How Many Bullets Do You Need? 
Contrasting and Comparing Behavioral 
Outcomes and Cognitive Abilities 
When Using a Semiautomatic Versus 
Automatic Firearm

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Civilian, police, and military policies about firearms attract significant attention, yet the corresponding discussions tend to focus on retrospective evidence, such as the effectiveness of previous policies or reactions to recent tragedy. Less attention is devoted to proactive research issues. In particular, recent evidence has demonstrated a strong link between shooting performance and cognitive abilities, which provides numerous implications for policy decisions, assessment procedures, and firearm training. One important issue is how the weapon’s rate of fire affects performance. Specifically, how does behavior differ when one is using a semiautomatic versus automatic weapon, and which cognitive abilities are most important with each weapon type? Results indicated that participants fired nearly twice as many rounds when armed with automatic versus semiautomatic weapons, yet they showed no difference in successfully neutralizing hostile targets. However, participants were more than twice as likely to inflict civilian casualties with automatic weapons, and different cognitive tasks aligned with the likelihood of inflicting civilian casualties for each specific weapon type. This evidence suggests substantial differences in shooting behavior based on the rate of fire. Furthermore, the cognitive evidence predicted performance regarding hostile casualties and civilian casualties inflicted even when accounting for differences in gender, previous firearm use, and video game experience. This evidence supports the idea that different cognitive mechanisms may underlie different aspects of shooting performance, which could allow for targeted assessments and training based on firearm type.

KEYWORDS: shooting cognition, firearms, guns, rate of fire, semiautomatic, automatic

The second amendment of the U.S. Constitution secures the right to bear arms for all U.S. citizens. This freedom has made firearms a cultural ubiquity in the United States as 34% of U.S. households contain at least one firearm, although even that substantial number is a decline from 50% in the 1970s (Tavernise & Gebeloff, 2013). Given such widespread firearm ownership, it is important to fully understand the pervasive impact of firearms on behavior. Previous research has been largely retroactive, that is, studying the impact, prevalence, or attitudes toward guns and gun control as a policy issue, to track criminal
violations of firearm policies, or in light of a recent tragedy (e.g., Koper, 2014; Laine et al., 2013; Lott, 2013). Recent years have seen a greater emphasis on new forms of training; specifically, what new systems and techniques can we use to improve performance with a firearm?

Firearm Training and Evaluation
Simulators have emerged as one of the primary means to create a suitable training environment with realistic situations in a safe and reliable manner (Bennell, Jones, & Corey, 2007; Getty, 2014; Jensen & Woodson, 2012; Saus et al., 2006). There is the obvious advantage to practicing firearm use in a more realistic scenario than simply firing on a range, although there are significant limitations. Evidence does suggest that deliberate practice alone may not be enough when dealing with trained professionals (Macnamara, Hambrick, & Oswald, 2014), and this issue is only exacerbated by practice having a further limited impact for threat-based scenarios (Nieuwenhuys, Savelsbergh, & Oudejans, 2015).

New alternatives have tried to circumvent the deliberate practice issue with a greater emphasis on selection. In other words, if training alone is not enough, then performance could be improved by finding new predictors to identify the best person for a particular role. For example, numerous factors can be linked to marksmanship performance, including heart rate variability (Thompson, Swain, Branch, Spina, & Grieco, 2015), postural balance (Mononen, Kouttinen, Viitasalo, & Era, 2007), and grip strength (Anderson & Plecas, 2000). These factors represent the typical approach to marksmanship training, which focuses on posture and motor control when pressing the trigger or orienting the weapon (Morrison & Vila, 1998). There are also numerous situational factors and further individual differences that affect performance. For example, shooting performance is strongly affected by racial bias (Correll et al., 2007; Correll, Urald, & Ito, 2006) and stress (Nieuwenhuys, Cañal-Bruland, & Oudejans, 2012; Nieuwenhuys & Oudejans, 2010; Nieuwenhuys et al., 2015; Nieuwenhuys, Weber, Hoeve, & Oudejans, 2016). However, one underexplored predictor involves the cognitive abilities of the shooter. After all, firearm use is often considered a lethal force decision, and so it stands to at least superficial reasoning that cognitive abilities involved in making the decision should likewise be related to the outcome performance.

Some evidence has already started to examine this link. An exploratory study using active duty U.S. soldiers examined whether cognitive abilities correlated with marksmanship performance (Kelley et al., 2011). Their findings indicated that marksmanship was related to numerous cognitive abilities, including attention, spatial orientation, and visual scanning. Although this study helps support a link between cognitive abilities and marksmanship, it remains an initial and exploratory step. Substantial additional research is necessary to fully explore the many different ways cognition could be linked to shooting performance. This information could be exceptionally useful in crafting new policy—both civilian and military—as it pertains to effectively and safely using a firearm. The current question then becomes what information we might already know about the link between firearms and cognition.

The Relationship Between Firearms and Cognition
Substantial evidence has already demonstrated that the mere presence of a weapon affects cognition. The classic finding is known as the “weapon focus effect,” where victims of a crime remember less about an armed perpetrator than an unarmed perpetrator (Loftus, Loftus, & Messo, 1987; Pickel, 1998, 1999; Steblay, 1992; for a recent review, see Fawcett, Russell, Peace, & Christie, 2013). Weapon focus effects occur because the victim pays more attention to weapons than neutral objects, which limits attention toward other aspects of a scene (Hope & Wright, 2007; Kramer, Buckhout, & Eugenio, 1990). However, weapon focus effects are examined primarily in the context of an unarmed observer faced with an armed assailant. Armed observers are influenced by orthogonal cognitive biases in addition to weapon focus effects. For example, an armed person has an increased bias to see guns in the hands of others (Witt & Brockmole, 2012). Armed observers also bias their attention toward faces in a scene, which can counteract the influence of weapon focus effects (Biggs, Brockmole, & Witt, 2013). Both findings demonstrate how holding a weapon can alter cognition beyond the mere presence of a weapon in the scenario.

Although holding a weapon can alter cognitive biases, actually using a firearm is also tied directly
into cognitive functioning. According to the cognitive cascade hypothesis (Biggs, Cain, & Mitroff, 2015), every step in successfully shooting a firearm can be linked to a particular cognitive ability. For example, finding a target involves visual search, distinguishing friend from foe involves object recognition, taking aim involves perceptual judgments of distance and motion, and squeezing the trigger involves response execution (or inhibition to withhold a trigger squeeze). This cognitive cascade presents a series of predictable and necessary steps in successful and safe firearm use. Moreover, each step in the cascade must be completed in turn to reach the desired outcome. An armed person does not know to begin the cascade without finding a target, and poor perceptual judgments in aiming will probably prevent successful execution. Thus, ultimate success requires success at each step, and any operator-based failures in shooting performance can be linked, in theory, to a particular cognitive failure.

The link between cognitive abilities and shooting performance also suggests new potential in firearm training methods. A person with a particular cognitive detriment will probably demonstrate a predictable shooting error, which also provides the possibility for a targeted intervention. For example, response inhibition abilities have been linked to unintended casualties, and furthermore, response inhibition training has been shown to reduce the likelihood of inflicting unintended casualties—at least in simulation (Biggs et al., 2015). This link helps to validate the cognitive cascade hypothesis but also supports a causal relationship between cognitive abilities and shooting performance. Moreover, this evidence could help identify the people most likely to inflict unintended casualties based on cognitive assessments. These people could then receive directed cognitive training before they enter the field to avoid committing the particular errors in question.

STUDY

METHODS

Participants and Sample Selection
All participants (N = 88; mean age = 24.92, SD = 7.48; 52 female) completed a 2-hour session and were given $20 for their time. Participants were recruited from advertisement materials indicating either a single 2-hour session or a 5-day cognitive training initiative to improve attention (see Biggs et al., 2015, for full details). All participants in the cognitive training initiative were recruited with the same materials to provide equivalent expectations across cognitive training groups (Boot, Simons, Stothart, & Stutts, 2013), and all single-session participants completed a session identical to the pretest session of the cognitive training initiative. For the current analyses, 57 participants came from the cognitive training initiative and 31 came from the single session testing. The ad-
Additional participants were recruited for the initial sessions to increase the statistical power for examining individual differences in shooting performance and cognitive abilities. Specifically, power calculations indicated that moderate effect sizes would require a total sample of approximately 63 for the cognitive training assessments and approximately 85 for the individual difference assessments. These total sample size differences result from the different assumptions going into each program and the types of analyses being conducted (e.g., t test vs. correlations).

Research Aims and Objectives

The present study investigated relative performance differences when participants were provided a semi-automatic firearm versus a fully automatic firearm. Simulated shooting environments provided the dependent variables for shooting performance, whereas computer-based tasks provided direct assessments of related cognitive abilities. Shooting assessments included several primary variables to distinguish whether behavior differed based on the weapon’s rate of fire. Direct shooting behaviors were measured through the total number of shots fired and shooting accuracy (i.e., whether a fired shot hit an intended target or not). Casualties inflicted were measured based on the number of “hostile individuals” and “civilians” shot during the exercise (i.e., intended targets vs. unintended targets). Additionally, although behavioral differences and casualties inflicted were the shooting-related, dependent variables of primary research interest, participants explicitly attempted to earn points during the simulations by shooting hostile targets and avoiding civilian targets, thus making the point system the most salient evaluation metric for the participants. Therefore, differences in total points earned were also compared between groups.

This article reports how the five dependent shooting variables (shots fired, accuracy, hostile casualties inflicted, civilian casualties inflicted, and points earned during scenarios) differ based upon the weapon’s rate of fire. The article also provides further in-depth comparisons, including how the shooting simulation metrics relate to previous experience with a firearm, self-reported comfort holding a firearm, and self-reported comfort using a firearm. Finally, the article compares the influence of cognitive abilities with respect to the self-reported firearm experience and comfort levels on how well these various factors predicted performance during the shooting simulations. The Appendix includes an ecological validity assessment of the shooting simulation to determine whether it provides a reasonable facsimile of firing a real weapon.

Simulated Shooting Scenarios

Participants completed each shooting simulation on the Nintendo Wii game Reload: Target Down (2013). Mock firearms were created from a black Wii Motion Plus remote controller positioned inside a black plastic holder (Figure 1). Participants moved the mock weapon in real space to aim and simulated firing by squeezing the trigger, which vibrated to indicate that a round had been expended. Gameplay included a targeting reticle on screen to indicate where the participant currently aimed, and upon a trigger squeeze, a fired shot landed where the target reticle indicated. This particular gameplay element significantly aided participants who may not have been capable of lining up a shot with a real firearm. All participants stood 1.75 m from a 28” LCD screen.

FIGURE 1. Sample stimuli used during the shooting task, including the simulation with a semiautomatic weapon (top left), simulation with an automatic weapon (bottom left), hostile targets to shoot (top right), mock firearm used during simulation (middle right), and civilian targets to avoid (bottom right)
to destroy (i.e., they needed to be hit twice in quick succession). Additional points could be earned by completing a scenario early (i.e., destroying all targets with time still on the clock), and for every remaining second, participants earned 100 points, which encouraged speed as well as accuracy. Participants were instructed to earn as many points as possible, although no one was allowed to advance beyond the practice round without successfully destroying at least 100 targets (5 of 88 participants needed a second practice round to meet the minimum).

**EXPERIMENTAL SCENARIOS.**

Experimental data were collected from two simulated scenarios: “Embassy Training” and “Apartment Training.” The instructions encouraged participants to earn as many points as possible when going through each scenario. The point structure for each experimental scenario remained similar to that of the practice scenario, although the targets changed. Possible targets included hostile targets, for which participants could earn up to 100 points if shot, and civilian targets, for which participants lost 1,000 points if shot. Participants cleared each room by shooting as many hostile targets as possible during the allotted time, and participants earned additional points by clearing a room of hostile targets with time remaining. Hostile and civilian targets were differentiated primarily by clothing and weaponry (Figure 1). Hostile targets aimed weapons at the participant and wore darker clothing, whereas civilian targets were unarmed and wore brighter clothing. There were four possible hostile targets and four possible civilian targets, and although more than four of each could be present in a given room, the actual set of targets contained in a specific room was drawn from these two pools of four possible targets. Actual target positions were selected from a pool of predetermined possible positions within an individual room, but presented targets were randomly assigned to a subset of these possible target positions. Each room presented at least three hostile targets with a maximum of nine hostile targets, and each room presented at least one civilian with a maximum of five civilians. The individual scenario continued until the participant had visited all rooms, or until the participant “failed” by shooting five civilians, at which point their participation in the scenario would be discontinued.

Six total scenarios were completed by each participant. These scenarios were counterbalanced to limit memorization of the possible target positions. If participants went through Embassy Training first, then the order would be Embassy, Apartment, Embassy, Apartment. If the participant went through Apartment Training first, then that participant would begin with a round of Apartment Training and end with Embassy Training. Data from the first attempt at completing each scenario were discarded because of the newly introduced gameplay elements; specifically, the scenario was the first time participants encountered hostile and civilian targets after a briefing as to their identities, the first time participants used a fully automatic weapon in simulation, or potentially both. Furthermore, the first pass established the personal score to beat for that participant in that specific scenario. Participants were reminded of this score during subsequent scenarios and encouraged to beat their personal best. This gameplay element provided participants with incentive and an attainable goal structure when participating in subsequent scenarios, and similar gamification elements have been suggested to ensure effortful performance (cf. Miranda & Palmer, 2014). The final four scenarios (two from Embassy Training and two from Apartment training) constituted the experimental dataset.

**DEPENDENT VARIABLES.**

Several dependent variables were obtained from the shooting scenarios: two variables about shooting behaviors and two variables about casualties inflicted. Shooting behavior variables included the number of shots fired and shooting accuracy. Shots fired represents the total number of simulated rounds expended during a particular scenario. Shooting accuracy represents the percentage of expended rounds that struck a hostile target. Casualties inflicted includes both hostile casualties and civilian casualties. Hostile casualties represents the number of intended targets hit, which participants earned points for shooting. Civilian casualties represents the number of unintended targets hit, which participants lost points for shooting. Finally, total points earned served as the primary and most salient performance metric from the participants’ point of view. Total points earned represents the outcome performance of the scenarios based on the points accumulated by accurately shooting hostile targets, accidentally shooting civilian targets, and any bonus points earned for clearing a room early.

**Survey Assessments**

Participants provided several pieces of information about themselves via self-report survey. This information included age, gender (male or female), previous firearm experience (“Have you previously used a firearm?”; yes or no), comfort holding a firearm
Computer-Based Cognitive Assessments

Two response inhibition assessments were included in these analyses because response inhibition has been linked to the likelihood of inflicting civilian casualties (Biggs et al., 2015). Participants completed both tasks on Dell Vostro 260 computers with 23.6” widescreen LCD monitors. Stimuli were presented and responses collected with Matlab software (The MathWorks, Natick, MA) and the Psychophysics Toolbox version 3.0.8 (Brainard, 1997; Kleiner, MathWorks, Natick, MA) and the Psychophysics Toolbox version 3.0.8 (Brainard, 1997; Kleiner, MathWorks, Natick, MA) and the Psychophysics Toolbox version 3.0.8 (Brainard, 1997; Kleiner, MathWorks, Natick, MA). Each participant sat approximately 57 cm away from the monitor.

Go/No-Go Task. Blue and orange squares (1.32° × 1.32°) appeared against a gray background at fixation. Participants identified whether a “go signal” or “no-go signal” was present by either hitting the spacebar when the go signal appeared or withholding a response when the no-go signal appeared. Signal color was counterbalanced across participants, where half saw a blue go signal and orange no-go signal, and the other half saw the remaining color combination. Each trial began by presenting a fixation circle to participants for a random interval between 0.5 s and 1.5 s. The square stimulus then appeared for up to 2 s or until response before the computer automatically proceeded to the next trial. In total, the procedure included 20 practice trials and 200 experimental trials. Both practice and experimental trials divided the task into 80% go signals and 20% no-go signals. Response time was measured as the average time to correctly respond to the presence of a go signal. Accuracy was measured as the percentage of trials displaying a no-go signal in which the participant correctly withheld a response.

Stop Signal Reaction Time (SSRT). The SSRT task assessed the ability to withhold an initiated response, which provides a more nuanced measure of response inhibition than a straightforward go/no-go task. As with the go/no-go task, participants were assigned a “go” color and a “stop” (i.e., no-go) color. However, every stimulus began as a go signal, and only a subset of trials included a stimulus that changed color from the go signal color to the stop signal color. Participants were instructed to withhold any response if they saw the signal change into the stop signal.

Each trial started with a fixation circle that appeared on screen for a random duration between 1.25 s and 1.625 s. Green and purple squares (3.18° × 3.18°) were the experimental stimuli, which appeared against a black background at fixation. Participants were randomly assigned one color as a go signal and one color as a stop signal. Go signal stimuli appeared on screen and remained on screen until response, whereas stop signal stimuli appeared on screen and remained on screen for 1 s. Responses were made by pressing a spacebar for the assigned go signal, although participants had to keep from responding if the stimulus changed into the stop color. Go signal trials constituted two thirds of all trials, and stop signal trials constituted one third of all trials. Participants completed a practice block (90 trials) before the experimental trials, although the practice trials were not used for any analyses. Experimental trials continued until the participant reached 312 trials or spent more than 16 min to complete the task (1 of 88 participants reached the time limit). Participants received a warning “beep” sound during experimental trials if their response time exceeded their mean go signal response time from the practice block by more than two standard deviations (to emphasize speed in responding).

Data Analysis

All statistical analyses were evaluated against a statistical significance level of $\alpha = .05$; that is, a finding will be significant if $p \leq .05$. For theoretical reasons, the evaluations were divided into three groups: behavioral differences, survey results, and cognitive comparisons. Behavioral differences require numerous $t$ tests, and to avoid inflating the error rate, the alpha level was adjusted based on the number of comparisons. In this case, 7 $t$ tests were conducted, and so a finding was considered significant if $p \leq .007 (\alpha = .05/7 = .007)$. Notably, all $t$ tests for these behavioral findings
RESULTS

Shooting Behaviors
See Table 1 for full descriptive statistics of shooting performance metrics. Participants fired significantly fewer shots when provided a semiautomatic weapon (\(M = 149.89, SE = 2.88\)) versus an automatic weapon (\(M = 296.11, SE = 7.40\)), (t(87) = 21.53, \(p < .001\), \(d = 2.78\)). Similarly, accuracy was significantly higher when participants used a semiautomatic weapon (\(M = 75.82\%, SE = 0.94\%\)) versus an automatic weapon (\(M = 39.00\%, SE = 0.89\%\)), (t(87) = 35.17, \(p < .001\), \(d = 4.31\)). These findings are not surprising because an automatic weapon can fire significantly more rounds per second than a semiautomatic weapon. However, it is a necessary methodological check to determine whether participants truly used the capabilities of a fully automatic weapon, and given the robust difference, it validates the opportunity to explore further outcome differences between these weapon types. Notably, these effect sizes exceed what Cohen (1992) considered to be a small \((d = 0.20)\), medium \((d = 0.50)\), or large effect \((d = 0.80)\).

### TABLE 1. Descriptive Statistics for Shooting Behaviors by Weapon Rate of Fire

<table>
<thead>
<tr>
<th>Weapon rate of fire</th>
<th>Semiautomatic (SEM)</th>
<th>Automatic (SEM)</th>
<th>Difference</th>
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<tbody>
<tr>
<td>Shots fired</td>
<td>149.89 (2.88)</td>
<td>296.11 (7.40)</td>
<td>146.22**</td>
</tr>
<tr>
<td>Shooting accuracy</td>
<td>75.82% (0.94%)</td>
<td>39.00% (0.89%)</td>
<td>36.81%**</td>
</tr>
<tr>
<td>Hostile casualties</td>
<td>112.19 (1.84)</td>
<td>111.64 (2.21)</td>
<td>0.56</td>
</tr>
<tr>
<td>Civilian casualties</td>
<td>3.34 (0.22)</td>
<td>7.26 (0.26)</td>
<td>3.92**</td>
</tr>
<tr>
<td>Points earned</td>
<td>19,496 (659)</td>
<td>14,319 (723)</td>
<td>5,177**</td>
</tr>
</tbody>
</table>

Note: Shots fired represents the total number of rounds shot during the scenarios; shooting accuracy represents the percentage of shots fired that struck an intended target; hostile casualties represents the number of intended targets shot during the scenarios; civilian casualties represents the number of unintended targets shot during the scenarios; points earned represents the total number of points accumulated during the scenarios. Standard errors are presented in parentheses, and difference scores are presented as absolute values.

*p < .05; **p < .001.
Casualties Inflicted
Participants did not inflict more hostile casualties (i.e., shooting intended targets) whether they used a semiautomatic weapon (M = 112.19, SE = 2.21) versus an automatic weapon (M = 111.64, SE = 2.21), t(87) = 0.38, p = .70. However, participants did inflict significantly fewer civilian casualties (i.e., shooting unintended targets) with a semiautomatic weapon (M = 3.34, SE = 0.22) versus an automatic weapon (M = 7.26, SE = 0.26), t(87) = 13.84, p < .001, d = 1.75. With the automatic weapon, participants actually shot more than twice as many civilian targets compared with the semiautomatic weapon.

One obvious concern is that unintended targets were more likely to be shot as more rounds were fired. However, the correlation between shots fired and civilian casualties inflicted was not significant for the automatic weapon, r(86) = –.06, p = .58. Thus, although participants with an automatic weapon shot more civilians on average, there was no relationship between civilian casualties inflicted and the total number of shots fired. Interestingly, though, the correlation between shots fired and civilian casualties inflicted was significant for the semiautomatic weapon, r(86) = .37, p < .001. This distinction probably suggests strategic and behavioral differences in performance based on weapon type, which will be addressed further in the General Discussion.

Points Earned
Total points earned in the scenarios remained the most salient aspect of performance for participants, and the point structure was identical for scenarios including the semiautomatic weapon or the automatic weapon. Participants scored significantly more points on average with a semiautomatic weapon (M = 19,496.35, SE = 659.46) compared with an automatic weapon (M = 14,318.89, SE = 722.95), t(87) = 10.53, p < .001, d = 0.80. Although participants could conceivably clear rooms faster with automatic weapons, and thereby earn more points, participants scored higher with semiautomatic weapons rather than automatic weapons. Notably, civilian casualties accounted for nearly three quarters of the difference, on average, because participants lost 1,000 points per inflicted civilian casualty (mean difference of civilian casualties = 3.92; mean earned points difference = 5,177; 3,920/5,177 = 75.72%). Therefore, the discrepancy in total points earned was attributable largely to inflicting unintended casualties.

Survey Comparisons
See Tables 2 and 3 for descriptive statistics. A 2 × 2 × 2 mixed model ANOVA was conducted with 2 between-subject factors in gender (male, female) and previous firearm use (fired a gun previously, never fired previously), and the single within-subject factor being hostile casualties inflicted based on weapon rate of fire (semiautomatic or automatic). There was a significant main effect of gender as men inflicted more hostile casualties (M = 118.09 hostiles, SE = 2.87 hostiles) than women (M = 108.27 hostiles, SE = 2.45 hostiles), F(1, 83) = 6.76, p = .01, ηp² = 0.08. There was also a significant main effect of previous use as those who had previously used a firearm inflicted more hostile casualties (M = 118.09 hostiles, SE = 2.87 hostiles) than those who had never previously used a firearm (M = 108.27 hostiles, SE = 2.45 hostiles), F(1, 83) = 4.41, p = .04, ηp² = 0.05. Notably, these two findings overlap as men had significantly higher scores due to the significant main effect of gender. However, the interaction between gender and previous use was not significant, indicating that the effect of previous use was consistent across genders.

### Table 2. Descriptive Statistics for Hostile Casualties by Gender and Previous Firearm Experience

<table>
<thead>
<tr>
<th></th>
<th>Hostile casualties</th>
<th>Civilian casualties</th>
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<tbody>
<tr>
<td></td>
<td>Semiautomatic (SEM)</td>
<td>Automatic (SEM)</td>
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<tr>
<td>Gender</td>
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<tr>
<td>Female (N = 52)</td>
<td>107.54 (2.22)</td>
<td>107.37 (2.63)</td>
</tr>
<tr>
<td>Male (N = 36)</td>
<td>118.92 (2.83)</td>
<td>117.81 (3.65)</td>
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<tr>
<td>Firearm experience</td>
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<tr>
<td>Yes (N = 38)</td>
<td>116.29 (2.51)</td>
<td>118.66 (2.94)</td>
</tr>
<tr>
<td>No (N = 49)</td>
<td>109.27 (2.60)</td>
<td>106.37 (3.06)</td>
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more previous firearm experience than women, $\chi^2(1, N = 88) = 4.32, p = .05^1$.

A 2 × 2 × 2 mixed model ANOVA was conducted with 2 between-subject factors in gender (male, female) and previous firearm use (fired a gun previously, never fired previously) and the single within-subject factor being civilian casualties inflicted based on weapon rate of fire (semiautomatic or automatic). There was a significant main effect involving rate of fire as more civilian casualties were inflicted with an automatic weapon than a semiautomatic weapon, $F(1, 83) = 165.74, p < .001, \eta^2_p = 0.67$. However, this effect was reported previously in the behavioral findings. No other main effects or interactions were significant (all $p$s > .25, except the interaction between rate of fire and gender, which had a $p$ value of .12).

Cognitive Tasks
For the semiautomatic weapon, civilian casualties were significantly related to no-go signal accuracy in the go/no-go task, $r(86) = .31, p < .01^*$ $r(86) = .25, p = .02^*$ $r(86) = .24, p = .02^*$ $r(86) = -.05, p = .65$

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| First-person shooter expertise ($N = 88$, $M = 1.95, SD = 1.94$) | $r(85) = .23, p = .04^*$ $r(85) = .18, p = .11$ $r(85) = .06, p = .59$ $r(85) = -.15, p = .18$
| Comfort holding ($N = 87$, $M = 4.59, SD = 2.49$) | $r(84) = .13, p = .22$ $r(84) = .18, p = .10$ $r(84) = .07, p = .54$ $r(84) = -.12, p = .27$
| Comfort using ($N = 86$, $M = 3.72, SD = 2.38$) | $r(84) = .13, p = .22$ $r(84) = .18, p = .10$ $r(84) = .07, p = .54$ $r(84) = -.12, p = .27$

Note that first-person shooter gaming expertise is reported on a 0 (none) to 6 (expert) Likert-type scale, whereas the comfort holding a firearm and comfort using a firearm are reported on a 1 (not at all) to 9 (very) Likert-type scale. $^*p < .05; ^{**}p < .001$.
beyond gender, firearm experience, and gaming expertise. Moreover, the combined self-report measures accounted for none of the variance in civilian casualties inflicted, whereas inhibitory control could explain a significant portion of the variance. This evidence further highlights the importance of cognitive abilities in predicting and assessing firearm performance.

**GENERAL DISCUSSION**

Firearm use is particularly widespread in some cultures, such as in the United States, yet most research into firearm or gun control has been retroactive, that is, discussed in light of past events or tragedies rather than ongoing and pervasive issues. For example, evidence is often provided relative to past bans or protocols (Gius, 2014, 2015a, 2015b; Lanza, 2014; Safavi et al., 2014), the relationship between gun ownership and violent crimes (Kleck & Patterson, 1993; Siegel et al., 2014; Siegel, Ross, & King, 2013), or the relationship between gun sales and criminal use (Koper, 2014; Webster, Vernick, McGinty, & Alcorn, 2013). In discussing firearm policy, less discussion centers on the mental processes involved in the act of shooting a firearm, probably because the relationship between cognitive abilities and firearm use is poorly understood. The current study intended to fill some of this gap by providing empirical evidence as to behavioral and cognitive differences when providing someone with a semiautomatic weapon versus an automatic weapon.

The results indicated that participants in these shooting simulations fired fewer shots when given a semiautomatic weapon versus an automatic weapon. Similarly, participants demonstrated higher accuracy with a semiautomatic weapon versus an automatic weapon. These differences are consistent with the basic functionality of the weapon type and serve largely as a methodological check against this manipulation rather than an innovative finding. Despite the robust differences in fundamental shooting behaviors, there was no difference in the number of hostile casualties inflicted between the weapon types. However, participants did inflict approximately half as many civilian casualties with a semiautomatic weapon as with an automatic weapon. This disparity suggests that using an automatic weapon may come with an increased chance of inflicting collateral damage, yet an automatic weapon might not result in increased effectiveness against hostile targets.

**Strategic Versus Disposition: Itchy Trigger Finger or an Itchy Brain?**

An important discussion point then becomes whether civilian casualties were related to the total number of shots fired, especially given the substantial decrease in total shots fired with a semiautomatic weapon relative to an automatic weapon. For the semiautomatic weapon, fewer total shots were fired, yet there was a significant relationship between number of shots fired and the likelihood of inflicting a civilian casualty. This evidence suggests that firing additional shots with a semiautomatic significantly increased the likelihood of hitting a noncombatant, which could be attributed to taking fewer strategic, carefully aimed shots. Conversely, for the automatic weapon, there was no significant relationship between the number of shots fired and the likelihood of inflicting a civilian casualty. This discrepancy indicates that the increased civilian casualties cannot be attributable solely to the increased number of shots fired by the automatic weapon.

An automatic weapon may carry the increased probability of hitting a noncombatant, yet it appears...
that the added potential for collateral damage is attributable to characteristics of the shooter rather than the increased rate of fire. Previous evidence has attributed this danger to reduced response inhibition abilities (Biggs et al., 2015). However, the issue may be more sensitive as to the specific inhibitory control involved in the task. The current evidence demonstrated that increased civilian casualties were related to a go/no-task for a semiautomatic weapon, whereas increased civilian casualties were related to an SSRT task for an automatic weapon. At face value, this distinction makes logical sense because each inhibitory control task better replicates the response inhibition condition relevant to the specific weapon type. A go/no-go task requires that a participant either make a response or withhold a response to a single stimulus, which maps well conceptually onto a semiautomatic weapon as each additional shot requires an additional response (i.e., trigger squeeze). An SSRT task requires a participant to withhold an initiated response because a particular stimulus can change mid-trial, which maps conceptually well onto an automatic weapon because a shooter must inhibit the initiated response (i.e., the trigger squeeze) to cease firing. Subtle differences in these cognitive tasks may thus have important differences in describing and predicting shooting behaviors. In this case, it is not simply that inhibitory control is related to the likelihood of inflicting civilian casualties. Specific differences in the inhibitory control task can map onto very important differences in the weapon type concerned.

These new findings also suggest that cognitive factors may be as important in evaluating shooting performance as physiological factors. Previous research has noted important relationships between marksmanship performance and heart rate variability (Thompson et al., 2015), postural balance (Mononen et al., 2007), and grip strength (Anderson & Plecas, 2000). However, the current research suggests that underlying cognitive abilities may have a predictive power independent of these differences. When considered along numerous other factors with cognitive implications such as racial biases (Correll et al., 2007) or anxiety (Nieuwenhuyx & Oudejans, 2010, 2011), cognitive predictors represent one of the largest and most underexplored possibilities in performance predictors and training methods. This approach would be a departure from typical marksmanship training that focuses on posture and motor control (Morrison & Vila, 1998), although new cognitive evaluation and training methods could be developed to supplement—not replace—existing methods to yield an overall improvement in firearms safety and performance.

Implications of the Current Findings
When one is evaluating someone’s readiness to use a firearm, both before they begin training and even after training, specific cognitive tasks could be used to determine the person’s likelihood of committing a particular type of error. For example, based on the evidence provided here, automatic weapons may not be well handled by people with poor abilities to withhold an initiated response (e.g., as measured through an SSRT task). People could potentially be screened on this factor before handling this particular weapon type. Alternatively, inhibitory control training could be assigned to all people who will handle an automatic weapon. Either possibility represents an important policy issue arising from the link between cognitive abilities and firearm use. Specifically, this shooting–cognition link creates the potential for new evaluation and training, which could address some gun control issues based on proactive elements, such as related cognitive abilities, rather than solely basing policy on retroactive incidents.

Furthermore, the evidence provided here cannot be taken solely as evidence against the use of automatic weapons. The data suggest that these firearms carry an increased likelihood of inflicting civilian casualties without a corresponding increase in hostile casualties, yet there are numerous situations where automatic weapons could prove beneficial. For example, automatic weapons can provide suppressing fire in a far more effective and efficient manner than semiautomatic weapons. Although this example concerns primarily military operations or some special response law enforcement teams, the particular uses for any given weapon must be considered when determining the appropriate situations for it and the relevant cognitive abilities for those situations.

Limitations and Future Directions
When interpreting these findings for policy issues regarding firearm use, it is also important to consider the possible limitations of the methodological design. Foremost, our participant population included primarily untrained people recruited from
the community sample. This quality could limit any possible translation of this research to a more highly trained participant population. However, several aspects of gameplay, such as the targeting reticule, aided untrained participants and allowed a more focused examination involving the shooting–cognition link without several extraneous factors (e.g., can the participant accurately line up a shot, how well can the participant handle the weapon recoil). It is also important to consider that an untrained population can yield important insights regarding firearm legislation. Substantial training may be necessary when it comes to properly handling different firearms, but substantial training is not necessary when it comes to owning firearms. Several effects observed here could be exacerbated by an untrained population when they are not provided the shooting aids available in gameplay. Specifically, gameplay limited the weapon’s recoil, which is a significant problem when handling an automatic weapon. Even trained people can struggle to keep high levels of accuracy when handling the nearly continuous recoil of an automatic weapon. There is also specific literature to note that cognitive predictors can differ between trained and untrained people even if they are completing the same task (Biggs & Mitroff, 2014; Biggs, Cain, Clark, Darling, & Mitroff, 2013), which brings up a multitude of issues in attempting to translate basic science research findings to field applications (Clark, Cain, Adamo, & Mitroff, 2012).

These limitations suggest the need for caution and nuanced interpretation when considering the impact of these results for many different situations involving firearms, yet there remains a persistent need for continued research in this area so that policy issues and corresponding legislation can be informed by empirical evidence about the shooting–cognition link. Taken together, these points suggest that there may be robust behavioral differences and cognitive relationships when a person is using a semiautomatic versus automatic weapon, yet these findings must be replicated in a population with more firearm expertise and using as realistic or more realistic shooting simulators.

Summary

In conclusion, important behavioral differences and inclinations underlie the different capabilities of a semiautomatic weapon versus an automatic weapon. People may be more prone to inflicting collateral damage with an automatic weapon without a corresponding increase in effective rounds on target, although there remain numerous situations where an automatic weapon is a necessary tool. Beyond the empirical evidence into the broad behavioral differences between semiautomatic and automatic weapons, the present findings also offer insight into how subtle differences in cognitive abilities can have important implications when applied to real-world weaponry. For example, a go/no-go task maps cognitively and conceptually better onto a semiautomatic weapon, whereas an SSRT task maps cognitively and conceptually better onto an automatic weapon—at least as far as the likelihood of inflicting civilian casualties is concerned. Additional evidence can help inform the shooting–cognition link, and ultimately this evidence is essential in helping craft future public policy and legislation that seeks to be proactive about firearm use rather than purely reactive.

APPENDIX. ECOLOGICAL VALIDITY OF THE SHOOTING SIMULATION

One important issue is whether the shooting simulation can generalize to a realistic shooting task. Although the current study does not involve shooting assessments with live ammunition, previous firearm experience can be compared with in-task performance with the hypothesis that those with prior weapon experience should perform better on a shooting simulation than those without prior weapon experience. Of the 88 participants, 38 had previous weapon experience and 49 had no weapon experience (1 did not answer the questions about weapon experience). This difference allowed for a broad split between participants based on prior weapon experience. The clear hypothesis is that people with prior weapon experience should perform better, which establishes sufficient criteria to perform one-tailed t-tests, thus evaluating a measure of significance against a p value of 0.10 rather than 0.05.

The baseline scenario provided a simulated shooting range, which served as a practice session for the experimental data, but also the first experience using the mock weapon in simulation. Participants with prior weapon experience had better accuracy during the baseline session ($M = 64.48\%$, $SE = 1.63\%$) than participants without prior weapon experience ($M = 60.00\%$, $SE = 1.59\%$), $t(85) = 1.94$, $p = .06$, $d = 0.42$; participants with prior weapon experience hit more targets during the baseline session ($M = 162.79$, $SE = 3.89$) than participants without prior weapon experience ($M = 152.14$, $SE = 5.01$), $t(85) = 1.68$, $p = .10$, $d = 0.35$; and participants with prior weapon experience scored more points during the baseline session ($M = 142.46$, $SE = 6.43$) than participants without prior weapon experience ($M = 12,331$, $SE = 668$),...
t(85) = 2.02, p = .05, d = 0.44. Thus, there are reasonable differences between the two groups based on performance in the practice round. However, no participant had performed this particular task previously, and so adapting and identifying aspects of gameplay could complicate any differences due to previous weapon experience.

For the actual experimental sessions, participants had sufficient practice after the simulated shooting range to adapt their existing skillsets to the parameters of the gameplay. These experimental scenarios, from which the key experimental data are drawn, provided a better view of the differences between groups. In this case, the hypothesis is once again that participants with prior weapon experience should perform better than participants without prior weapon experience. The primary goal of the experimental shooting scenarios involved shooting hostile targets. For this variable, participants with prior weapon experience shot significantly more intended targets (M = 234.95, SE = 5.00) than participants without prior weapon experience (M = 215.63, SE = 5.33), t(85) = 2.58, p < .01, d = 0.56. Participants with prior weapon experience had also better accuracy during the experimental sessions (M = 59.11%, SE = 1.05%) than participants without prior weapon experience (M = 56.15%, SE = 1.03%), t(85) = 1.99, p < .05, d = 0.43; and participants with prior weapon experience scored more points during the experimental sessions (M = 36,554, SE = 1,880) than participants without prior weapon experience (M = 31,777, SE = 1,766), t(85) = 1.84, p < .07, d = 0.40.

Taken together, these data show numerous significant differences between participants with prior weapon experience and participants without prior weapon experience on numerous aspects of performance, including number of targets hit, accuracy, and points scored in both the practice session and the experimental sessions. These shooting simulations therefore provide at least a reasonable proxy for the actual task being simulated.

NOTES
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1. Men actually self-reported significantly higher on most aspects of firearm use than women, including men being more comfortable holding a gun than women, t(85) = 2.97, p < .01, d = 0.65, men being more comfortable using a firearm than women, t(84) = 3.07, p < .01, d = 0.67, and men having more first-person shooter gaming experience than women, t(86) = 7.07, p < .001, d = 1.48.

REFERENCES
between the lab and the field. In The influence of attention, learning, and motivation on visual search (pp. 147–181). New York, NY: Springer.


