COLLEGE OF INFORMATION SCIENCES AND TECHNOLOGY
THE PENNSYLVANIA STATE UNIVERSITY

# Testing the Revised Moving Target Tutor

**(evaluation of D2P/MTT 11/27/2012)**

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# Technical Review of the Declarative to Procedural Tutor for Moving Target Tutor (review of D2P/MTT 11/27/2012)

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**Abstract**

The Moving Target Tutor (MTT) is a computer-based, multimedia tutoring system designed to teach people an important skill in marksmanship: shooting moving targets. To hit moving targets, a person must be able to quickly retrieve the correct Points of Aim (PoA). PoA is how far to lead a moving target based on the range of the target, how fast it is moving, and the angle between shooter and the target's heading. MTT uses a learning theory (Kim, Koubek, & Ritter, 2013) implemented in an architecture called D2P (Ritter, Yeh, Cohen, Weyhrauch, Kim, & Hobbs, 2013). MTT contains approximately two to three hours of instructional materials, including instructional text, pictures, audio, videos, and quizzes. These materials are then presented in the D2P program that is capable of handling other tutoring content. In this paper, we present the effect of using MTT in learning PoA by university students. We found our participants improved in accuracy (more than tripled their ability to judge PoA, effect size = 3.7)and an improvement in PoA of ) and, simultaneously, reduced the time to determine PoA. Although the participants may not have had a need to master marksmanship for purposes outside of this study, this report still provides insights about the effectiveness of using MTT, along with D2P, and points to directions for future improvements.

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Mtt2ndtestV10.doc

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# 1.0 Introduction

The Moving Target Tutor (MTT) is a computer-based, multimedia tutoring system designed to teach people an important skill in marksmanship: shooting moving targets. To hit moving targets, a person must be able to retrieve the correct Points of Aim (PoA) in a short period of time. This consists in learning how far to lead a moving target based on the range of the target, how fast it is moving, and the angle between shooter and the target's heading. Consequently, determining the correct PoA is the result of combining the range, speed, and angle of a moving object.

MTT uses a learning theory (Kim, Ritter, & Koubek, 2013) that emphasizes how declarative knowledge is transferred into procedural knowledge, and how these types of knowledge have different learning mechanisms and different forgetting mechanisms. To test and apply this theory we created the Declarative to Procedural (D2P) tutoring architecture (Ritter et al., 2013).

The D2P/MTT contains roughly two to three hours of instructional materials, including instructional text, pictures, audio, videos, and quizzes. These materials are then presented in the D2P program that is capable of handling other tutoring content.

In this paper, we present the effect of using MTT in learning PoA by university students. We found our participants improved in accuracy and, simultaneously, reduced the time to determine PoA. Although the participants may not have had a need to master marksmanship for purposes outside of this study, this report still provides insights about the effectiveness of using MTT, along with D2P, and points to directions for future improvements.

In a previous study (Ritter et al., 2013; Yeh & Ritter, 2012) with a previous version of the tutor, we examined how well D2P/MTT improved tutees' abilities. In the previous study tutees improved their abilities from 20% to 47% as measured by time of retrieving PoA. The previous study found an effect size (a way of measuring tutoring impact) of 1.48 compared to baseline. We believe that the Marine Corps currently does not use a tutoring approach that leads to any procedural learning with respect to hitting moving targets, although the tutoring could lead to some knowledge about the declarative elements.

During and after the previous study (Yeh & Ritter, 2012) we examined how the tutor could be improved, and created a revised version of the tutor. We made approximately 100 corrections and additions to the tutor.

In this paper, we present the effect of using this revised MTT in learning PoA by university students. We found our participants improved in accuracy and simultaneously reduced the time it took them to determine PoA. Although the participants may not have had a need to master marksmanship for purposes outside of this study, this report still provides insights about the effectiveness of using MTT, along with D2P, and points to directions for future improvements.

# 2.0 Method

## 2.1 Materials

To measure learning, we used a pre-test and a post-test that each consisted of 24 multiple choice questions without feedback asking participants to judge angle, range, speed, or points-of-aim to hit a moving target, using videos showing targets running or walking (varied target speed), at 25, 50, or 100 meters (varied range), and at 45 or 90 degree angles (varied angle). They each had equal number of questions of each type.  Figure 1 shows a screen shot of an example pre/post test question.


**Figure 1.  An example video pre- and post-test video question.**

We used the D2P/MTT tutor, version of 1.4.1 of 27 November 2012.  It contains 141 pages of instructional material—roughly two to three hours of instructional materials, including text, still images, audio material, videos, and quizzes. Figure 2 shows an example screen shot of a video included in the tutor, and Figure 3 shows an example training test included in the tutor. The specific topics covered are, in order, pre-qualification exercises to establish a baseline about user knowledge, an assessment of user ability to estimate a target's range, speed, and angle, a points-of-aim training section, an observation and engagement section, a qualification exam to assess what the user has learned, and a final practice module to reinforce PoA estimation. The RUI keystroke and mouse logger (Kukreja, Stevenson, & Ritter, 2006; Morgan, Cheng, Pike, & Ritter, 2013) was running on the laptop.

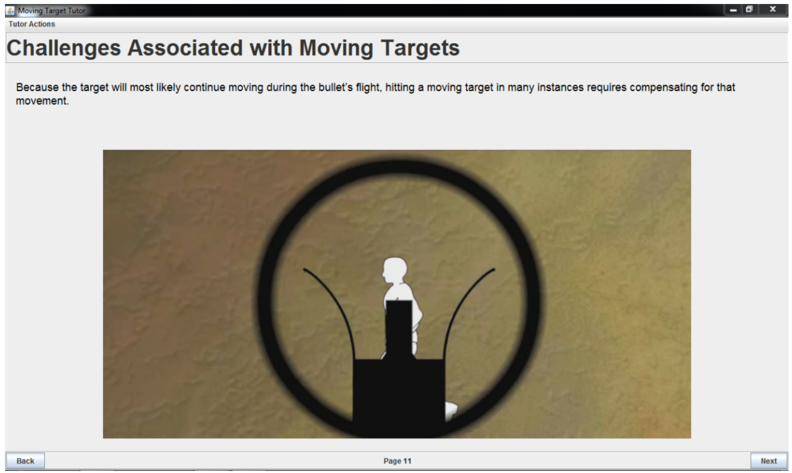


**Figure 2. Screen shot of an instructional video used in MTT.**

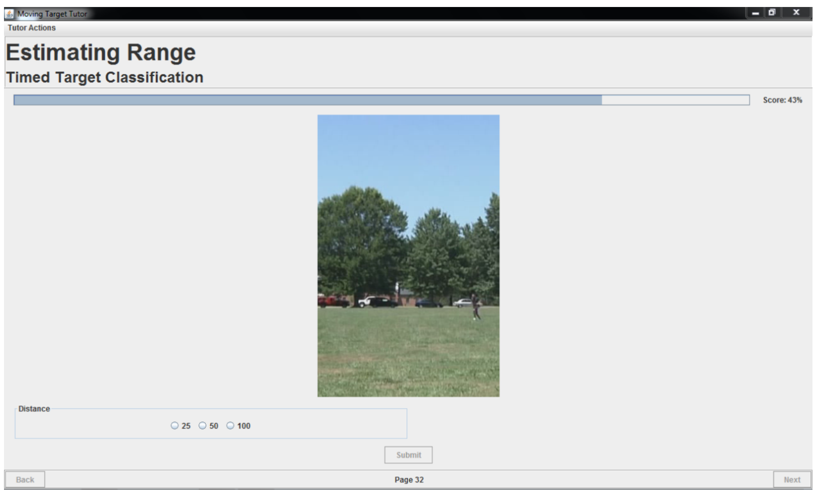


**Figure 3. A screenshot of a question used in the range assessment section of MTT.**

## 2.2 Subjects

There were 23 subjects who were university students 18 to 27 years of age. They were recruited with a flyer asking for subjects to test software for the Marine Corps. They were paid $7 per hour to the nearest half hour rounded up.

## 2.3 Design

The study design was a within-subject design across question type. Each subject was measured by their performance of before and after the experiment. The assessment consisted 4 types of questions: judging speed, angle, distance, and retrieved PoA.

## 2.4 Procedure

Participants used D2P/MTT in a quiet room on a Windows XP laptop, with the experimenter in an adjacent room separated by a partially closed door. Participants were encouraged to ask the experimenter if they needed any assistance.

Upon arrival, each participant was first told that they would be working through a tutor that was designed to teach them how to shoot moving targets, and that this tutor was intended to be used by U.S. Marines in the future. They were told that they would take a short break after 1.5 hours. Then a consent form was presented to them that outlined the risks of the experiment, followed by a two-page questionnaire about basic personal information as well as past experience shooting moving targets, simulated or real.

Participants then took a multiple choice 24 question pre-test without feedback asking them to judge angle, range, speed, or points-of-aim to hit a moving target, using videos showing targets running or walking (varied target speed), at 25, 50, or 100 meters (varied range), and at 45 or 90 degree angles (varied angle).

Participants then began using the D2P/MTT. 1.5 hours after the participant arrived, they were asked to conclude the section they were working on to take a short break (approximately 5 to 10 minutes). After the break, they resumed using the tutor. After finishing the MTT, they took a multiple choice post-test without feedback that consisted of pre-test questions reordered to assess MTT's effectiveness in teaching them how to retrieve PoA for moving targets.

# 3.0 Results

All 23 participants completed the D2P/MTT tutor training. To compute time on task we measured the difference between the starting time of pre-test and the starting time of post-test (both are recorded in RUI) and report it as the time on task. The actual time of using MTT is, therefore, shorter than what we report in this paper. A pre-test takes approximately 10 to 15 minutes. The most time any of the subjects took was 3 hours 24 minutes in total. The average time with the tutor was 1 hour 55 minutes, and the SD was 27 minutes.

Among all participants, seven required some form of assistance to deal with frozen pages in the tutor. The experimenter resolved each issue within two minutes, typically by restarting the tutor, and participants were able to continue using the tutor in all but one case. In that one case, S12 encountered a frozen on page 129 that the experimenter was unable to fix; they had already completed over 90 percent of the tutor and the only section they did not complete was a practice section with a format identical to previous practice sections. This subject was not excluded from analyses.

The average score of all questions in the pre-test (24 questions total) is 3.43 (SD = 2.46). In addition, the average PoA score (out of 10) is 2.39 (SD = 1.34). After completing D2P/MTT, the average of post-test (24 questions total) score is 22.70 (SD = 1.87) and the average of PoA score is 8.91 (SD=1.38).

Table 1 shows that our participants improved in all categories after completing the tutor. Overall and for the PoA questions the differences are reliable, as shown in the last column. The greatest improvement is in the PoA category that most people do not have prior knowledge and is not one of skills we use daily. Subjects more than tripled their ability to judge PoA. For the non-PoA categories, although the participants scored high in the pre-test, their post-test scores generally showed greater consistency (lower SDs) across all types of questions.

**Table 1. Scores on the pre- and post-test. (N=23).**

| | Average Score | | | |
|---|---|---|---|---|
| **Category (# of questions)** | **Pre-test (SD)** | **Post-test (SD)** | **T** | **P** |
| Overall (24) | 13.43 (2.46) | 22.70 (1.87) | 4.24 | .0003 |
| Distance (6) | 4.13 (1.25) | 5.84 (0.63) | 1.73 | .0981 |
| Speed (4) | 3.52 (0.67) | 3.91 (0.29) | 0.76 | .4580 |
| Angle (4) | 3.39 (0.89) | 4.00 (0.00) | 0.97 | .3429 |
| PoA (10) | 2.39 (1.34) | 8.91 (1.38) | 4.79 | .0001 |

Table 2 shows on average, participants performed the post-test much faster than the pre-test. We used the starting time ($t_1$) that the experimenter pressed F11 to maximize the browser window and handed the task over to the participants and the time ($t_2$) that the participants to the participants returned the control to the experimenter who pressed F11 again to calculate the duration ($t_2$-$t_1$). Individually, all but one (from 333.6 in pre-test to 399.0 in post-test) participants shortened the duration of the post-test, compared to the duration of the pre-test.

**Table 2. Average time to complete pre-test and post-tests (N=23)**

| | Pre-test (SD) | Post-test (SD) | T | P |
|---|---|---|---|---|
| Average time (seconds) | 435.1 (124.17) | 240.5 (53.13) | 2.04 | .0538 |

We would like to compute the effect size of this tutor. To do this, we need a control group showing what learning occurs if you do not use the tutor or what learning occurs during the current training. Current Marine Corps policy is to teach how to shoot moving targets based on a single, annual, 1-hour PowerPoint lecture. What we know about learning procedural skills, all that we know about learning procedural skills, predicts that this lecture, theoretically, does not lead to any procedural learning (Anderson, 1995; Anderson, Greeno, Kline, & Neves, 1981; Kim, Ritter, & Koubek, 2013; Larkin, McDermott, Simon, & Simon, 1980; Newell & Rosenbloom, 1981). So, to compute effect size we use the initial scores as the control group. This approach may have to be modified when using Marines because we may find that they do learn from a lecture without any practice, quiz, or training, but it is highly unlikely. We may have to do this condition as future work, because some informal reviewers have suggested that such learning is perhaps possible.

So, the t-test values in Table 1 provide initial effect sizes for the tutor's components. Overall, for PoA and for all the questions, the tutor has an effect size greater than 4 over all questions and for the most important type of question, point of aim.

The results from the post-test are exceptionally high, which suggests a ceiling effect occurs. Therefore, including the standard deviation from the post-test would generate a larger effect size because of small standard deviation. If we choose to use the more conservative standard deviation (from the pre-test) to compute and report our effect size of the tutor (Olejnik & Algina, 2000), we still have an effect size of 3.7 overall and 4.8 for the PoA questions. Using either calculation the effect size is very high, and we will take up its import in the next section.

# 4.0 Discussion and Conclusions

The result of our experiment indicates that using the revised MTT is better than the previous version (Yeh & Ritter, 2012), and that the revised version can significantly improve the ability to judge PoA by practicing the other common, component skills, i.e. judging distance, speed, and angle, and retrieving PoA. We attribute the improvement to three features of the MTT: (1) practicing declarative knowledge explicitly, (2) doing this enough to increase the chance of proceduralizing these skills, and (3) providing heuristics for learning these skills.

The design goal of MTT is to promote procedural declarative knowledge through repetitive reinforcement. The MTT fulfills this design goal and helps learners improve their proficiency at judging PoA. Learners receive plenty of opportunities to practice the skills the tutor is intended to teach them. Each practice increases the chance of proceduralization. However, we do not know whether the learners in fact proceduralize the declarative knowledge. We only know their performance does increase after the tutor training. A measurement of reaction time is required for this type of analysis.

Essentially we need learners to estimate PoA quickly. In the MTT, we teach learners to use heuristics such as the height of runner's knee to estimate their speed, and in turn determine the PoA. Our results also indicate that the instructional strategies of MTT are effective with an effect size greater than 3.7. This effect is almost twice as large as the largest reported (1.95) in a recent review of intelligent tutoring systems (VanLehn, 2011), and larger than the previous version of the tutor (Ritter et al., 2013). This is partly due to the baseline we chose, which is no learning, which is the result of this otherwise essential skill currently not being trained by the Marine Corps. The large effect size is, of course, also partly due to the tutor tutoring and getting many learners to the ceiling in the tutor.

This study is our attempt to understand whether MTT is useful and usable. Throughout the process of design, deployment, and evaluation, issues related to the system and to its usability were fixed after each pilot test and we are still improving it. The major contribution of this study is to demonstrate that, with our tutoring architecture, D2P, creating useful tutors can be efficient and require relatively minimal system training.

We are planning additional tests of the MTT. First we want to compare the MTT with a human instructor or the existing field manual. This may have to be tested by using just the current instructional material used by the Marine Corps. Second we want to measure memory retention in both the MTT and human instructor situation. If we have enough resources and support, testing to see whether learners can transfer their PoA knowledge to actual firing situations would allow us to quantify the real-world usefulness of the MTT.

We will also test whether instructional designers or people who do not possess deep understanding of D2P architecture can create an effective tutor or not. Our intention is to build a set of toolkits for people who are outside of the cognitive science/modeling area of study.

In terms of the tutoring work, we will continue to use and improve our tools, including MTT and D2P in other appropriate learning settings.

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