A Simulation Based Application for Naval Navigation Training

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ABSTRACT

Recent high profile collisions involving naval vessels point to potential deficiencies in current training processes. The current work evaluates a training tool, the Target Angle Simulator (TAS) which aims to improve junior officer bridge skill sets. TAS provides the ability for students to practice skills in a simulated environment, providing hands on experience which could improve knowledge retention when compared to traditional, classroom-style instruction. The current work reports the results of two experiments demonstrating the value added of the new training tools. Experienced (Advanced Division Officer Course) and inexperienced (non-military) populations used the new target angle simulator to learn how to estimate angle-on-bow calls and identify vessel types in both day and nighttime conditions. A pre-test/post-test protocol resulted in significant improvement for the inexperienced population when they were allowed to practice with the target angle simulator. Improvement was not significant for the experienced group but feedback was extremely positive. The results suggest that the TAS is an effective tool which may be most effective for incoming Basic Division Officer Course students, who have some sailing experience but little prior experience making angle-on-bow calls.

ABOUT THE AUTHORS

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INTRODUCTION

The recent at-sea collision incidents involving the destroyers USS Fitzgerald and USS John S. McCain and merchant vessels have increased the importance of effective maritime rules of the road training for sailors. The investigation of the USS Fitzgerald incident implicated watch station manning by junior officers with deficient at-sea training as a potential causal factor. Since this condition may have resulted from a lack of sufficient schoolhouse-based training, methods for providing this training are under comprehensive review. The current work reports the results of an experiment designed to assess the effectiveness of a new Target Angle Simulator (TAS) in teaching novice sailors how to make accurate Angle-on-Bow (AOB) calls. This new training capability represents an attempt to modernize naval training by using a simulation-based tool to help teach a topic that up until now has been delivered via very brief classroom instruction.

Simulation-based training has shown to be valuable in both military (Bruzzone, 2017) and medical fields (Chang, et al. 2017). By immersing the student in an environment similar to the target task, simulation-based training theoretically provides better transfer to at-sea performance and stronger mental connections. Knowledge and experience are separate, and simulation based training provides a proxy for real-life experience that cannot be replicated in traditional classroom settings, while still imparting the needed underlying knowledge. Furthermore, as these systems move toward virtual reality (VR) and technology improves, the improved sensory fidelity they provide should greatly improve the realism and effectiveness of the training.

Estimating AOB from visual presentation is an important ship handling skill. Experienced sailors can easily and accurately estimate the AOB of a nearby vessel based on visual features (during the day) and configuration of shipboard lights at night. Failure to accurately estimate AOB of nearby vessels can pose a critical threat to the safety of the ship, as recent at-sea collisions discussed above demonstrate. Successful estimation of AOB from visual inspection includes two skills. First, operators must be able to accurately judge the angle a target vessel is offset from 90 degrees, and second, the operator must be able to avoid reversing the heading of the vessel, particularly one headed toward own-ship at an acute angle.

A common mistake when estimating target angle is to reverse the heading of the approaching vessel. Often the predicted AOB is the correct displacement from 180 degrees, but due to a visual illusion the ship appears to be moving in the opposite direction. This is a very common illusion experienced by sailors at sea. These reversal errors tend to occur when the target vessel is on a narrow path (e.g. heading directly toward or away from own-ship). This phenomenon has been validated in previous research (Ralph, Gabriel and O'Donnell 2017) which found a drop in accuracy rates for vessels traveling directly toward or away from own-ship when compared to more broad (e.g.15-30 degrees) AOB. In this condition, features of the target vessel are difficult to discern and students may be unable to distinguish whether they are viewing the stern or bow of the ship. For example, such a reversal might occur when a subject enters 170 degrees (e.g. ship is heading directly away) when the actual AOB is 10 degrees (ship is on a collision course). The resulting error is 160 degrees, but this error does not result from a failure to predict the relative angle, but rather the direction of travel.

The current approach to training for this skill is delivered via a power-point presentation, augmented by at-sea, on-the-job training (OJT), so junior officers often begin their sea duty without mastery of this important skill. The development of a TAS could fill this training gap and provide a higher level of initial skill for junior officers who will be tasked with performing these duties at sea, without having to wait for opportunities for OJT.

Target Angle Simulator

Navy officers need knowledge of Navigation Rules of the Road and related strong seamanship skills to reduce collision risk and improve tactical warfighter performance. The Target Angle Recognition Simulator (TAS) trains and assesses students' ability to identify the target angle and ship type of other stationary ships at sea during the day and at night, and at three different distances. This simulator places 3D models of different types of ships in the open ocean. The student views this ship on the computer screen and is then asked to identify the ship type and target angle. Recognizing target angle is critical to identifying the current navigational situation prior to deciding on a course of action and then executing this action.

TAS has three modes of operation, quiz, practice, and sandbox, respectively. In **quiz** mode, students are presented with questions and are assessed on the number of correct responses with respect to both ship classification and target angle error. For night-time examples, students are asked to identify light configurations instead of ship type. **Practice** mode enables students to take practice quizzes where they can control some aspects of the simulation environment, for example, switch from night to day, and thus learn while practicing. **Sandbox** mode enables students to place and orient their choice of ship in the ocean; students play with ships, lighting, orientation, and distance to learn to recognize target angle.

Quizzes and practice quizzes have three levels of difficulty and are automatically generated and assessed. Probabilities associated with ship type, ship distance, and time of day determine the question generated at beginner, intermediate, and advanced levels of difficulty. TARS can display over thirty different ship types at one (near), three (mid), and five (far) nautical miles distance, during the day and at night. TAS' beginner quizzes have a higher probability that ships will be near and that scenarios occur during the day. Intermediate TARS scenarios will have more night scenes and ships will have a higher probability of appearing at mid distance. Finally, advanced quiz questions will be predominantly night scenes, with ships at mid and far distances, and with less common ship types and night lighting configurations. In TAS, novice students augment their knowledge of nautical rules of the road by playing in sandbox mode. As they learn, they can take practice quizzes to gauge progress. Once they have confidence, they can take progressively more difficult quizzes and get assessed. The screenshots below show examples of TAS simulations of ships at day and night, respectively, during a quiz.

Figure 1: Sample screenshot of TAS

EXPERIMENTS

This study included two experiments. The first experiment examined the ability of TAS to improve the ability of inexperienced subjects to make AOB calls and identify ship types. AOB ability was determined by analyzing mean error (e.g. called AOB-truth), and the likelihood of a reversal, in which the called AOB is the correct displacement from 180 degrees, but the direction of the target vessel is “flipped.” For instance, a called AOB of 165 degrees for a ship approaching (closing) at 15 degrees would be considered a reversal. All AOB calls with an absolute error greater than 90 degrees were coded as reversals. Participants for this study were non-sailor engineers working at the Naval Undersea Warfare Center (NUWC) and submariners without significant periscope operation experience.

The second experiment tested the value of TAS at improving the abilities of moderately experienced sailors who were beginning their Advanced Division Officer Course (AD OC) class at the Surface Warfare Officer School (SWOS) in Newport, RI. This second study also employed an active control group who performed a similar but unrelated task in order to isolate the effect of TAS sandbox use on learning gain.

EXPERIMENT 1

Experiment 1 was a pilot study performed with non-sailors to determine the value of using TAS to teach AOB skills to novices. Subjects were given a pre-test, asked to use the TAS software in sandbox (free play) mode and then given a post-test.

Subjects

The subjects were three civilian NUWC employees with no prior sailing experience and four submariners from NUWC’s military detail (Mildet). These submariners had received periscope operations training, but had no surface ship experience. As these groups were sufficiently small and their performance did not significantly differ, we combined them for analysis purposes.

Procedures

Upon arrival, subjects completed a standard informed consent procedure. Subjects then were given 10 minutes to study an informational packet including descriptions of standard nighttime ship light configurations. They were informed that this information would be important to memorize as they would be asked to identify ships and AOBs using only light configurations as a guide.

Each subject completed a 25-item pre-test using the TAS software (including both night and day images), followed by a 10-minute period in which they were encouraged to use TAS in sandbox mode to "play" with different ships, target angles, and light configurations. Finally, each subject took a second 25-item post-test. Both the pre- and post-tests required participants to identify the ship type and target angle (AOB) of each ship presented. Subjects were encouraged to use the binoculars feature to view ships at further ranges.

Metrics

Data was coded to allow for analysis of the following metrics related to performance

- *Ship classification accuracy*: Proportion of ships accurately classified
- *AOB Error:* Average (mean) difference between called angle and ground truth
- *Reversals:* number of angle calls with AOB Error greater than 90 degrees

Results

Researchers used the data collected from the TAS software to assess the accuracy of ship classification and target angle predictions. Due to the software not having been tested previously, the extracted data only included AOB error values, and not the true angle or time of day for each trial. As a result, researchers were unable to analyze the effect of these variables on performance. The analysis, then, was limited to the overall effectiveness of TAS at improving the classification accuracy and AOB skills of the participants.

Analyses were performed both with raw errors and with a corrected version, in which errors of greater than 90 degrees were changed to 180 – error. The number of such reversals was also collected and analyzed.

A paired-sample t-test revealed that subjects in experiment 1 showed statistically significant improvement from pre-test to post-test for ship classification accuracy, $t(6) = 3.64$, $p=.01$. The mean difference between pre-test and post-test subject assessment accuracy was +20% with a 95% confidence interval of [6.6%, 33.4%]. These classification decisions were also entered significantly faster on the post-test (Mean difference = 7.73 seconds 95%CI = [1.19, 14.27]), $t(6)=2.90$, $p<.03$.

There were no other significant main effects, regardless of how target angle error was calculated. It is possible that if more subjects were tested, a main effect of AOB reversals may have developed. Of the seven subjects involved, only one made more reversals on the post-test than on the pre-test, while four subjects improved from pre-test to post-test, as expected. This data is displayed in Figure 2 below.

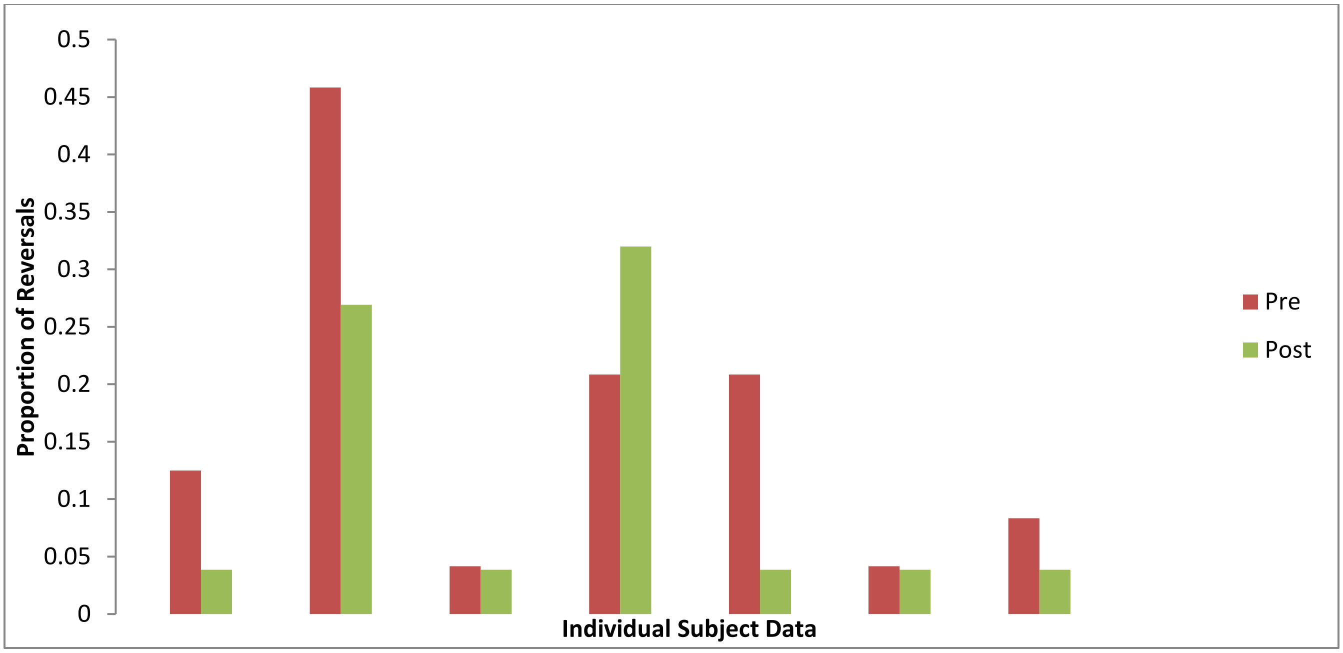

Figure 2. AOB reversals (pre-test/post-test) for each of the 7 subjects in experiment 1.

Discussion

Experiment 1 demonstrated significant improvement in ship type classification for novices. Subjects improved accuracy by an average of 20% between the two tests, suggesting that the ability to freely manipulate different ships and view them from multiple angles may have improved recognition and retention. This finding is likely not the result of the experience gained from taking the pre-test in the TAS software and more likely caused by having time to explore during the sandbox period between tests. While there was no significant decrease in mean AOB errors, four of the five subjects who made reversals on more than 10% of trials in the pre-test reduced that incidence during the post-test. This is also likely due to the ability to practice during the sandbox period.

Overall, these results suggest that the TAS simulator has promise for use as a training product. Given the small amount of practice allowed (10 minutes), it is notable that any improvement was found. It is not knowable from this study alone what the true value of the TAS simulator would be given multiple sessions and more sandbox exposure. Further, since this was the first exposure many of these subjects have had with estimating target angle, it is possible that TAS would be even more effective with a more experienced population whose prior experience could guide their use of the sandbox application.

EXPERIMENT 2

Experiment 2 was performed with a more experienced cohort, incoming Advanced Deck Officer Course (ADOC) students at SWOS. This experiment was performed with the purpose of addressing the weaknesses of experiment 1, namely the use of inexperienced subjects and the lack of an active control group. Control groups are used to disassociate the effect of merely having taken a pre-test from the factor of interest (in our case the use of the TAS sandbox between tests). In this context, control groups can be either active or passive. Passive controls are subjects who do nothing between the pre-test and post-test. Active controls, by contrast, are subjects who perform some similar task, similar to the target task in as many ways as possible, between the two tests. The advantage of using an active control group is that any difference found between the experimental group and the control group can be attributed to the target task (sandbox play). Differences in experimental results between an experimental group and a passive control group may be confounded by the fact that the experimental group "did something" while the control group "did nothing."

In experiment 2, researchers used a ship bridge simulation called Conning Officer Virtual Environment (COVE) as the active control task. COVE allows a student bridge officer the ability to provide ship steering commands to navigate a surface vessel. COVE was selected as the active control task because it is an "at-sea" simulation and would provide subjects with an active task to perform between the pre and post tests. Active control tasks allow for the ability to reject the hypothesis that simply "doing something" can be credited for any improvement between tests. Subjects in the control condition were asked to use COVE to practice docking a vessel to a pier, a skill that requires focused attention, but is not comparable to the AOB calls.

Subjects

Study participants were 12 incoming ADOC students. All subjects had between three and eight years' experience in the Navy and had served at least one tour aboard a surface vessel. Six of the subjects were randomly assigned to the experimental (TAS) group and six were assigned to the control (COVE) group.

Procedure

Experimental procedures were identical to those used in experiment 1 with the exception of the control group: instead of spending time "playing" with the TAS in sandbox mode, these subjects spent 10 minutes with the COVE simulation, practicing ship-handling skills.

Results

There were no main effects or interactions for ship type classification or target angle detection. These results are likely due to the population of subjects used. These sailors had previously been trained to detect target angle and all had significant at-sea experience. Reversals were not an issue in this cohort , and the subjects correctly classified 91% of ships (day and night). This compares to ~30% for the subjects in experiment 1. It seems clear that the lack of improvement captured by the current experiment is likely due to these subjects being "overqualified."

Despite not helping these students improve their already excellent target classification abilities, questionnaires filled out at the end of the experiment revealed that these students did see the value of the TAS system. On a 7-point Likert scale, the six participants using the TAS rated the system highly for the usefulness of the sandbox application (6.17/7), use as a memory refresher (6.5/7), and general usefulness (6.3/7). Subjects in the COVE group were also asked for their general impression of the TAS system they used for the pre- and post-tests. Although they rated the system favorably, their ratings were significantly lower (5.16/7) than the TAS group $t(10)=2.57$, $p<.03$.

CONCLUSION

The quantitative results from experiment 2 were inconclusive due to the high degree of prior knowledge and ability possessed by the subjects. Despite not realizing any tangible gain from using TAS, subjects generally rated the system favorably and thought it would be useful as a training aid for novice sailors. They especially liked the sandbox application and the realism of the dial control for entering AOB values. Several also noted that TAS would be a useful tool for refreshing their memory in preparation for a new tour.

FUTURE WORK

The current study serves as a starting point for future effectiveness testing for TAS and related tools. In future investigations, researchers should be sure to collect data from more subjects and extract data relevant to more variables than was possible in the current study. The current study demonstrated that previous experience level is critical in determining the value of a training tool. In experiment 1, TAS showed limited value, likely because the population tested had no experience in the target skill. In experiment 2, despite positive subjective comments, TAS did little to improve skills for a cohort who had already received in-person at sea training in the AOB skill. It is likely that the correct target audience is students entering the Basic Deck Officer Course (BDOC) course as these sailors have minimal (but non-zero) experience at sea.

Future studies should also collect the data required to determine which aspect of AOB skill (if any) is improved by TAS. Analysis of variables such as time of day and truth angle would allow researchers to conclude if TAS is causing improvement in specific abilities, such as the recognition of light configurations or AOB calls of specific trajectories.

Discussion

Taken together, the results of the two experiments detailed here suggest that the TAS system has promise as a training aid for the Navy's maritime rules of the road training. Despite only using the sandbox for 10 minutes, complete novices were able to significantly improve their ability to recognize various types of vessels both during day and night conditions, and improved their ability to avoid reversals, a common error when estimating AOB. It is possible that with further practice, these gains will increase.

The second experiment was performed with subjects who were clearly outside of the target population for this tool to be effective. The target population is likely BDOC students, who are less experienced than ADOC students, but more experienced/knowledgeable than our non-military NUWC employees from experiment 1. This highlights the importance of testing an application to verify the target population and to consider the ability level of test participants when analyzing data. Future testing should be performed with incoming BDOC students to verify that TAS would be an effective training aid for these tasks. Enhancements to the TAS software completed since this testing should also be assessed by experienced sailors to verify the usability of the software.

In conclusion, the TAS software is proving to be a useful addition to the PowerPoint based rules of the road training and shows promise in helping the Navy train officers shore-side with the type of realistic simulation that could provide or improve skills currently developed (at increased risk) aboard operational surface vessels.

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