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Cognitive Training Can Reduce Civilian Casualties in a Simulated Shooting Environment

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Abstract
Shooting a firearm involves a complex series of cognitive abilities. For example, locating an item or a person of interest requires visual search, and firing the weapon (or withholding a trigger squeeze) involves response execution (or inhibition). The present study used a simulated shooting environment to establish a relationship between a particular cognitive ability and a critical shooting error—response inhibition and firing on civilians, respectively. Individual-difference measures demonstrated, perhaps counterintuitively, that simulated civilian casualties were not related to motor impulsivity (i.e., an itchy trigger finger) but rather to an individual's cognitive ability to withhold an already initiated response (i.e., an itchy brain). Furthermore, active-response-inhibition training reduced simulated civilian casualties, which revealed a causal relationship. This study therefore illustrates the potential of using cognitive training to possibly improve shooting performance, which might ultimately provide insight for military and law-enforcement personnel.

Keywords
shooting cognition, guns, attention, response inhibition, cognitive training, civilian casualties

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Shooting a firearm involves a complex cascade of actions, and each action can be linked to a specific cognitive ability. For example, finding appropriate targets involves visual search, determining whether someone is a friend or foe involves decision-making processes, taking aim involves perceptual estimations of distance and motion, and squeezing the trigger (or withholding the shot) involves response execution (or inhibition). Given this hypothesized series of cognitive functions, shooting behaviors provide an excellent opportunity to examine the links between action and cognition. However, there is little existing evidence linking shooting performance and cognition, which is why, in the current study, we attempted to support this larger concept by providing initial evidence to tie a particular shooting error to a particular cognitive ability.

The present investigation focused on one potential relationship between shooting and cognition—civilian casualties and response inhibition. Civilian casualties occur when shooters hit noncombatants with weapons fire (Kahl, 2007; Wright, 2003; cf. friendly-fire incidents, in which an ally is hit with weapons fire; Webb & Hewett, 2010), and this critical shooting error can have dramatic psychological, ethical, economic, and practical implications. Thus, every effort should be made to minimize these occurrences. In the current project, we looked to understand and provide potential insight into reducing civilian casualties by comparing performance in a simulated shooting environment with response inhibition—the ability to stop performing an already initiated behavior (Eagle et al., 2008; Logan, 1994; Logan, Schachar, & Tannock, 1997; Menon, Adleman, White, Glover, & Reiss, 2001; Verbruggen & Logan, 2008). For example, when

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you start to hit the "send" button on an e-mail, you might suddenly realize that it is addressed to the wrong person. Sometimes you abort the button-press behavior (i.e., successful response inhibition), but sometimes you do not (i.e., failed response inhibition). Initiated responses can be successfully withheld despite very brief time windows between the decision to respond and the response-inhibition signal (Bissett & Logan, 2011; Chikazoe et al., 2009; Leotti & Wager, 2010), although this process can be cognitively challenging. When applying the logic of response inhibition to shooting a firearm, consider the situation in which shooters initiate the process to fire the weapon—but then realize that their target is a civilian. In this case, the shooters must rely on response-inhibition skills to successfully inhibit a trigger squeeze.

Exploring this particular relationship between shooting and cognition can offer numerous practical benefits. First, the action-cognition links between shooting and cognitive abilities could help identify individuals well-suited for performing specific shooting tasks—or conversely, individuals who are most likely to make particular types of errors. For example, if the proposed relationship between civilian casualties and response inhibition exists, the individuals most likely to inflict civilian casualties could be identified before being sent into combat. Second, if specific cognitive abilities can predict specific aspects of shooting performance, then individualized training could be developed to help individuals avoid the particular errors to which they are predisposed. Ultimately, these combined efforts could potentially inform military and law-enforcement efforts in performance, training, and evaluation. Such new training methods are particularly important given recent evidence that deliberate practice alone may not be as influential for performance in professional tasks as once believed (Macnamara, Hambrick, & Oswald, 2014). That said, new training methods do not dismiss the importance of practice in improving performance; rather, they highlight the potential in improving performance beyond practice alone.

The present study contained three components to test this proposed relationship: baseline participants to assess relationships between attentional abilities and simulated civilian casualties, a response-inhibition training (RIT) group to assess the efficacy of training, and an active control training group (visual search training, or VST). Baseline measurements consisted of shooting performance, cognitive abilities, and self-report surveys to examine whether simulated civilian casualties were related to individual differences in response inhibition, attentional deficits, or impulsivity. RIT consisted of three sessions with a 30-min computer-based stop-signal reaction time (SSRT) task and a 30-min iPad-based go/no-go task. VST consisted of three sessions with a 1-hr, computer-based visual search task designed to enhance search consistency (Biggs, Cain, Clark, Darling, & Mitroff, 2013; Biggs & Mitroff, 2014). Both training groups completed a 5-day protocol: a 2-hr pretraining session on Day 1, a 1-hr cognitive-training session on Days 2 through 4, and a 2-hr posttraining session on Day 5.

The key dependent variable was civilian casualties within a simulated shooting environment that contained both intended targets (i.e., hostile individuals) and unintended targets (i.e., civilians; see Fig. 1). This simulated shooting scenario was designed to model the key components of realistic shooting, including squeezing a trigger to fire and moving the mock firearm in real space to aim. We hypothesized that response inhibition would be related to the number of simulated civilian casualties inflicted, and therefore training response-inhibition abilities would reduce these unintended casualties. Notably, cognitive-training designs can be subject to various methodological concerns, such as placebo effects (Boot, Simons, Stothart, & Stutts, 2013; Green, Strobach, & Schubert, 2014; Stothart, Simons, Boot, & Kramer, 2014), which is why we used an experimental protocol with two active training groups. Visual search, while possibly related to overall shooting performance, is not conceptually related to this particular shooting error. As such, VST should not reduce simulated civilian casualties, but this active training reduces methodological concerns about placebo effects because both groups are actively training—albeit through conceptually different procedures.

Method

Participants

All participants (N = 88; mean age = 24.92 years, SD = 7.48; 52 female, 36 male) completed the baseline session. A subset (n = 57) was randomly assigned to either the RIT (28 participants) or VST (29 participants) condition. The number of participants was determined prior to collecting data and was based on a reasonable number for individual-difference analyses (approximately 30 per training group and more than 80 participants for baseline analyses). We stopped collecting data when we reached participant numbers that satisfied these criteria.

Procedure

All participants completed a 2-hr baseline (pretraining) session on Day 1, in which they played the shooting game and completed five surveys and four computer-based tasks. In addition, the two training groups completed a 1-hr cognitive-training session on Days 2 through 4 and a 2-hr posttraining session on Day 5, in which they again played the shooting game.

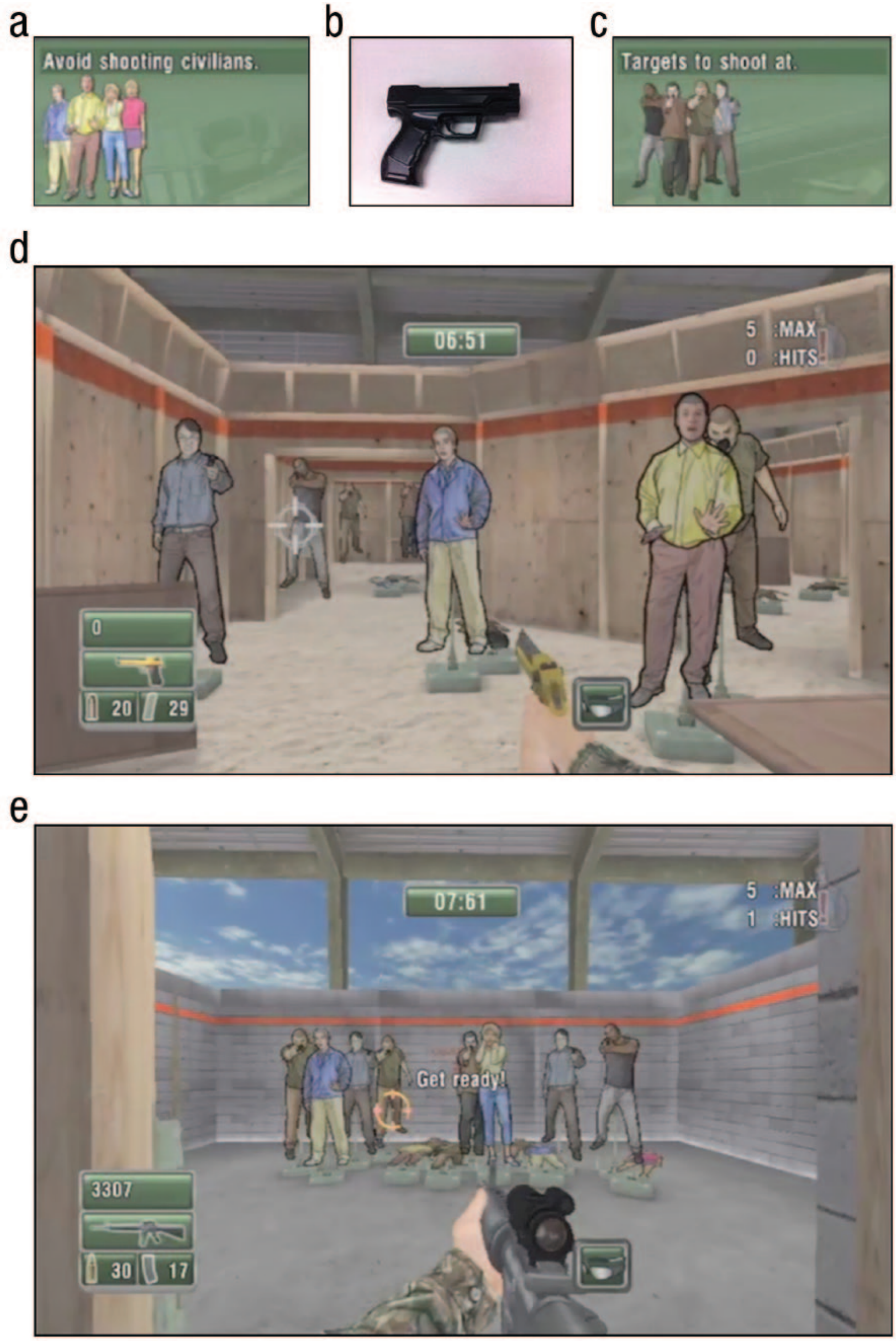

Fig. 1. Sample screen shots and equipment from the video game *Reload: Target Down* for the Nintendo Wii (Mastiff, 2013; reprinted with permission). The top row provides examples of (a) an instructional screen showing which civilian targets to avoid, (b) a remote used to simulate firing a weapon during the experiment, and (c) an instructional screen showing which hostile targets to shoot. The two experimental scenarios—(d) "Embassy Training" and (e) "Apartment Training"—included both unarmed civilians and hostile individuals pointing weapons.

Baseline session

Surveys. Five self-report surveys were administered to participants. The Jasper-Goldberg Adult ADD Questionnaire (Jasper & Goldberg, 1993) assesses attention-deficit/hyperactivity disorder (ADHD) symptoms, with higher scores indicating more symptoms. The Barratt Impulsivity Scale (Barratt, 1959; Patton, Stanford, & Barratt, 1995) uses three subscales to measure various forms of impulsivity: attentional impulsivity, motor impulsivity, and nonplanning impulsivity. The Autism-Spectrum Quotient (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001) measures autism symptoms, with higher scores indicating more symptoms. The Maximization Scale (Schwartz et al., 2002) assesses an individual's desire to maximize outcomes. Finally, we administered a video-game questionnaire constructed in the Duke Visual Cognition Lab (see Appelbaum, Cain, Darling, & Mitroff, 2013), which measured self-reported expertise, preferences, and extent of video-game playing. Note that survey data were excluded only if participants did not complete all questions for that particular scale.

Simulated shooting scenarios. All shooting scenarios were completed on the Nintendo Wii game *Reload: Target Down* (Mastiff, 2013). Participants stood 1.75 meters away from a 28-in. LCD television screen. A black Wii Motion Plus remote was placed into a black plastic holder designed to resemble a more realistic weapon (see Fig. 1b). Participants simulated shooting a firearm by squeezing the trigger, which caused the remote control to vibrate as identification that the shot had been fired. A targeting reticle appeared on screen to indicate precisely where the gun was aimed, and a shot would land precisely at the center of the crosshairs after a trigger squeeze. This aspect of game play provided the opportunity to explore shooting cognition while minimizing concerns about whether the participant could accurately aim.

All participants began with a practice round (on a simulated shooting range) to become accustomed to game play. The simulated weapon for the entire round was a semiautomatic pistol. Different targets appeared (e.g., paper bull's-eyes, silhouettes, bottles), and the game slowly introduced various elements to participants (e.g., the timer indicating how much time remained in the round). Each shot could earn a maximum of 100 points depending on how accurately the participant hit each simulated target. Targets burst apart on being shot, and a number appeared in white above the target to indicate how many points had been earned. Some targets in later practice rounds required a "double tap" to destroy, which required that participants hit the target twice in rapid succession—a procedure that helped participants become accustomed to firing multiple shots in short order. Points could also be earned by completing a round (i.e., destroying all targets) with time remaining; 100 points were awarded for every second remaining on the timer. This encouraged participants to shoot all targets as quickly as possible in addition to as accurately as possible. Participants were instructed to gain as many points as they could during the round, although no participant was allowed to advance beyond the practice round without successfully destroying 100 targets. Five out of 88 participants failed to meet this 100-target minimum, but reached at least the minimum after two practice rounds.

The rounds used for experimental data were the scenarios entitled "Embassy Training" and "Apartment Training." Each scenario presented the same mix of intended targets (i.e., "bad guys") and unintended targets (i.e., "civilians"). Participants were instructed to clear individual rooms by shooting hostile targets without hitting civilians. Each scenario continued until the participant had gone through all rooms or failed the scenario. A participant failed by shooting five civilians, whereupon the game exited the scenario to a screen that said "You failed! You have shot too many civilians. You must be more careful next time."

Both scenarios presented the same set of four possible hostile targets and four possible civilians. Individual rooms in each scenario presented a randomized set of hostile targets and civilians in a predetermined arrangement of possible positions. All rooms contained at least one civilian and at least three hostile targets, with a maximum of five civilians and nine hostile targets. The key difference between scenarios was the rate of fire for the weapon (Embassy Training was completed with a semiautomatic handgun and Apartment Training with a fully automatic M16 rifle).

All targets were simulated cardboard cutouts that burst apart when shot. Hostile targets were armed and pointing weapons at the participant, whereas civilian targets were unarmed. Points varied based on where the hostile target had been shot: in the head (100), torso (~80), or legs (~50). A number in white appeared above the target to indicate how many points had been earned. Participants lost 1,000 points for shooting a civilian target, and "−1000" appeared over the target in red along with an audio message (e.g., "Stop shooting hostages!" or "Watch out for civilians!").

Participants completed six scenarios counterbalanced by type to limit any memorization of target positions (e.g., if the participant went through Embassy Training first, then the order would be Embassy, Apartment, Embassy, Apartment, Embassy, Apartment). The first pass through each scenario was treated as practice as it was the first experience with the fully automatic rate of fire, the first experience with hostile and civilian targets, or potentially both. The first pass-through thus familiarized participants with an automatic weapon and helped the

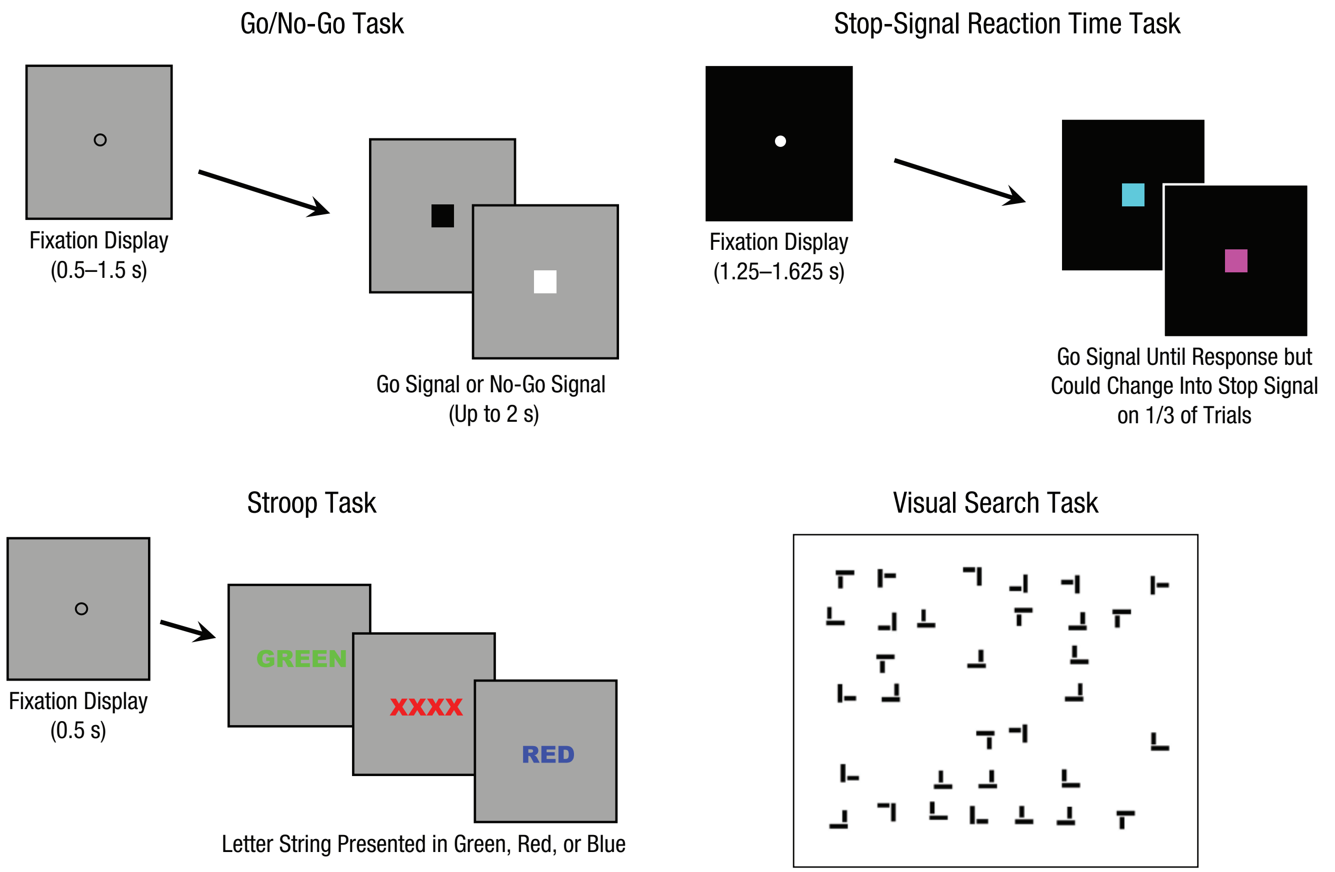

Fig. 2. The four tasks completed in the baseline session. In the go/no-go task, participants pressed the space bar when one of two colors appeared and withheld response when the other color appeared. The stop-signal reaction time task was similar, except that the trial always began with a go signal that would sometimes change into a no-go signal. On the Stroop interference task, participants had to identify the font color of letter strings that contradicted, did not contradict, or had no relation to that color. On the visual search task, participants identified whether a target was present or absent among distractors in an array.

participant dissociate between hostile targets and civilians—the game heavily reinforced that civilians should not be shot (the penalty was 10 times larger than the maximum points earned for shooting a bad guy, shooters failed the round if they hit five civilians, and the audio message exhorted shooters not to hit civilians). Additionally, the first pass yielded the score to beat for each individual. This gamelike feature provided an incentive and an attainable goal for each subsequent round to ensure effortful performance (cf. Miranda & Palmer, 2014). The experimental data were drawn from the final four rounds: Our civilian-casualties measure used throughout this study was the sum of civilian targets hit during these four rounds.

Computer-based tasks. Participants completed four computer-based tasks at baseline: a go/no-go task, an SSRT task, a Stroop interference task, and a visual search task (see Fig. 2). Participants completed the computer-based tasks on Dell Vostro 260 computers with 23.6-in. 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, Brainard, & Pelli, 2007; Pelli, 1997). Participants were seated approximately 57 cm from the screen without head restraint.

In the go/no-go task, blue and orange squares (1.32° × 1.32°) appeared one at a time against a gray background. Participants pressed the space bar if one color appeared (the go signal) and withheld a response if the other color appeared (the no-go signal). The go-signal color was counterbalanced across participants. The colors of the go and no-go signals were reversed at posttraining for participants in the two training conditions (e.g., someone with a blue go signal at pretraining had an orange go signal at posttraining). Each trial began with a fixation circle that appeared for a randomly determined time between 0.5 s and 1.5 s before the stimulus appeared. The colored square then appeared for up to 2 s at fixation before the computer proceeded to the next trial. The 200 experimental trials were preceded by 20 practice trials with 80% go signals and 20% no-go signals. No-go signal accuracy for experimental trials was measured as the percentage of trials in which the participant correctly withheld a response.

The SSRT task was similar to the go/no-go task in structure, but it assessed a different aspect of response-inhibition abilities: the ability to withhold an already initiated response. Participants responded as quickly as possible when they saw a go signal, yet some trials included a change—the go signal turned into a no-go signal. The task required participants to withhold a response when they saw the signal change.

Green and purple squares (3.18° × 3.18°) appeared on screen one at a time against a black background. Participants were instructed to press the space bar if one color appeared (the go signal) but withhold a response if the other color appeared (the stop signal). The go-signal color was counterbalanced across participants. Each trial began with a fixation circle that appeared for a randomly determined time between 1.25 s and 1.625 s. On go trials, a go signal appeared and remained on screen until response. On stop trials, a go signal appeared initially, but the color switched to the stop signal during the trial and remained on screen for 1 s afterward. Two-thirds of trials were go trials, and one third were stop trials. Participants completed a first block of 90 trials as practice (discarded from analyses) and then experimental trials until reaching 312 trials or a maximum of 16 min spent completing the task. Only 1 participant out of 88 reached the time limit. In the experimental blocks, participants received a warning beep from the computer if their go-signal response time (RT) exceeded their mean go-signal RT from the practice block by more than 2 standard deviations.

Performance was primarily determined by the stop-signal delay (SSD)—the time difference between the appearance of the go signal and its change into a no-go signal. The SSD was altered on the basis of an individual's performance by utilizing a one-up/one-down staircase procedure. If participants correctly withheld the response when a stop signal appeared, the SSD increased by 33 ms to make stopping more difficult. If participants did not withhold the response when a stop signal appeared, the SSD was reduced by 33 ms to make stopping easier. The time needed to respond to a go signal was calculated as the median RT for correct responses on go-signal trials (no response or hitting a key other than the space bar would have been an incorrect response). However, stopping time could not be directly measured, because no overt response was to be made.

The staircase procedure was designed to produce 50% accuracy on stop-signal trials. Final SSRT for each participant was calculated using the integration method (Verbruggen, Aron, Stevens, & Chambers, 2010; Verbruggen, Chambers, & Logan, 2013). This approach uses the go-signal RT on the *n*th trial minus the average SSD to calculate the SSRT, for which the *n*th trial is calculated by rank-ordering the correct go-signal RTs and using the trial that corresponded to the probability of responding on a stop-signal trial (i.e., failing to withhold a response). For example, a participant might see 150 go-signal trials during the experiment and respond accurately on 56% of the stop-signal trials (i.e., successfully withhold a response), which would indicate that the *n*th trial contained the 66th fastest correct go-signal response. SSRT was calculated for all trials across the experiment.

The experiment-wide SSRT integration-method calculation could be errant if there is gradual slowing across the experiment (Verbruggen et al., 2013). However, the correct go-signal RTs revealed no systematic effect of slowing (Block 1: M = 473 ms, SD = 161 ms; Block 2: M = 465 ms, SD = 165 ms; Block 3: M = 470 ms, SD = 207 ms). Note that data from 4 participants were removed: 2 participants who had stop-signal accuracy more than 2.5 standard deviations below the group mean and 2 participants who had average go-signal RTs more than 2.5 standard deviations above the group mean.

In the Stroop interference task, participants viewed words printed in red, green, or blue font and were required to identify the font color of the word. Each letter was approximately 1.22° × 1.03°. *Incompatible* trials presented a printed word that contradicted the font color (e.g., the word "RED" written in blue font), *neutral* trials presented a string of three to five "X"s in any color (i.e., red, green, or blue), and *compatible* trials presented a word that matched the font (e.g., the word "RED" appearing in red font).

Each trial began with a dot appearing at fixation for 0.5 s. A letter string then appeared, and participants identified the font color by pressing the left arrow key to signify red font, the down arrow key to signify green font, and the right arrow key to signify blue font. Participants completed 30 practice trials before 180 experimental trials, which were divided between incompatible (20%), neutral (20%), and compatible (60%). Stroop interference effects were measured by taking the RT for *incompatible* trials with correct responses and subtracting the RT for neutral trials with correct responses.

In the visual search task, participants searched among a display of 32 items for a prespecified target item and indicated whether the target was present or absent (for details about the stimuli, see Biggs, Cain, et al., 2013). Target-absent trials consisted of all "L"-shaped distractors, whereas target-present trials contained a target "T" among the distractors. Each trial began with a fixation cross for 250 ms. The cross then disappeared, and the search array appeared until response. Target-present and target-absent judgments were made using one of two assigned keys ("z" and "/"; counterbalanced across participants). Ten

Table 1. Description of the Two Training Conditions

Characteristic	Response-inhibition training (RIT): RIT SSRT task	Response-inhibition training (RIT): *Smack That Gugl!* game	Visual search training
Task goal	Avoiding civilian casualties	Avoiding civilian casualties	Detecting targets
Duration	30 min	30 min	1 hr
Task medium	Computer	Handheld tablet	Computer
Stimuli	Green and purple arrows	Claylike blobs	Rotated "C"s
Purpose	Learn to withhold an initiated response	Learn to avoid certain stimuli while performing quickly	Learn to consistently perform a visual search
Difficulty	Increased with correct responses	Increased with accuracy	Increased by training day
Task	Respond to the go color, withhold the response for the stop color	"Smash" blobs with finger taps, avoid smashing some blobs	Make a present or absent judgment about a reversed "C"

Note: SSRT = stop-signal reaction time.

practice trials preceded 100 experimental trials. Both practice and experimental trials were divided among equal numbers of target-present and target-absent trials. Accuracy feedback was provided for practice trials but not for experimental trials. Search arrays disappeared after a response, and the next trial began automatically. Participants were given the opportunity to rest every 25 experimental trials. Search accuracy was calculated as the number of trials in which the participant correctly responded that the target was present (i.e., a hit) or that the target was absent (i.e., a correct rejection).

Response-inhibition training (RIT). Participants in the RIT condition completed three 1-hr training sessions. Each session consisted of two tasks: an SSRT task and an interactive go/no-go task (see Table 1). Each task took approximately 30 min, and task difficulty adapted to individual performance—that is, the task became more difficult as the participant performed better.

RIT SSRT task. Previous evidence has demonstrated that inhibitory control could be trained through stop-signal tasks (Berkman, Kahn, & Merchant, 2014; Manuel, Bernasconi, & Spierer, 2013), and so a stop-signal task was included in RIT. Stimuli were left- or right-pointing arrows (4.3° × 3.7°) presented at the center of the screen (see Fig. 3). The same stimulus colors (green and purple) were used here as in the baseline task, and the go-signal versus stop-signal color was counterbalanced across participants and across training sessions. Many aspects of the design were similar to the baseline SSRT task, including the one-up/one-down staircase procedure used to alter the SSD. However, participants now responded by indicating the direction of the arrow (left or right) as opposed to simply hitting the space bar for the go signal. A fixation dot appeared for 1.25 s before being replaced by the arrow (see Fig. 3). The task ended when participants completed five blocks of trials with 104 trials per block or they reached a 30-min time limit (forced ceiling). In the experimental blocks, participants received a warning beep from the computer if their go-signal RT exceeded their mean go-signal RT from the practice block by more than 2 standard deviations.

On Training Day 1 (Day 2 of the study), participants responded via pressing either the left or right arrow on the keyboard with their dominant hand only (i.e., if they squeezed the trigger with their right hand for the shooting assessments, then only the right hand could be used to respond on Training Day 1). On Training Days 2 and 3 (Days 3 and 4 of the study), participants were required to use both hands to respond (pressing the "z" key for a left-pointing arrow and the "/" key for a right-pointing arrow). The one-up/one-down staircase was calculated separately for each hand as only the left hand was used to respond to left-pointing arrows, and only the right hand was used to respond to right-pointing arrows.

Interactive go/no-go task. Participants in the RIT condition also played the iPad game *Smack That Gugl!* Participants smacked puttylike figures ("*gugls*") by tapping the screen. Some *gugls* required only one tap, some required two, certain *gugls* could split from one into two when tapped (and then participants had to tap the two new *gugls*), and some had spikes or red bumps to indicate that they should not be tapped (i.e., they required response inhibition).

Participants began each level with five lives. A life was lost if participants failed to tap *gugls* quickly enough or if they tapped a *gugl* with spikes or red bumps. Participants began each training session at Level 1 and proceeded until they lost five lives. During the training portion of each day, participants began at the highest level they had previously completed and continued until losing five more lives. Participants advanced to a new level by smashing 100 *gugls* (e.g., participants went from Level 2 to Level 3 after smashing 200 *gugls* and would restart

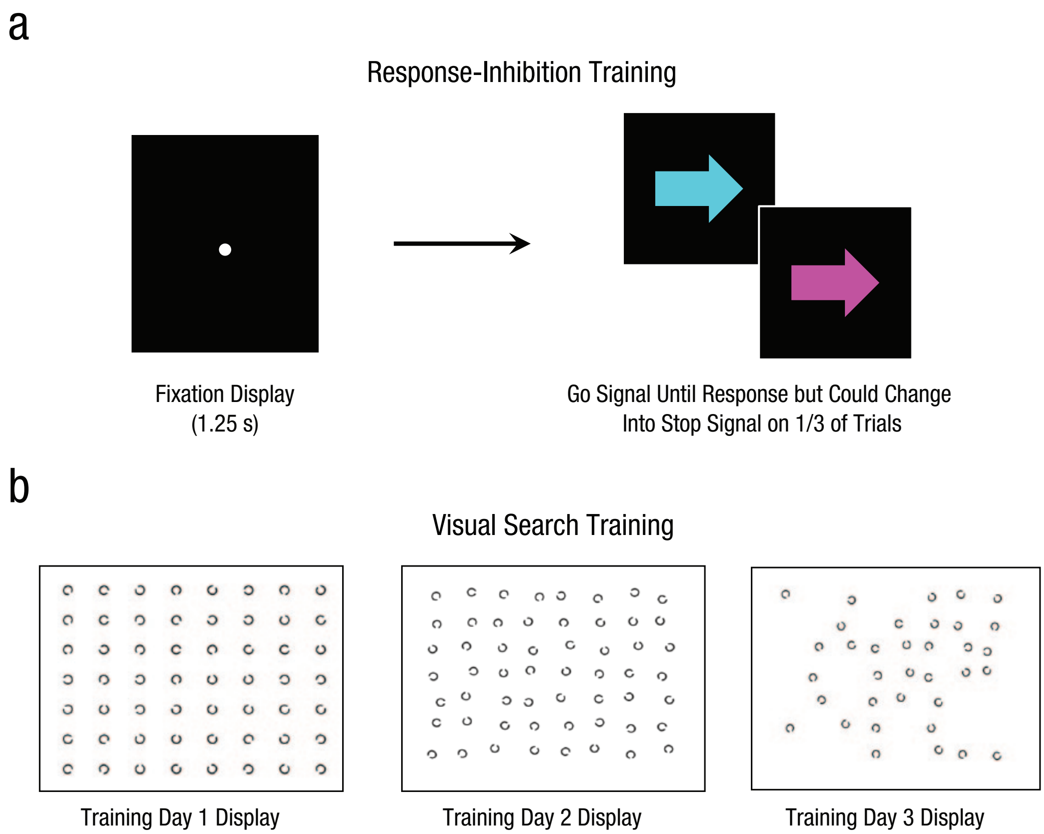

Fig. 3. Sample displays from the (a) stop-signal reaction time task in the response-inhibition training condition and (b) search task in Part 1 of the visual search training condition. In the stop-signal reaction time task, participants had to indicate the direction in which the go arrow was pointing and make no response for the no-go arrow. However, the go arrow turned into the no-go arrow on one third of the trials. Visual search training differed across the 3 training days: On Day 1, perfectly aligned grid displays were presented. On Day 2, spatial jitter was introduced, and on Day 3, there was spatial jitter and gaps between items. On each day, participants had to identify whether a target (a "C") was present or absent.

from Level 3 after losing five lives). Each training day ended with a final round in which participants again began from Level 1 and proceeded as far into the game as they could before losing five lives.

Visual search training (VST). Participants in the VST condition completed three training sessions designed to enhance search consistency with a particular search strategy. Each session increased the difficulty for consistent search: Session 1 (on Training Day 2) presented perfectly aligned grid displays, Session 2 (on Training Day 3) introduced spatial jitter, and Session 3 (on Training Day 4) introduced spatial jitter and gaps between items (see Table 1).

Each display item was a circle (0.6° in diameter) with a portion removed to make it resemble the letter "C" (see Fig. 3). Targets were perfectly reversed "C"s (i.e., rotated 180°), and distractors were drawn from a pool of "C" stimuli rotated in increments of 5° (5°, 10°, 15°, etc., except for 175° and 185°). Each training day included three parts. In Part 1, full displays were presented, and participants were required to make one target present/absent response per display. In Part 2, each display was presented one line at a time starting from the top, and participants were required to make a target present/absent decision about each line of the display before it disappeared and the next line appeared. Part 3 was identical to Part 1.

On all training days, participants were instructed to search left to right, starting at the top left as though "reading from a book." On Training Day 1, search displays were presented with 56 items perfectly aligned in an 8 (horizontal) × 7 (vertical) grid during Part 1 and with 8 items per line during Part 2. On Training Day 2, search displays were presented with 56 total display items aligned in an 8 × 7 grid during Part 1 and with 8 items per line during Part 2, but randomized spatial jitter was applied to prevent perfect grid alignment. On Training Day 3, search displays were presented with the same

Table 2. Behavioral and Survey Results From the Baseline Analyses

Psychological measure	Statistical comparison
Behavioral tasks	
Go/no-go	$r(86) = -.18$, $p = .09$
Stop-signal reaction time	$r(82) = .25$, $p = .02$
Stroop interference	$r(86) = .06$, $p = .58$
Visual search	$r(86) = -.07$, $p = .52$
General surveys	
Attention-deficit/hyperactivity disorder	$r(84) = .21$, $p < .05$
Autism	$r(75) = .01$, $p = .93$
Maximization	$r(84) = .17$, $p = .12$
Video-game expertise	$r(86) = .10$, $p = .35$
Impulsivity	
Attentional	$r(82) = .24$, $p = .03$
Motor	$r(83) = .12$, $p = .27$
Nonplanning	$r(81) = -.03$, $p = .79$

Note: Each measure was compared with the number of civilian casualties inflicted during the video game played in the baseline session (pretraining session for the two training groups).

randomized spatial jitter as on Training Day 2, but with 35 total items (5 per line during Part 2). This design allowed participants to volitionally use the search strategy (Parts 1 and 3) but also provided a more targeted training opportunity with the provided visual search strategy (Part 2). We increased the difficulty of using the left-to-right strategy each day by making the search grid less symmetrical.

Results

Baseline differences

All baseline measures were compared with the number of civilian casualties in the *Reload: Target Down* game. Table 2 presents the correlation and significance values. Note that participant counts vary by measure because of data filtering for behavioral performance (i.e., values more than 3 standard deviations below the group mean were removed as outliers) and because not all participants answered all questions in a particular survey. Performance on the SSRT task, which measured an individual's ability to withhold an initiated response, was significantly related to the number of simulated civilian casualties at baseline, $r(82) = .25$, $p = .02$, with poorer SSRT performance related to greater simulated civilian casualties. Two self-report scales were significantly related to the number of simulated civilian casualties at baseline: More simulated civilian casualties were related to higher ADHD scores, $r(84) = .21$, $p < .05$, and greater attentional impulsivity, $r(82) = .24$, $p < .05$. Simulated civilian casualties were not related to self-reported motor impulsivity, $r(83) = .12$, $p = .27$, nor the total number of shots fired in the simulated shooting task—a behavioral measure of motor impulsivity, $r(86) = .08$, $p = .44$.

Training effects

Simulated civilian casualties were significantly reduced from pretraining to posttraining for the RIT group but not for the VST group, $F(1, 55) = 4.10$, $p < .05$, $\eta_p^2 = .07$ (Fig. 4). This reduction could not be explained by a group difference in simulated civilian casualties at pretraining, $t(55) = 0.69$, $p = .49$, nor by a reduction in the number of intended targets hit, as RIT participants improved more than VST participants in number of targets correctly shot, $F(1, 55) = 3.87$, $p = .05$, $\eta_p^2 = .07$. Finally, more self-reported ADHD symptoms were associated with a larger reduction in civilian casualties from pretraining to posttraining for the RIT group but not the VST group (Fig. 5).

General Discussion

The current study revealed several possible links between civilian casualties in a simulated shooting environment and the cognitive ability of response inhibition. First, individuals with lower inhibitory control and higher attentional impulsivity were more likely to shoot civilians in the simulated scenarios. Second, significant relationships between simulated civilian casualties and attentional measures, but not between civilian casualties and motor-impulsivity measures, suggest a cognitive underpinning of the relationship—an itchy brain more so than an itchy trigger finger. Third, response-inhibition training offers exciting potential to inform future training procedures, which might ultimately reduce unintended casualties. Finally, individuals who self-reported high levels of ADHD symptoms benefited most from the response-inhibition training—which suggests not only that some people benefit more from training than others, but also that such individuals could be identified prior to training. These findings provide some enticing preliminary evidence that shooting performance could be linked to cognitive abilities and—potentially—that cognitive training could enhance shooting performance.

These results add to the mounting evidence that inhibitory control can be improved through cognitive training (e.g., Guerrieri, Nederkoorn, & Jansen, 2012; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009; for a review, see Spierer, Chavan, & Manuel, 2013). Some previous efforts have demonstrated stimulus-specific response-inhibition training by reducing alcohol consumption via enhanced response inhibition for alcohol-related stimuli (Houben, Havermans, Nederkoorn, & Jansen, 2012; Houben, Nederkoorn, Wiers, & Jansen, 2011), or more generalized response-inhibition training by demonstrating reduced risk taking in gambling after

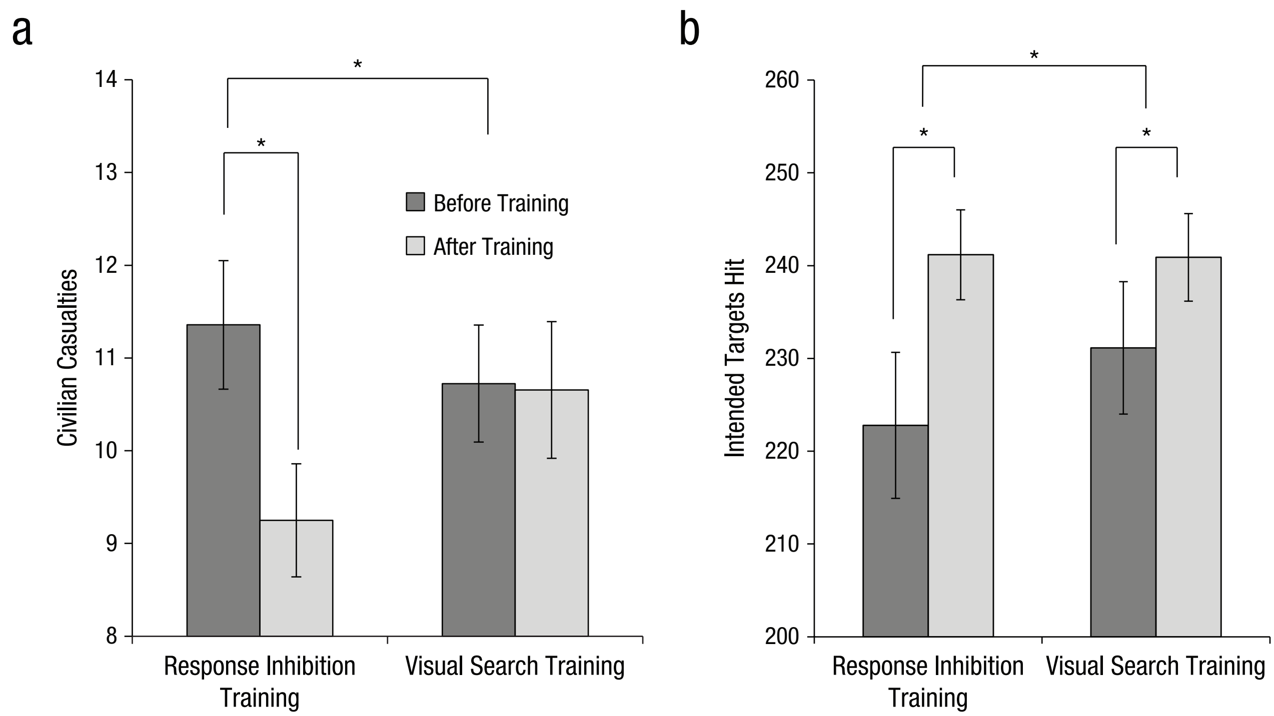

Fig. 4. Mean number of (a) civilian casualties and (b) intended targets hit as a function of training condition and time of test. Asterisks indicate a significant difference between testing occasions or training conditions (*$p < .05$). Error bars show standard errors of the mean.

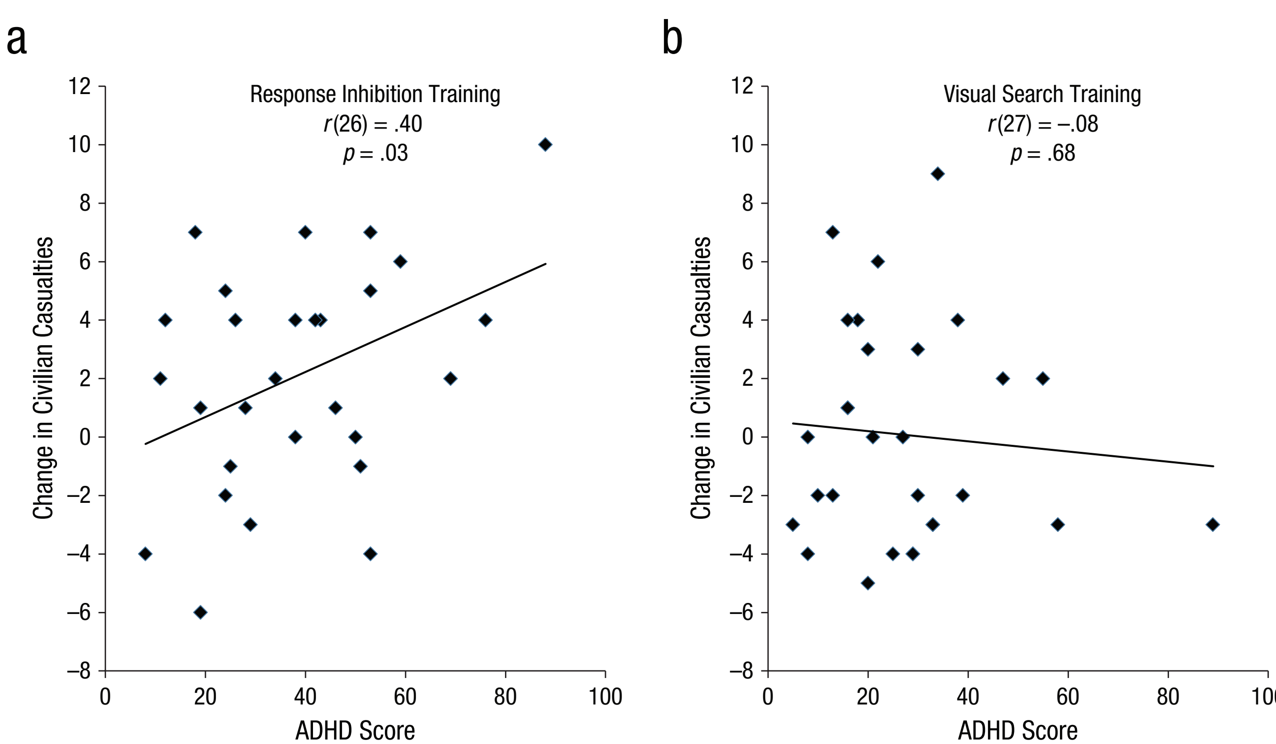

Fig. 5. Scatter plots (with best-fitting regression lines) showing the change in the number of civilian casualties (pretraining minus posttraining) as a function of the number of self-reported attention-deficit/hyperactivity disorder (ADHD) symptoms, separately for the (a) response-inhibition training group and (b) visual search training group. On the *y*-axes, higher values equal lower civilian casualties.

inhibitory training (Verbruggen, Adams, & Chambers, 2012). The current findings suggest another potential area to which response-inhibition training could be applied—shooting a firearm. Namely, squeezing the trigger or not squeezing the trigger is akin to a go/no-go task, albeit one with more complicated lead-up processes than in standard laboratory tasks. Cognitive training can improve response-inhibition abilities, which could likewise potentially reduce shooting errors due to response-inhibition failures. The present study provides initial insight into this relationship by comparing performance on laboratory-based, response-inhibition tasks with a simulation designed to mimic the basic response procedure of shooting a firearm. This link will need to be further supported by additional evidence, although the present study provides enticing preliminary results.

The current study also adds to a growing literature linking gun presence and gun use to cognitive abilities. For example, previous research has revealed a *weapon-focus effect*—individuals remember fewer details about the perpetrator of a crime if the perpetrator was armed than if the perpetrator was unarmed (Loftus, Loftus, & Messo, 1987; for a recent review, see Fawcett, Russell, Peace, & Christie, 2013). The weapon-focus effect involves situations in which someone else is holding a weapon, though recent evidence has demonstrated that wielding a gun also affects cognition. For example, a person holding a gun was more biased to see a gun in the hands of others (Witt & Brockmole, 2012), and wielding a gun altered where an individual looked in a scene (Biggs, Brockmole, & Witt, 2013). The present study extends the previous research by providing preliminary evidence to link shooting performance and cognitive abilities, and, more important, supports the possibility that shooting performance could be improved through cognitive training. Here, we focused on civilian casualties and response inhibition, but there are many possible action-cognition links involved in shooting to explore in future research.

From a practical perspective, the current findings suggest potential promise for improving shooting performance for a wide range of individuals, including military and law-enforcement personnel. Similar training efforts could yield further targeted training regimens so that the most effective training can be implemented for any given scenario. For example, competitive sports shooters might want to enhance their ability to pick up potential targets through visual search, whereas soldiers might want to enhance their ability to avoid hitting unintended targets.

Finally, given that this project serves as an initial step in relating shooting abilities to cognition, there are several limitations. First, the current study demonstrated a significant training benefit, but it remains unclear which aspect of the training was the primary influence. The benefit could be due to the stop-signal training task, the interactive go/no-go training task, or a combination of the two. The critical point is that training occurred, but future work will be needed to elucidate the primary mechanisms. Second, the current design used two active training groups (rather than an active training and control group), which limited placebo effects. However, it is possible that participants expected certain benefits from the training (e.g., Boot, Blakely, & Simons, 2011; but see Green et al., 2014), and these expectations could, in theory, have influenced their performance.

It is also important to highlight that the shooting simulation implemented here may or may not adequately compare with performance among the associated professional populations (e.g., military and law-enforcement personnel). Several aspects of the shooting scenarios were specifically chosen for implementation with an untrained population (e.g., a targeting reticle helped the novice participants aim), but additional scenarios are required to better assess performance among trained populations. Additionally, the present study isolated a particular, simulated situation in which civilian casualties might be inflicted. Participants knew precisely which targets were hostile and which targets were not—yet civilian casualties were still inflicted. There are numerous other situations, depending on the rules of engagement, that could lead to civilians being hit with weapons fire. Inhibitory control may or may not be important for reducing civilian casualties across all circumstances. The present study demonstrates an initial, basic research instantiation of a potential link between inhibitory control and simulated civilian casualties, but future work is needed to expand this result before it is proper to make policy suggestions.

In conclusion, the present study represents an important step forward in the exciting prospect of better understanding both shooting and cognition by studying them in unison. The current evidence was obtained using a simulated environment to link a particular shooting error—civilian casualties—to a particular cognitive ability—response inhibition. This link demonstrates the potential benefit of predicting shooting performance through cognitive abilities, but it also highlights the opportunity to potentially improve shooting performance through cognitive-training methods. Future work can examine additional stops along the shooting-cognition continuum (e.g., target identification and object recognition) to offer additional insight into shooting performance, cognitive processes, and the link between the two.

Author Contributions

A. T. Biggs, M. S. Cain, and S. R. Mitroff designed the study. A. T. Biggs collected and analyzed the data. A. T. Biggs, M. S. Cain, and S. R. Mitroff discussed the results and helped prepare the manuscript.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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