Research Proposal

Effects of Distractions on Shooting Performance

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Abstract

This experiment examines the extent to which the presence of visual and auditory distractions in an environment affects shooting performance. Addressing a significant gap in the existing literature, this research intends to provide useful information for future firearms training instructional design. To minimize the potential for collateral damage, and to maximize the odds of a favorable outcome, all who carry firearms in public (including security, law enforcement, military, and lawfully armed citizens) need to be proficient with their firearms under a variety of conditions; some of them, unfavorable. To determine whether visual and auditory distractions affect shooting performance, ten participants will shoot a timed course of fire against moving targets under two separate conditions (a within-subjects method). For safety and convenience, a light gun controller will be used in conjunction with an original shooting gallery video game for personal computer. In the control condition, distractions will not be present. In the treatment condition, distractions will be present. The order in which the conditions are presented will be randomized to control for learning and fatigue effects. A difference score for each participant will be calculated, and the resulting set of difference scores will be analyzed using a dependent sample t-test. It is anticipated that distractions will negatively affect shooting performance to a statistically significant degree.

Effects of Distractions on Shooting Performance

Developing and maintaining firearms proficiency is an important objective shared by militaries, police agencies, and vigilant citizens alike. In a dynamic and volatile situation, a well-meaning person with a gun can be more of a liability than an asset, if they are not competent enough with their weapon to ensure hitting their intended target with high probability. Every stray shot can carry with it the potential to cause a tragedy. Bullets from modern firearms easily penetrate walls of the type used in most structures (Schildt, 2013), and thus can pose a threat to people who are not even in the shooter's line of sight. This makes accurate shot placement doubly important for any shooter who is concerned with minimizing the risk of collateral damage.

As the U.S. military is being used increasingly to patrol and police occupied foreign territories, training soldiers to carry out these nontraditional missions has become a high priority for the Department of Defense; so much so that elaborate mock villages have been constructed in the deserts of the American Southwest to simulate U.S.-occupied Arabian cities (Taylor, 2013). There is a demonstrated need to better understand the factors that influence a person's firearms shooting performance. As Thomasson, Gorman, Lirgg, and Adams noted in 2014, American case law actually demands that police officers receive “realistic training” that extends beyond simply firing slowly at a stationary target. Although leisurely target shooting can be quite an enjoyable activity, it is believed that training under more stressful conditions better prepares a trainee to perform under the conditions they are likely to encounter in the field.

While the effects of stress on shooting performance have been studied (Thomasson, Gorman, and Lirgg, 2014), the existing literature is deficient with regard to the topic of how certain other factors, like the presence of distractions, affect a shooter's performance. This experiment aims to discover the extent to which the presence of visual and auditory distractions in an environment is detrimental to shooting performance. Although it is suspected that shooting performance will be affected negatively by the presence of distractions, a nondirectional research hypothesis (and two-tailed hypothesis testing methods) will be used to minimize the effects of researcher bias on the results of the experiment. Thus, the research hypothesis is that the mean shooting score of people in the population subjected to the presence of distractions will differ from the mean shooting score of people in the population not subjected to the presence of distractions.

For safety and practicality reasons, an original light gun controller and shooting gallery software simulation will be used in lieu of a real firearm. The system will allow participants to shoot moving targets on a computer display with no danger to anyone.

The independent variable (IV) is the presence of distractions. This variable will be manipulated to assume two levels:

Level 0: Distractions are not present.

Level 1: Distractions are present.

Two dependent variables (DVs) will be recorded: the participant's number of hits, and the participant's number of misses. Each of the two stages of the experiment (corresponding to the two levels of the IV) will be timed, and will be of equal duration. From the two measured DVs, it will be possible to compute many secondary DVs, such as total shots fired, shots per minute, hits per minute, hit/miss ratio, etc., and statistical analysis will be performed on these variables as well. Both measured DVs are of the ratio type, and can take on any integer value from zero to positive infinity. In practice, there will be a fixed upper bound to the number of targets a person could possibly shoot within the provided time window, since the software will only be capable of displaying a finite number of targets within this window. The exact level of this upper bound would be difficult to calculate. It will be a function of the software's frame rate, and is expected to exceed the performance capabilities of the shooter by such a wide margin that no ceiling effect is expected to result from its existence.

The advantage of gathering data on both conditions of the independent variable from all participants is that this method maximizes the amount of data collected, and allows many options for subsequent data analysis. For instance, a researcher could, working from the raw data, later decide to divide the participants into two groups (either randomly, or according to some other method), discarding the treatment condition data from the control group, and the control condition data from the treatment group. Since there are many ways the two groups could be divided, there are many ways in which the raw data could be analyzed.

Although no existing literature has been found that addresses this specific research question, there have been several studies that show a negative relationship between the presence of distractions, and the ability to proficiently perform tasks. In 2014, Foroughi, Werner, Nelson, and Boehm-Davis found that interruptions negatively affect quality of work when performing a creative writing task. Fox, Rosen, and Crawford (2009) found that the distraction of instant messaging while trying to complete a reading comprehension task increased the time required to complete the task. This is consistent with the findings of prior researchers that interruptions generally increase the time required to complete tasks (Gillie & Broadbent, 1989). In 2012, Kaber et al. found that cognitive distractions increase workload for motor vehicle drivers, and visual distractions contribute to steering errors. Given this existing body of knowledge, there is reason to suspect that distractions may negatively affect shooting performance.

If the research hypothesis is supported, evidence will be found for a relationship between the presence of distractions and shooting performance. If this relationship is a negative one (as one might suspect from reviewing the literature), this could inform future development of combat-oriented firearms training courses. If it is possible for a shooter to become acclimated to distractions, such that their shooting performance is not diminished in the presence thereof (or is diminished to a lesser degree), it may be beneficial to incorporate distractions into training scenarios to better prepare the trainee for future encounters. However, further research may be required to determine whether distractions are something to which a shooter may be acclimated.

If the research hypothesis is not supported, this will suggest that no significant relationship between the presence of distractions and shooting performance exists. If this is found to be the case, this fact would be informative to firearms instructors as well. It would also beg the question, “Then what factors *are* related to shooting performance?” This is a much broader topic of research that could be explored in virtually unlimited ways.

Method

Participants

Ten participants of mixed gender, ethnicity, and age will be selected from the researcher's pool of colleagues and affiliates in the Socorro, New Mexico area. This is a form of *convenience sampling*, and although this method raises questions as to the representativeness of the sample (and thus the external validity of any findings), it is unfortunately the only viable method available to the researcher for various reasons. Because the experiment must be conducted under tightly controlled conditions, it must be carried out in the researcher's private laboratory. Due to security necessities, only participants known personally to the researcher can be granted entry. At present, the list of proposed participants includes three Caucasian males, four Caucasian females, two Hispanic males, and one Black male. No participants will be excluded on the basis of demographic, since it is hoped that the findings of this experiment may be generalized to military, police, and lawfully armed citizens who increasingly represent a wide range of demographics.

Materials

Three essential materials are needed to conduct the experiment: 1) A computer with the original shooting gallery software installed. Since the software was developed in Processing and compiles to Java bytecode, it can be executed on any modern computer. For convenience and reliability, the computer of choice is the researcher's Apple MacBook Air 11" laptop. A fallback option exists in the form of an Asus 10" netbook running Ubuntu 14. 2) A large external display device, connected to the computer via HDMI. The primary display device on hand is a 32" LG television. A backup exists in the form of a 24" Samsung computer monitor. 3) A Lyratron light gun prototype, which connects to the computer via USB. The light gun is composed of 3D printed ABS polymer, laser-cut acrylic glass, laser-cut wood, and hand-soldered electronic circuitry centered around an Arduino Nano microcontroller.

Design

In this experiment, the independent variable is the presence of distractions. This variable has two levels: zero (no distractions are present), and one (distractions are present). Visual distractions consist of animated creatures and objects that wiggle, wobble, hop, and hover around in roughly the same position on the screen, but whose slight motion is intended to draw the participant's gaze toward the distraction, and away from the designated target (see Figure 2, or this demonstration video). Auditory distractions include comical, cartoon-like sounds that correlate with the motions of the distraction objects, but not with the relevant action (i.e. the gun or target). Since this is a within-subjects design, all participants will be exposed to both levels of the independent variable.

The dependent variables being measured are the number of target hits, number of misses, total shots fired, and hit ratios recorded under each condition. From these, various shooting scores may be computed post factum via somewhat subjective formulas. For example, a positive point value could be assigned to each hit, and a negative point value assigned to each miss, and the score would be found thusly:

$$score = hits \cdot points_{hit} + misses \cdot points_{miss}$$

In the above example, if the participant made 23 hits and 7 misses, and if each hit were worth 10 points, and each miss were worth -20 points, the participant's score would be:

$$score = 23 \cdot 10 + 7 \cdot (-20) = 230 - 140 = 90$$

Computing a final score, however, could be said to be rather subjective, since the choice of formula, and even (as in the above example) point value coefficients, can be seen as highly arbitrary. Choosing a significant penalty for missed shots, for instance, would penalize the score of a participant who achieved many hits with just a few misses, while favorably computing the score of someone who made very few hits (and no misses) because they took their time to aim and fire slowly. Thus, the relative importance of speed and accuracy would have to be weighed in determining any final score, and since these are probably debatable even among firearms experts, making such value judgments will be avoided to the extent possible by simply collecting and analyzing the raw data.

Procedure

Each participant will be positioned five feet from the display screen, given a light gun, and allowed up to five minutes of free (not scored) play to familiarize themselves with the shooting gallery game (in *sans distractions* mode). This is meant to minimize the extent to which the participant's changing level of familiarity with the game might skew data being collected over a finite time interval. Once the free play period has elapsed, or the participant has indicated that they feel confident enough to begin the test, a coin toss will be performed to determine which experimental condition to introduce first: the treatment condition (*with distractions* mode), or the control condition (*no distractions* mode). The game will be played for exactly five minutes in the first mode. When the time has elapsed, the participant's hits and misses will be recorded (making note of which condition was active). The game will then be toggled to the alternate mode (from treatment to control condition, or vice versa), and the participant will be asked to play again for another five minutes, after which time, their scores will again be recorded.

In addition to the previously mentioned *learning curve* or *testing effect*, another extraneous factor that could potentially influence the dependent variables is the physical presence of any distractions external to the shooting gallery game. These could include people talking, phones ringing, alarms going off, lights being switched on or off; even a nearby dog barking, or a bird singing outside the window. Every effort will be made to ensure that the environment is free from these distractions to the extent possible. Phone ringers will be switched off, lights will be set to a comfortable level prior to beginning the test, and any bystanders will be instructed to please abstain from talking or attempting to interact with the participant during the test.

Analysis

Since each participant is being scored twice, under two different conditions, the data collected during this experiment is ideally suited for analysis by *dependent sample t-test*. Using the DSTT involves first computing a set of difference scores, by subtracting one set of scores from the other. In this case, the control condition scores will be subtracted from the treatment condition scores, resulting in a set of difference scores that signify the effect distractions had on each dependent variable (if any). For example, if a participant scored 80 hits during the treatment condition, and 100 hits during the control condition, that participant's difference score would be -20, meaning that their score during the treatment condition was 20 points below that of their score during the control condition.

Taking a mean of each set of difference scores will immediately show the directionality and magnitude of any possible relationships. For instance, if the mean of the *hits* difference scores is negative, that would indicate that among the sample, more hits were made during the control condition than during the treatment condition. However, no such findings can be generalized to the population without first conducting a test for statistical significance, which is what the DSTT is for.

First, the *t critical value* (t_{cv}) for statistical significance is found by consulting a standard t distribution table. This requires the *degrees of freedom* or *df* (equal to $n - 1$), alpha level or *p* value, and tailedness. Consulting Table A-2 from *Statistics* by Aron and Aron (2002) yields a t_{cv} of 2.262 for $df = 9$, $p = .05$, two-tailed design. Results of the experiment will be considered to be statistically significant iff (if and only if) the absolute magnitude of the *t obtained* (t_{obt}) exceeds t_{cv}.

Since, according to Aron and Aron (2002), the standard error of the sampling distribution is given by:

$$SE_d = \sqrt{\frac{\frac{\sum (X_d - \bar{X}_d)^2}{n-1}}{n}}$$

And *t obtained* is given by:

$$t_{obt} = \frac{\bar{X}_d - \mu_d}{SE_d}$$

It follows that:

$$t_{obt} = \frac{\bar{X}_d - \mu_d}{\sqrt{\frac{\frac{\sum (X_d - \bar{X}_d)^2}{n-1}}{n}}}$$

Where t_{obt} is the *t obtained*, $\bar{X}_d$ is the difference score mean of the sample, μ_d is the estimated difference score mean of the population (assumed to be zero), X_d is each individual difference score, and n is the sample size.

Once a t_{obt} has been computed for each of the two dependent variables (*hits* and *misses*), it will be compared with the t_{cv} found previously to determine statistical significance. If the absolute magnitude of t_{obt} is seen to exceed t_{cv}, support for the research hypothesis will be found, and it will be concluded that the presence of distractions appears to affect shooting performance. These hypothesis tests will be repeated with secondary (computed) dependent variables, such as *total shots fired* (the sum of *hits* and *misses*), and *hit ratio* (the quotient of *hits* over *total shots fired*), to determine if these are affected by the presence of distractions as well.

Results

It is expected that the results of this experiment will confirm the research hypothesis that the presence of distractions affects shooting performance to a statistically significant degree. Specifically, it is expected that shooting performance will be negatively impacted by the presence of distractions in the environment. Since a *within-subjects* experimental design is being used, this will be evidenced by a lower mean number of hits, and/or a higher mean number of misses, by participants during the treatment condition (when distractions are present), compared with that of the control condition (when distractions are not present). It is essential that both of the aforementioned dependent variables be analyzed since: 1) Participants might compensate for the adversity of distractions by shooting fast and indiscriminately, resulting in (potentially) the same number of hits, with simply more misses. 2) In a real world combat situation in an environment where innocent bystanders are present, every stray bullet carries with it the potential for collateral damage. For this reason, it is essential that any factors that might contribute to such undesired outcomes be adequately studied and understood.

As described in the *Methods* section, the same group of participants will be exposed to both levels of the independent variable: with distractions (the treatment condition), and without distractions (the control condition). Two sets of shooting scores will be collected from each participant; one from each condition. Difference scores will be computed by subtracting the control condition scores from the treatment condition scores. If the mean of the difference scores is positive, it will be concluded that the dependent variable in question was positively influenced by the independent variable. A dependent sample t-test will be performed on each of the two sets of difference scores (one for each dependent variable: hits, and misses), to determine the statistical significance of any nonzero difference score means. Also noted in the *Methods* section is that the chosen t_{cv} for statistical significance at the $p = .05$ level is 2.262. This is based on nine degrees of freedom, or $n = 10$ participants (Aron and Aron, 2002). If the absolute value of either of the two computed t_{obt} variables exceeds this threshold, it will be concluded that statistically significant results were obtained.

If statistically significant results are obtained, this will be consistent with prior research findings in this area. In 2014, Foroughi, Werner, Nelson, and Boehm-Davis found that interruptions negatively affect quality of work on an essay writing task, with a remarkable statistical significance of $p < 0.001$. In 2009, Fox, Rosen, and Crawford found that participants who engaged in instant messaging during a reading comprehension exam took significantly longer to complete the test. These results were also significant at the $p < 0.001$ level. Since, in this shooting performance test, participants will be given a finite time window to make hits, taking even slightly longer to make each hit will result in fewer hits being made within the allotted time window. Finally, Kaber et al. found in 2012 that visual distractions are likely to induce steering error in young drivers ($p < 0.001$); as are cognitive distractions ($p < 0.002$). In light of the aforementioned prior research, the likelihood that this experiment will fail to produce statistically significant results appears to be low.

Discussion

As stated in the introduction, this experiment aims to determine whether the presence of distractions affects a person's shooting performance. This is accomplished by contrasting performance under a control condition (Figure 1) with performance under a treatment condition (Figure 2) while playing an original shooting gallery video game. Using a within-subjects method, each of the ten participants has the opportunity to shoot both *with* and *without* distractions present, and both scores are recorded. Difference scores are computed by taking the difference between each treatment condition score and each corresponding control condition score. A dependent sample t-test is performed on these difference scores to determine statistical significance. The research hypothesis is that the presence of distractions affects shooting performance to a statistically significant degree. Furthermore, it is anticipated that distractions affect shooting performance negatively, i.e. participants shoot worse when distractions are present than they do when distractions are not present.

A correct research hypothesis implies that shooting performance is affected by distractions. It is strongly believed that distractions affect shooting performance negatively, so the obvious implication of this finding is that knowledge of this fact should influence future designs of firearms training programs. If it is possible to acclimate a person to the presence of distractions, such that their shooting performance is minimally affected thereby, then incorporating distractions into training scenarios might make sense. This would help to prepare a shooter for a future hypothetical real world scenario in which distractions are present. If the shooter had previously trained with distractions present, perhaps they would be less affected by them and more able to shoot quickly and accurately in their presence. It is noteworthy that the value of this proposed remedy is speculative. Further research will be required to ascertain the extent to which training in the presence of distractions makes a shooter more tolerant of them, if indeed *any* benefit is obtained by such an approach. Additionally, if the research hypothesis is correct, this fact may inform rule-making processes for future shooting events, to determine what constitutes “interference”, i.e. what conditions might affect a shooter's performance so adversely as to discard that shooter's score and allow them to repeat the course, or even punish the person responsible for the interference by disqualifying them from the competition, or imposing point penalties on their score.

An incorrect research hypothesis implies that shooting performance is not affected by distractions; positively, or negatively. In all likelihood, the mean of shooting performance difference scores will be nonzero, meaning that some relationship between *distractions* and *shooting score* may be observed. But if the absolute magnitude of the difference score mean is not sufficiently large, it will not be possible to conclude with confidence that the observed effect is not simply due to random chance. So, this will be interpreted to mean that the research hypothesis is incorrect. This would be useful information for firearms training professionals also. If the presence of distractions has no effect on shooting performance, this fact would allow firearms training professionals to ignore whether or not distractions are present in a training environment, since this would not affect shooting performance either way. Also, this would be informative for shooting competition organizers, who might be less concerned about the prospect of interference to shooters knowing that such interference should not affect shooting performance.

This research extends and significantly improves previous research by focusing specifically on the influence of distractions on shooting performance. While previous researchers have studied the effects of distractions on things like driving performance (Kaber et al., 2012), the effects of distractions on shooting performance have not been studied. Likewise, other factors influencing shooting performance have been studied, such as stress (Thomasson, Gorman, and Lirgg, 2014), but again; distractions specifically have not been studied.

While the psychological literature is remarkably deficient on the subject of factors influencing shooting performance, a fair amount of research has been conducted on how distractions and interruptions affect the performance of other tasks. It has been discovered that essay writing is one such task, the performance of which is negatively affected by the presence of interruptions (Foroughi, Werner, Nelson, and Boehm-Davis, 2014). Similarly, Fox, Rosen, and Crawford found in 2009 that engaging in instant messaging caused participants to take significantly more time to complete a reading comprehension test. If shooting performance under simulated combat conditions is taken to be a factor of both speed and accuracy, it stands to reason that anything that causes a shooter to shoot slower (without also improving the shooter's accuracy) will be detrimental to the shooter's performance. It is believed that distractions are just such a variable.

Other interpretations of the findings might include potential criticisms of the experimental design, such as the notion that participants are more reluctant to fire when distractions are present for fear of hitting the distraction objects, or a possible bias on the part of participants that they will not shoot as well when distractions are present, which could conceivably result in a self-fulfilling prophecy. Further, a self-selection bias may be present, caused (potentially) by an increased willingness of firearms enthusiasts to volunteer to participate, while those with little or no interest in (or experience with) firearms may be less inclined to participate. It is theorized that such a self-selection bias would be apt to produce Type II error, because firearms enthusiasts might be more comfortable shooting under a wide variety of conditions, and thus less prone to being adversely affected by distractions.

Assuming the experimental design is good, it is possible that the influence of distractions on shooting performance is indirect rather than direct, i.e. that there is some intermediary variable that is affected by the presence of distractions, and it is this intermediary variable that is ultimately responsible for any observed effect on shooting performance. This would not invalidate the experimental results, but it would be an interesting topic of further study. One such intermediary variable might be stress. If the presence of distractions induces stress on the shooter, and this stress is detrimental to the shooter's performance (as Thomasson, Gorman, and Lirgg found in 2014), this could potentially explain any negative effect distractions might have on shooting performance. Other possibilities might include distractions causing mental fatigue, or apathy, or a feeling of being overwhelmed, or simply a perceived need on the part of the shooter to constantly evaluate the distractions as being potential threats or targets themselves.

If distractions are found to influence shooting performance, future research might include examining whether such influence can be mitigated or nullified over time through specialized training. Such specialized training might be as simple as shooting with distractions present until the shooter's score improves to meet or exceed the score they normally achieve when distractions are not present. An experiment to test whether distractions are something a shooter can learn to tolerate might resemble this experiment in many ways, except that the shooter's score would be saved and reset repeatedly at predetermined time intervals. Thus, each participant would actually generate a *set* of scores; each corresponding to a progressively later time interval, representing progressively greater experience shooting in the presence of distractions. These scores could be plotted as a line graph, with the *x* axis representing time, and the *y* axis representing shooting score. This visual representation of the data could reveal not only an *experience effect*, but also a *fatigue effect*, if, after shooting for so long, a participant becomes physically or mentally fatigued, resulting in a downward trend in shooting performance. This too would be a worthy topic of study, because it could inform military strategists. If, for instance, it is found that engaging in protracted combat causes a fatigue effect that can decrease a soldier's performance, increasing the chance that he or she might make a fatal mistake, this could be an important fact to establish. Commanders who wish to avoid preventable losses might incorporate this proposed fatigue effect into their tactical considerations, perhaps avoiding protracted combat whenever possible by ordering soldiers to disengage from the enemy, only re-engaging once they have had an opportunity to recover their physical and mental stamina.

The gaping deficiency in the psychological literature on the topic of factors that affect shooting performance must be remedied. Many interesting avenues of research might be pursued by future researchers, including the effects of drugs and alcohol on shooting performance, the influence of subject variables like age and gender on shooting performance, whether shooting performance correlates with other subject variables, like self-esteem, self-efficacy, intelligence quotient, level of education, etc., and whether those with military or law enforcement backgrounds shoot any better than civilian firearms enthusiasts. Most military, law enforcement, and civilian concealed carry training courses require recertification by “qualifying” with the firearm one intends to carry every so many months or years, thus ensuring that one's shooting skills have not lapsed to an unacceptably low level. It would be interesting (and of practical significance) to study the time-proficiency curve of shooting performance to discover the extent to which shooting skills diminish over time, and how quickly this occurs.

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Figures

Figure 1. Screen shot of original shooting gallery game (sans distractions).

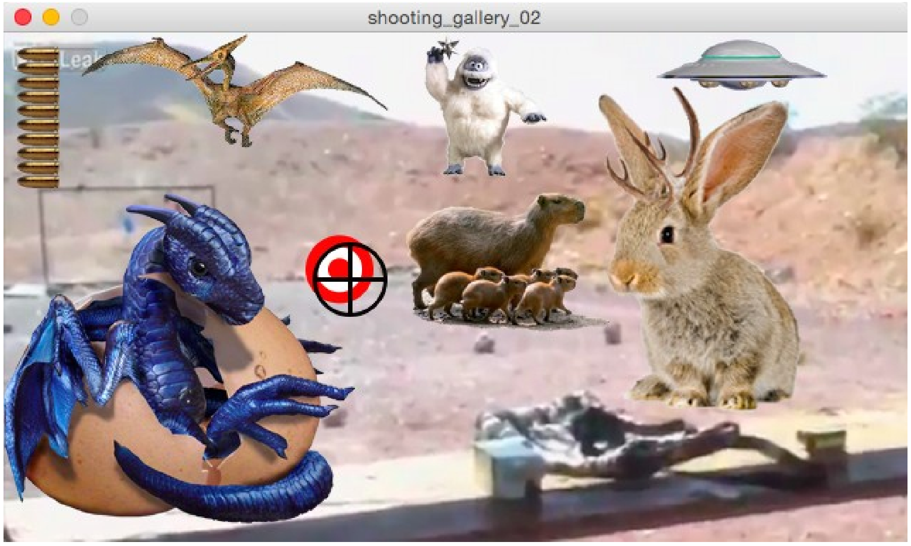

Figure 2. Screen shot of shooting gallery game (with distractions).