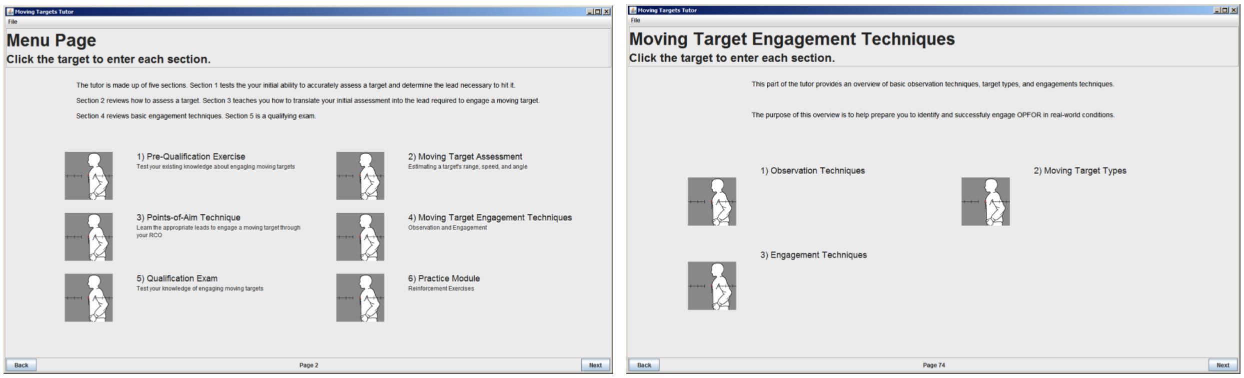

Figure 1. The MTT menu page (left), and an MTT sub section under Moving Target Engagement Techniques section (right).

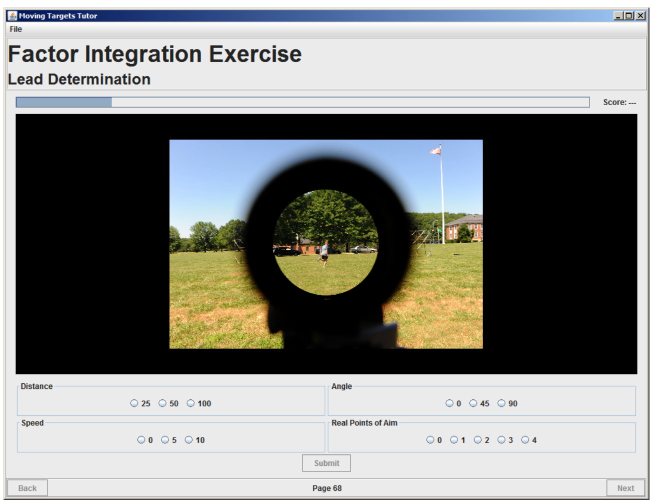

Figure 2. An example MTT exercise page.

3 Method

We tested how well D2P/MTT teaches points of aim with a small study at Penn State. This was in preparation for a larger study to be run at Quantico.

3.1 Participants

We recruited 27 undergraduate students. Each participant received $7 per hour for approximately 4 to 5 hours after the study was completed. Due to unexpected user behavior, mistakes, and data loss, we ended up collecting 10 sets of data (both pre- and post-test exist and valid) that we used for analysis.

3.2 Materials and Apparatus

All participants used a Windows laptop computer with build-in keyboard and touchpad in a lab environment. The D2P/MTT program of version 0.5.2 (17 January 2012 release) was installed and tested before an experiment was started. All activities were completed in an isolated, closed room with no/minimal distraction.

3.3 Research Design and Procedure

Participants first finished a pre-test asking them to judge angle, range, speed, and POA of 24 videos showing a moving target who is running (10 mph) or walking (5 mph) at 25, 50, or 100 meters (range) at 45 or 90 degree angles (summary of questions is shown in Table 1) without feedback so that they did not know whether their answers were right or wrong. Questions were presented in a fixed order for all participants. There were no time constraints for both pre- and post-tests—Participants, however, were instructed to complete both tests as fast as they could.

Table 1. Number of questions for each type

Categories	Number of Questions
Angle (45 and 90 degree)	4
Range (25, 50, and 100 yards)	6
Speed (5 and 10 mph)	4
Point of aim	10

Both pre- and post-test were administrated online and the questions were stored online. Participants used a web browser to complete both tests. The first page of both pre- and post-test is the instruction for completing the test. Figure 4 shows one of the pre-test questions. A participant typically reads the question, clicks “Play Video”, enters an answer, and then clicks “Next” to advance to the next question. All key strokes, mouse movements, and mouse clicks were recorded using a keystroke logging application named RUI (Kukreja, Stevenson, & Ritter, 2006) to capture their answers for data analysis.

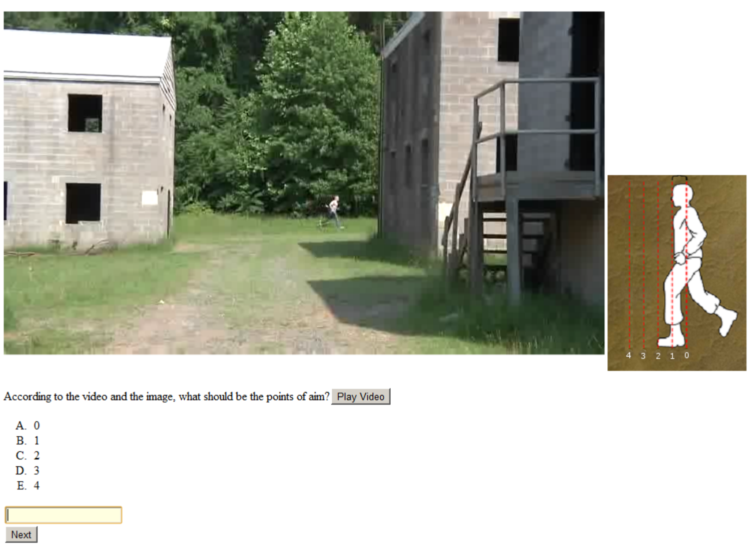

Figure 3. An example of one pre-test question asking the POA

After the pre-test, participants used the instructional materials in the D2P/MTT. They completed the training that includes practicing exercises with feedback showing whether their answers were right or wrong and what the right answer was if wrong. The number and length of training sessions varied across participants. . Participants completed the training at their own pace, with no time limits, and all of them completed it within five hours.

In the end of the training, participants were tested again using the post-test. The processes of administering post-test were identical to the pre-test in terms of the format and the number of questions in each category. Key strokes, mouse movements, and mouse clicks were recorded using RUI (Kukreja et al., 2006). The only difference was the question sequence, which was a different, fixed order across participants.

4 RESULTS

The following results are based on ten sets of data that include both pre- and post-test so that we can compare participants' performance before and after the MTT training. The results are calculated from 10 participants because we experienced data loss in the experiment. We have both pre- and post-test from all these 10 participants and lost either pre- or post-test or both of the other 17 participants. This data loss will be discussed in the discussion section.

Table 2 presents the pre-test and post-test scores. Categorically, their performance of accuracy for target speed, angle, and range is significantly better than in POA (85%, 80%, and 72%, respectively, versus 20%). It appears most participants can basically recognize the components of the skill, but do not have the ability to retrieve the correct POA before the training. These results indicate that without training, our participants did not know how to determine POA. They may not have known what POA is and the concept of leads before the training.

Table 2. Results of Pre-test and Post-test Accuracy by Categories

	Mean		**SD**			
	pre-test	**post-test**	**pre-test**	**post-test**	**t-value**	**p**
All	54%	62%	32%	19%	-0.680	.505
All but POA	78%	72%	31%	12%	0.571	.575
Speed only	85%	70%	10%	22%	1.963	.065
Angle only	80%	75%	8%	6%	1.581	.131
Range only	72%	72%	18 %	8%	0	1.000
POA only	20%	47%	15%	18%	-3.644	.002

By comparing their POA performance of pre- and post-tests, we see an increase of correct answers from 20% (SD = 15%) to 47% (SD = 18%). It indicates that using D2P/MTT improves their performance by 1.8 standard deviations in POA category. This is a significant improvement for skill acquisition using computer-based tutoring system (Bloom, 1984), and Table 2 shows that this is a reliable difference.

To further understand the reason and area of improvement, we need to compare the MTT training with other learning conditions such as the current POA instructional condition. Also, the performance of both speed and angle drop slightly, and we do not know the reason without further analysis.

We also analyze our data based on the subjects' task completion time on the pre- and post-test, that is, the time from when the subject presses "Play Video" on the first question until he enters the last answer. Table 3 shows that the participants are on average 90 s faster in the post-test in responding to the questions. We also want to note that all ten participants improved in their completion time.

Table 3. Descriptive Statistics for POA Accuracy and Completion Time

	Pre-test (SD)	Post-test (SD)	t	p
POA accuracy (# of questions)	2.10 (1.66)	4.70 (1.77)	3.344	0.0086
Completion time (seconds)	279.56 (47.44)	189.71 (30.30)	5.341	0.00047

5 DISCUSSION

D2P/MTT is designed to teach judging POA quickly. Based on the collected data and results (both summary and descriptive statistics), D2P/MTT appears to be effective training users in the acquisition of POA. After the MTT training sessions (less than five hours), the participants improved in both accuracy and completion time significantly. The accuracy rate (only the POA score) improved almost two standard deviations, a relatively large effect.

We attribute the significant improvement in POA to the instructional design of MTT and the opportunity to practice to proceduralize the skill. This improvement may also be attributed to the novelty of our subjects before the training. Regular college students do not need to use POA skills in their everyday life, which reflects in their low pre-test scores (20%). Further studies are required to refine the results and to understand the attribution factors.

During the study, we lost 10 sets of data, we lost some or entire data sets from another 17 participants. The data loss rate is unusually high (63%). In the following sections we discuss things that can be improved in future or similar study.

5.1 Unexpected User Behavior

In the instruction of both pre- and post-test we stated "Do not change your answer." We still see several log files that have more answers than the number questions in the RUI log file. It is understandable that people in general want to receive a high score, even though they will not see the actual score in the end. But changing answers has made scoring difficult because with our initial software we could not completely correlate the answers with questions. We noticed this problem after we had collected several pre-tests. We reminded the rest of our participants to make sure they were all very clear about this instruction. However, some participants had been exposed to the training materials. We could no longer use their pre-test scores, and we could not ask them to retake the pre-test.

In addition, we instructed our participants to complete the test "as fast as you could." Several log files suggested that the "Play Video" button had been clicked more than once. Again, we realized this problem and used JavaScript to disable the "Play Video" button as soon as it was clicked. This approach makes the log file cleaner and timing should be more realistic to the purpose of the MTT training.

To avoid this problem we have revised our software and instructions. At Quantico, the new software should be used. Pilot logs should also be gathered and tested, and the people running the study should practice and be practiced in gathering the logs and saving them.

5.2 Administrative Oversight

The research assistants (RAs) who ran the experiment had piloted at least once using our lab members. We did not attempt to check/analyze log files because the pilot participants used paper and pencil to write down the answers. We changed the protocol to include the RUI software keystroke to reduce task switching—from computer screen to paper. As a result, the problems we had experienced were not discovered until the real data were collected.

There were also changes in the middle of the study that caused a problem in the post-test in which question number three was linked to question number thirteen. This results in only fourteen answers instead of the expected twenty-four. We managed to ask some participants to retake the post-test but not all came back. We end up having several subjects with a pre-test but without a corresponding post-test and we had to exclude them from our data analysis.

To avoid this problem the logs should be checked more often and the materials have been revised. At Quantico, the logs should be checked with pilot subjects and routinely collected after each pre- and post-test, and the logs checked after each Marine is run.

5.3 Data Loss

For unknown reasons, the RAs were not able to provide some pre-tests and post-tests. We do not know whether the participants did the test or not. We simply do not have the log files. We also have zero-sized log files, and we do not know the reason. This is the first experimental study that the RAs had run and the first we had run with multiple RAs, and the reasons for the random lose could be attributed to careless or novelty of the RAs when they ran the study, or our lack of detailed oversight.

To avoid this problem we will check the RAs checking the logs. At Quantico, the logs should be routinely collected after each pre- and post-test, and the logs checked after each Marine is run.

6 Conclusions and Future Study

This is the first experiment ran for the MTT. We want to know whether it is effective and useful the results confirm that the MTT is capable of what we had hoped for. The after training score (47% accuracy for POA) is not as high as we would like, and the ACS Lab is working on improving and polishing the instruction to ensure that the accuracy rate can be higher after the MTT training. The new and improved the MTT should be reevaluated when it is completed. This score might also be increased by providing additional time with the tutor.

This study does not confirm or deny that the skill acquisition moved from declarative to procedural for our participants through an entire MTT training. It takes other studies with different designs to test this statement. This work also required more knowledge about the retrieval time for declarative information as well as procedural knowledge. But, we know that the current tutor made learners are more accurate retrieving POA and faster at making the component judgments and retreieving the correct point of aim.

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