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Cover Page Footnote

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Using an Approach-Avoidance Framework to Understand the Relationship between Non-Lethal Weapons and Performance

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Abstract

It is proposed that performance degradation from exposure to non-lethal technology is mediated by impulsive and reflective approach-avoidance motivation. An approach-avoidance motivational framework was used to specify a four-stage information processing model that predicts performance degradation. The first stage is Evaluation: it processes physiological, sensory, perceptual, and cognitive information. The second stage is Comparison: it processes the content of the Evaluation into avoidance and approach motivational indices. The third stage is Probability: it processes information from previous stages into a probability of choosing to continue or abandon goal-directed behavior. Finally, the fourth stage is Performance: it processes performance accuracy on a given task and occurs only when people continue their goal after dissuasive technology exposure. Depending on previous stages, performance can be degraded on tasks relevant to goal completion. An experiment was used to validate the model. Results supported the hypothesis that information is processed using the approach-avoidance motivational framework.

Keywords: non-lethal weapons, approach-avoidance, impulse noise, performance

Approach-Avoidance Motivational Framework

Non-lethal weapons (NLWs) can be effective tools for military and civilian operations. Relative to lethal weapons (e.g., firearms), they have the potential to minimize the risk of causalities while still assisting with meeting mission objectives (e.g., crowd dispersal). However, NLWs have a complicated relationship with the intended behavioral objectives (e.g., preventing people from moving toward a restricted area). Knowledge of the pre-existing goals and environments of people targeted with an NLW can inform decisions about which type of NLW is appropriate for a given situation. For example, smoke is effective if the objective is to prevent people from performing a task that requires visual information (e.g., driving) but is ineffective at preventing verbal communication. Moreover, there are individual differences in how people react to a given dissuasive technology. For example, after a flashbang detonates nearby, some people may immediately flee while others are undeterred. Recent research used an approach-avoidance framework to understand how people process task-relevant information when exposed to NLWs (e.g., Bartak et al., 2021; Mojica et al., 2019). It can be argued that understanding this process can inform the selection of NLWs appropriate for a particular situation and improve the effectiveness of NLWs to produce intended behavioral outcomes.

People respond to NLWs with the same reactions as they experience to any aversive stimuli (e.g., a growling dog). An approach-avoidance motivational framework can be used to understand these reactions. Approach motivation refers to the stimulation of behavior by, or movement toward, positive things, events, or possibilities. In contrast, avoidance motivation refers to the stimulation of behavior by, or movement away from, negative things, events, or possibilities (Elliot, 2008). For example, unsuspecting people experience high levels of avoidance motivation when near effectors that have detonated because the sound of a loud explosion automatically captures attention, signaling a potentially dangerous situation (Baddeley, 2000; Parmentier et al., 2008).

Many psychological phenomena are associated with approach-avoidance motivation, such as emotions, action tendencies, behaviors, and cognitive states (e.g., Carver & Harmon-Jones, 2009; Frijda, 2007). A dual process theory can organize and explain how these various phenomena operate within an approach-avoidance motivational framework. Dual process theories are replete in the scientific literature and suggest that thoughts can arise in two systems with distinct capacities and processes (e.g., Kahneman, 2011; Kahneman & Frederick, 2002), which have been referred to as System 1

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and System 2 (Stanovich & West, 2000). Typically, researchers separate these processes into an implicit or non-conscious process and a more explicit, deliberative process. The reflective–impulsive model of behavior (RIM) is a prominent dual process model in psychological research (Deutsch & Strack, 2006, 2010; Strack, 1999; Strack & Deutsch, 2004; Strack et al., 2009). The RIM suggests two different yet related systems control behavior. These are referred to as the impulsive and reflective systems, and each has distinct psychological mechanisms. The impulsive system accumulates long-term memory components separated based on perceived patterns of thought or behavior. This system draws upon primitive associations and reacts quickly in all situations because it constantly functions regardless of available cognitive resources. The reflective system requires higher-order cognitive resources such as goals and logical reasoning. Unlike the impulsive system, it reacts in a malleable nature to novel events (Deutsch et al., 2006). However, engaging the reflective system requires sufficient cognitive resources (Strack & Deutsch, 2004). Researchers assume that the two processes operate simultaneously and compete to control overt responses (Strack & Deutsch, 2004).

A distinction between reflective and impulsive processes is implicitly found throughout the approach-avoidance literature. A subset of approach-avoidance theories focuses on how emotions change behavior and draw upon impulsive and primitive processes as driving forces (e.g., Gray, 1987; Lang, 1995; Lewin, 1935; Schneirla, 1959). In comparison, other approach-avoidance theories focus on the strategic (i.e., reflective) goals people pursue as the driving force of approach-avoidance, and regard approach-avoidance as the attainment of positive end states and the prevention of negative end states (e.g., Carver, 2001; Higgins, 1997). Considering these two subsets of theories, approaching or avoiding an object requires the use of behavior that corresponds to the impulsive system, whereas approaching or avoiding an event or possibility requires the construction or activation, and subsequent use of a goal, which corresponds to the reflective system.

Figure 1 represents a theoretical model of information processing when people encounter dissuasive technology. It is proposed that people's goals guide behavior by approaching positive or avoiding negative states (e.g., Hennecke, 2019). However, when they encounter dissuasive technology, they evaluate their experience (Madhavan & Dobbins, 2018; Madhavan & Srinivasan, 2018). The *Evaluation* stage (first gray box in Figure 1) includes physiological, sensory, perceptual, and cognitive reactions. For example, a change in heart rate represents a meaningful physiological marker that can represent this stage.

Next, the content of the *Evaluation* feeds into two indices, an avoidance motivation index and an approach motivation index, which are compared during the *Comparison* stage (second gray box in Figure 1). The approach index is informed by the strength of the initial goal (Mojica et al., 2019). In contrast, the avoidance motivation index is informed by the negative consequences of dissuasive technology exposure in the *Evaluation* stage. When this comparison yields an avoidance index that far exceeds the approach index (e.g., avoidance caused by the aversive technology far exceeds initial goal strength), individuals are likely to draw from the impulsive avoidance system and abandon the goal, as such an experience should produce strong negative emotions that capture attention (e.g., Deutsch et al., 2006). Likewise, when the comparison yields an approach index that far exceeds the avoidance index (e.g., initial goal strength far exceeds avoidance caused by the aversive technology), individuals are highly likely to draw upon the impulsive approach system and continue the goal, as the positive emotions attached to the initial goal should be of central importance (Deutsch et al., 2006). However, when the approach and avoidance indices are roughly equal, the reflective system should be engaged. In such an instance, people will need to draw upon cognitive resources to complete an internal cost–benefit

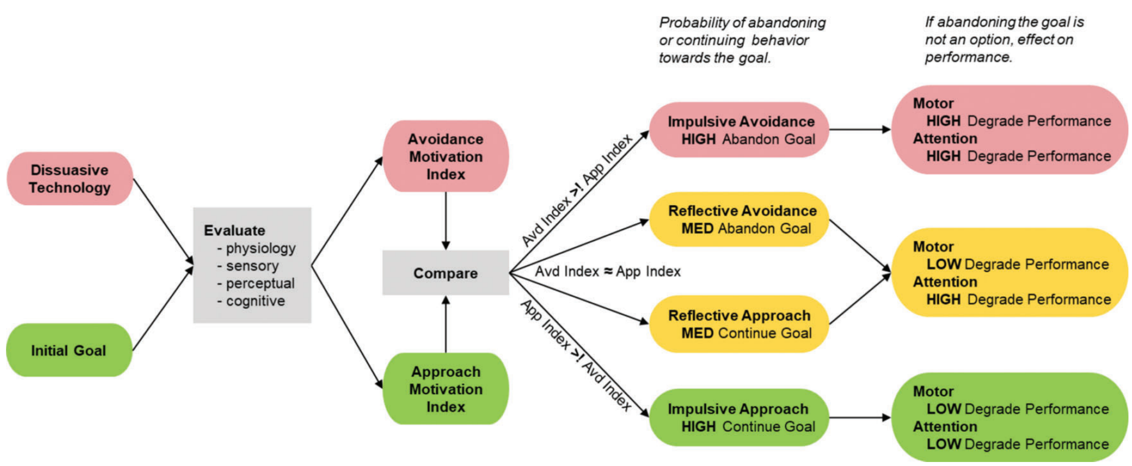

Figure 1. Dissuasive technology effects on performance through approach-avoidance motives.

analysis and decide whether continuing the initial goal is worthwhile or not. When individuals draw upon the reflective avoidance system, there is a medium likelihood that they will abandon their goal. However, when individuals draw upon the reflective approach system there is a medium likelihood that they will continue their goal. Using the reflective system requires higher-order cognitive resources (Deutsch et al., 2006).

When people continue the goal (last column of Figure 1), they carry remnants and consequences of the motivational system. In the model, it is predicted that performance-based effects differ as a function of task type. If the avoidance index was much higher than the approach index, people should experience strong performance degradation effects across both motor and attentional tasks. Attention-based tasks should be affected because cognitive resources are diverted from task engagement to processing the consequences of dissuasive technology exposure. Motor-based tasks should be affected because dissuasive technology can produce strong physiological reactions (e.g., startle reflex) that cause poor performance (e.g., Foss et al., 1989). Next, if the two indices are roughly equal, people should experience strong performance degradation effects on attentional tasks but not motor tasks. Because the reflective system was engaged, attentional resources would be diverted from the task to the evaluation of the approach-avoidance indices. However, motor tasks with few cognitive demands should be relatively unaffected when weak dissuasive technologies fail to produce physiological changes. Finally, if the approach index far exceeds the avoidance index, performance degradation effects are low or absent because adversity is not experienced.

The present research tests our model (Figure 1) via an experiment simulating an extreme environment in which flashbangs disarm the intended persons, giving the users (e.g., military personnel) a tactical advantage when they follow up the flashbang exposures with the use of kinetic weapons. A custom-built environment was built based on the real-world specifications of an underground nuclear silo where two opposing forces might battle. In the hypothetical scenario, enemy combatants control a nuclear silo, defending access to the facility, while a control force uses flashbangs in an attempt to stun the combatants and then recapture the facility. External features of the test environment simulate a real-world, life-threatening combat situation. Flashbangs emit bright light, loud impulse noise, and blast overpressure, causing anyone near the flashbangs detonating to experience significant physiological reactions. People exposed to flashbangs experience a startle reflex, an involuntary reaction that starts with a distinctive eye blink and ends with leg contractions (e.g., Madhavan & Srinivasan, 2018), and their autonomic system activates, resulting in significant physiological changes such as increased heart and breathing rates that facilitate fight-or-flight responses toward or away from danger (Madhavan & Dobbins, 2018).

People's internal experience inside this extreme environment may also potentiate initial physiological reactions to the NLWs, especially if they are concerned that an escalation of force may occur. Because encounters of this nature necessitate that one team or the other will likely die, the fear of death or serious bodily injuries could cascade into a fear-potentiated response, resulting in cognitive impairments that drastically reduce environmental awareness and rational decision-making (Staal, 2004). Although the test environment is only a simulation of an extreme environment, it retains two essential characteristics of real-world extreme environments that people experience:

(1) Activation of the autonomic nervous system.
(2) Attention to potentially dangerous stimuli.

Thus, using simulated extreme environments, the theoretical model used in this study can inform military and civilian operations as to which NLWs to use for a particular situation because the model provides a framework for how people respond to NLW exposure.

The analysis methods reported here are taken from Bartak et al. (2021), an applied research project that addressed multiple operational questions looking at how effector exposure influenced physiological reactions, psychological responses, and task performance. In the study, individuals were assigned either to a role heavily reliant on enacting motor actions with precision or to a role that was cognitively demanding. At present, a subset of analyses from Bartak et al. (2021) are presented to demonstrate the information processing model (Figure 1) and to identify intervening variables in the relationship between approach-avoidance and performance using mediation and moderation analyses. These analyses focus only on the results for the cognitively demanding role. Analyses pertaining to the motor task will appear in a future paper.

Method

Participants

Eleven subjects (8 male, 3 female) participated. This study was restricted to Southwest Research Institute (SwRI) employees between 18 and 55 years of age who were not pregnant and who did not have an aversion to impulse noises. Mean age was 34.8 years ($SD = 11.4$). Two participants reported military experience. Participants were recruited via an email flyer distributed to SwRI employees.

The study employed a single independent variable, a within-subjects manipulation using dissuasive technology. The dissuasive technology factor referred to whether the trial included effectors (6g concussion pack pyrotechnic devices) or not. The control trial did not include any effectors, while the experimental trial included 12 effectors activated at varying intervals throughout the trial. The study design is described in more detail later.

Materials and Apparatus

A custom-designed nine-button control panel (Figure 2) was operated using a microcontroller and relay switches found inside the device's metal enclosure. The control panel was programmed to illuminate buttons in a fixed, preset order and timing sequence that appeared random to observers. To keep the task challenging, a stimulus onset asynchrony (SOA) was incorporated into the button sequence that varied between 600 ms and 1100 ms. As with the button sequence, the SOA variation was random, predetermined, and fixed across presentations.

Buttons lit up individually for 200 ms with 81 total illuminations in the trial sequence. The control panel task involved correctly pressing buttons in a sequence that will be described shortly (see "Control Panel Task"). Responses were recorded from when one button started illuminating until the next began. Notably, the control panel recorded only the first response within the response period. In addition to response accuracy, response latency was also recorded.

The button panel was organized according to a standard Corsi block task pattern (Corsi, 1972) with a red LED inside each button. Small green LEDs on each side of the individual buttons illuminated briefly (for 100 ms) when participants correctly responded (no feedback was given for incorrect responses). Further, a numeric LCD on the side of the control panel indicated the percentage of correct responses during the sequence, counted the number of buttons that illuminated during the sequence, and provided error messages. A red–yellow–green tower LED light on top of the panel buzzed when a test began or ended or if an error occurred. An input line triggered the beginning and end of a test. An output line indicated the status of the main controller.

A Polar T34 392031128 heart rate transmitter monitored participants' heart rate throughout each study session. Past research has found that Polar heart rate monitors effectively monitor heart rate during physical and mental stress (Goodie et al., 2000). Heart rate monitors signaled the main system controller each time they detected a heartbeat. Timestamps produced by the main controller noted which heart rate measurements were recorded during which task.

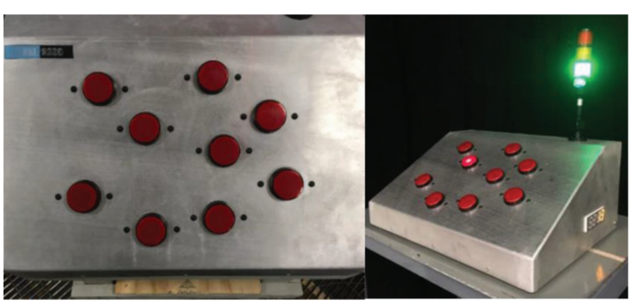

Figure 2. Photos of control panel.

Twelve effectors detonated during experimental trials. The dissuasive technology (6g concussion pack pyrotechnic devices) used by Mojica et al. (2019) was used again in the present study. These devices can be used at distances as close as three meters without issue with appropriate safety equipment (Mojica et al., 2019). Sound pressure levels were characterized at this study's test site. Pencil probes and sound pressure level monitors were positioned in various locations around the test site while effectors detonated. The resulting data confirmed that acoustic levels were at the upper end of the acceptable range (135–138 dBA).

To administer effectors during the experimental trial, a single, fixed detonation order and variable time sequence was created. The predetermined settings ensured that not only did each effector detonate at the same relative time in experimental trials (Table 1), but that the detonation timing also seemed random and unpredictable to participants. In the effector sequence, the first effector detonated 9.7 seconds into the trial, with the mean time interval between detonations at 4.94 seconds (SD = 3.48 seconds).

Control Panel Task

Participants completed the panel task during which they pushed buttons on the control panel as the buttons lighted. The proctor compared this task to the carnival game of "Whack-a-Mole," during which targets continually appear on a panel and players strike each target as it appears. However, in contrast to the carnival game, participants did not press each button as it lighted. Their task was to press the button that lighted two buttons earlier. This task was modeled after the *n*-back task developed by Kirschner (1958), and would be considered a 2-back task. Participants learned that if they lost their place, they were to start the memory sequence over by noting the next two buttons and hitting the first when the third new button illuminated, continuing in the same manner from there. Participants completed the task with their dominant hand, keeping their non-dominant hand by their side. Participants learned that the green lights on either side of the button they pressed would light up if they responded correctly so they could continually monitor their performance. The task lasted 70 seconds each trial (see Materials and Apparatus section for more details).

Survey Task

Participants responded twice to an approach-avoidance motivation survey. Participants answered 22 items about their motivation in the test area. These items assessed approach motivation, impulsive avoidance, reflective avoidance, and arousal. Two additional items were included in the second survey, asking participants to report on their experience with the effectors. Overall, participants responded to 20 items on a 10-point Likert scale anchored at 1 (not at all true) and 10 (extremely true), and three items that required an open-ended response.

Table 1
Effector detonation order and time sequence.

Detonation order	Time sequence (seconds)	Interval between detonations (seconds)
E1	9.7	
E2	15.7	6.0
E3	23.2	7.5
E4	28.4	5.2
E5	32.0	3.6
E6	43.3	11.3
E7	45.5	2.2
E8	52.9	7.4
E9	61.0	8.1
E10	62.5	1.5
E11	62.8	0.3
E12	64.0	1.2

Procedure

During the experimental session, participants arrived, put on a heart rate monitor, completed a rest period (all rest periods lasted for six minutes and thirty seconds), and were informed about their task (Figure 3). Next, participants toured the test facility, learned more about the task they would complete, learned how to perform the task correctly, and practiced the task (Figure 3). Participants proceeded to rest again before proceeding to the control trial in the test facility and then a first survey (Figure 3). Afterward, participants rested again before proceeding to the experimental trial and the second survey task (Figure 3). Finally, participants rested one last time before debriefing and dismissal (Figure 3). Each study component is detailed next.

Participants started the experiment with the first rest period (Figure 3). When participants arrived, a proctor demonstrated how to wear a heart rate monitor, verified that the monitors were transmitting properly before seating participants in a relaxed position in the rest area, and began their first rest period.

After completing the first rest period, a proctor escorted participants into the test facility and told them their task. Participants learned that the test facility represented a place where valuable resources such as dangerous materials were stored and that lives could be jeopardized if the facility fell into the wrong hands. The task was then described briefly. The participant learned they would complete a difficult button-pressing task on a control panel that ostensibly operated the facility.

The proctor described all the control panel features and operations (see "Control Panel Task" in Study Tasks section for details). Next, the participants observed while the proctor completed a trial himself, making correct and incorrect responses and showing how to recover from mistakes. The proctor addressed remaining questions about the panel task, and then the participants completed several practice trials until consecutive trials differed by no more than three points (Figure 3). Participants practiced 4.2 times on average ($SD = 0.98$). The practice count did not significantly correlate with any dependent variables of interest (all r = ns, $p > 0.38$).

Next, the proctor escorted participants to the survey room and provided an overview of the survey. Afterwards, the proctor escorted participants back to the rest area for their second rest period (Figure 3). While participants rested, researchers reset the test facility.

Then, participants proceeded to complete all control condition activities. To begin the control condition (Figure 3), participants wore safety goggles. Additionally, participants wore double hearing protection consisting of normal earplugs and 30 dB NRR-rated earmuffs. To be consistent with the experimental trial during which smoke was removed from the silo, a ventilation system was turned on. A buzzer signified the start of the trial. When this buzzer sounded, participants worked on their task until the buzzer sounded again, signaling the end of the trial. Afterward, the proctor escorted participants to the survey room to answer the control survey (Figure 3; see "Survey Task" in Study Tasks section for details) before the third rest period (Figure 3). Researchers reset the test arena while participants completed tasks elsewhere.

Participants next proceeded to the experimental activities. For the experimental trial (Figure 3), the ventilation fan was started as participants put on their hearing protection and safety goggles. The one novel feature of this trial was the 12 effectors that detonated throughout the trial. After the trial was completed, the proctor escorted participants back to the survey room to answer the experimental survey (Figure 3). Finally, participants returned to the rest area and completed the final rest period (Figure 3) before they were debriefed and dismissed.

Measures

Heart Rate

Heart rate data are the average beats per minute (bpm) five seconds after the first effector detonated during the

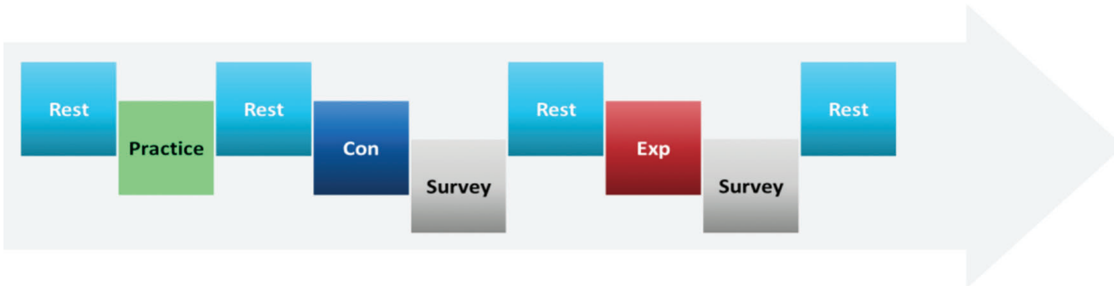

Figure 3. Visual aid depicting study event sequence.

experimental (with effectors) and control (without effectors) trials. Heart rate was restricted to the first five seconds because previous research found that most physiological reactivity to loud, impulse noise occurs within five seconds after the aversive stimulus (Thackray & Touchstone, 1970).

A principal component analysis (PCA) identified a subset of three latent variables among the survey items that informed decisions to categorize the items using three subscale labels: approach, impulsive avoidance, and reflective avoidance. The survey and PCA methods are reported in Bartak et al. (2021). Alpha values reported below for the approach motivation, reflective avoidance, and impulsive avoidance subscales are based on the original, full study sample ($n = 40$), not the subset of data analyzed in this paper ($n = 11$).

Approach Motivation

The survey contained seven items theoretically linked to approach motivation ($\alpha = 0.72$). Participants responded to each item on a 10-point Likert scale anchored at 1 (not at all true) and 10 (extremely true). The items assessed if participants believed negative experiences in the test arena would prevent task completion, if participants wanted to complete their task despite negative experiences they encountered, if participants were able to cope with the negative sensations, if participants believed they would have gotten used to the negative aspects of the test arena they could not avoid, if they wanted to do well at their task, if they liked their task, and if they wanted to do their task again. For both the control and experimental approach assessment, responses were averaged across the seven items after reverse-coding appropriate items.

Reflective Avoidance

The reflective and impulsive components of avoidance motivation (e.g., Strack & Deutsch, 2004) were treated as distinct constructs in this study. The survey contained five items with a theoretical link to reflective avoidance (Cronbach's $\alpha = 0.50$). While this Cronbach's alpha is lower than desired (i.e., 0.6 or higher), the subscale only has five items. A Spearman–Brown correction indicates that if the subscale had contained eight items with the same relationship strength, the Cronbach's alpha would reach 0.615. Participants responded to each item on a 10-point Likert scale anchored at 1 (not at all true) and 10 (extremely true). The items assessed if participants wanted to avoid areas that produced negative sensations, if participants experienced unpleasant sensations, if participants believed that features in the test arena were intentionally set up to produce the experience they had, and if participants felt that features in the test arena would lead to undesirable consequences. For both the control and experimental reflective avoidance assessment, responses were averaged across the five items after reverse-coding appropriate items.

Impulsive Avoidance

The survey contained five items with a theoretical link to impulsive avoidance ($\alpha = 0.69$). Participants responded to each item on a 10-point Likert scale anchored at 1 (not at all true) and 10 (extremely true). The items assessed if participants wanted to abandon their task, if participants wanted to destroy areas that produced negative sensations, if participants felt fear, if participants felt anger, and the extent to which participants felt an undue amount of force was used against them. For both the control and experimental impulsive avoidance assessment, responses were averaged across the five items after reverse-coding appropriate items.

Control Panel Accuracy

The control panel accuracy data were aggregated at two levels. The first level is the participants' overall accuracy throughout the entire experiment. The second level provides an estimate of how participants performed on each of the 79 trials. The proportion of participants who answered each trial correctly was calculated and difference scores were used. Descriptive statistics were used to capture the dynamic effects of effector detonation when participants systematically performed well or poorly at various points in the button sequence.

Organization of the Results Section

The presentation order of the results follows a set sequence. The results section is organized based on the stages of the model presented in Figure 1. As a reminder, there are four stages in the model sequence: *Evaluation*, *Comparison*, *Probability*, and *Performance*. The results appear in order of this sequence.

Evaluation

The first stage involves processing sensory and physiological information. It was predicted that participants would experience heart rate elevation after an effector detonates. Based on the model depicted in Figure 1, a significant change during *Evaluation* must occur for dissuasive technology to affect performance.

Comparison

The next stage is when the person exposed to the dissuasive technology compares the relative strength of approach and avoidance indexes. An increase in avoidance (impulsive and reflective) and a decrease in approach was expected during the experimental condition.

Probability

Outside of a laboratory setting, people may abandon goals if they encounter dissuasive technology. However, in this laboratory experiment, it was assumed that participants would not abandon their goal because it is believed they implicitly understood that their safety was a priority for investigators as an IRB board approved this study. No participants discontinued involvement in the study.

Performance

The main dependent variable was performance on the control panel task. Performance was evaluated using three types of analyses.

(1) Determine if the effectors degraded performance.
(2) Tested mechanisms through which effectors degrade performance using mediation analyses.
(3) Conducted moderation analyses to explore factors that interacted with dissuasive technology to degrade performance.

Results

The first type of analysis tested for performance degradation by comparing performance decline from the control (no effectors) to the experimental condition (effectors). The second and third types of analysis required mediation and moderation analyses to understand how and why dissuasive technology leads to performance degradation.

Mediation analyses specify a causal pathway through which the independent variable affects an outcome. This analysis tested if effectors degraded performance through the potential mechanism of approach-avoidance motivation. The Montoya and Hayes (2017) path-analytic technique for testing mediation in repeated measures designs called MEdiation and MOderation analysis for REpeated measures designs (MEMORE) was employed. The procedure described in Montoya and Hayes (2017) to conduct bootstrapping for mediation models in repeated measures designs was used via the MEMORE 2.3 add-on for SPSS. Ten thousand samples with replacement were drawn (typically, a minimum of 1,000 resamples is recommended; Hayes, 2009).

Moderation analysis determines if the relationship between a predictor and outcome variable depends on a third variable, a moderator, which interacts with the predictor to affect the outcome variable. Significant moderation effects require further estimates to probe conditional effects to determine the nature of the moderation effect. The MEMORE SPSS add-on was also used to conduct moderation analyses, which tests for significant moderation effects and conducts simple slopes analyses to probe meaningful effects.

Evaluation (Heart Rate)

A one-tailed t-test was conducted to test the effect of dissuasive technology on heart rate change. To calculate heart rate change, a difference score metric was calculated by taking mean heart rate in the experimental condition during the five-second interval after the first flashbang detonated and subtracting mean heart rate during the same five-second interval in the control condition. A significant increase ($M = 9.21$ bpm, $SD = 7.44$ bpm) in heart rate occurred during the five-second interval after the first effector detonated relative to the same time period in the control condition, $t(10) = 4.1$, $p = 0.001$; $d = 1.24$. This elevation in heart rate satisfies the criteria of the *Evaluation* stage of the proposed model.

Comparison (Approach-Avoidance)

One-tailed t-tests were conducted to test the effect of dissuasive technology on approach, impulsive avoidance, and reflective avoidance. Here again, difference scores were used whereby the score obtained on each subscale in the control condition was subtracted from the score obtained in the experimental condition. Relative to the control condition, approach decreased ($M = -1.04$, $SD = 1.38$), $t(10) = -2.5$, $p = 0.03$; $d = -0.75$, impulsive avoidance increased ($M = 1.71$, $SD = 2.39$), $t(10) = 2.37$, $p = 0.04$; $d = 0.72$, and reflective avoidance increased ($M = 3.44$, $SD = 1.66$), $t(10) = 6.88$, $p = 0.00004$; $d = 2.08$. These changes in approach-avoidance indices satisfy the criteria of the *Comparison* stage of the proposed model.

Performance (Accuracy)

Because participants continuously pressed buttons throughout the trial, changes in performance throughout the trial could be observed across each button press. The data were aggregated and analyzed at two levels to evaluate how performance changed on the control panel task when effectors were encountered. The first level represented performance over the entire trial. The second level represented performance for each individual response.

Overall Control Panel Accuracy

A one-tailed *t*-test was conducted to test the effect of dissuasive technology on control panel accuracy over the entire trial. A difference score metric was used which subtracted control panel accuracy during the control condition from control panel accuracy during the experimental condition. There was a significant effect of dissuasive technology on control panel accuracy, $t(10) = -2.16$, $p = 0.03$; $d = -0.65$. Performance on the control panel task degraded by 9% ($SD = 0.14$) when participants were exposed to dissuasive technology relative to performance during control trials. This analysis supports the hypothesis that effectors degrade performance on the control panel task.

Individual Response Accuracy

Figure 4 represents control panel accuracy for each of the 79 recorded responses. The proportion of participants who answered each response correctly was calculated and then difference scores were used to subtract control accuracy from experimental accuracy across all participants for each response. With this calculation, positive values indicate greater performance in the experimental than control trials, values around 0 indicate similar performance in the control and experimental trials, and negative values indicate worse performance in the experimental than control trials. This calculation allowed us to determine when performance declined on the control panel task and compare these declines to when effectors detonated. As demonstrated in the previous analysis, a main effect of dissuasive technology can be seen through a visual inspection of the difference score values presented in Figure 4. The majority of difference score values are below 0.0, indicating that participants typically performed worse after effector exposure for most individual trials.

Furthermore, these results can inform if performance is affected by habituation. Habituation and the relationship with NLWs are discussed in more detail in Bartak et al. (2021). It was expected that novel events that occur during the experiment would draw attention away from the task and contribute to performance degradation, but that participants would quickly rebound from those novel events, such that their performance would quickly improve.

Three distinct negative peaks corresponded with a large drop in performance in the dissuasive technology condition compared to the control condition (Figure 4). The first negative peak occurred when the first effector detonated. The second negative peak happened when the sixth effector detonated. The time gap between E5 and E6 was 11.3 seconds, which is the longest time delay between successive effector detonations in this experiment. Finally, there was a third negative peak that occurred because of a task being performed by a separate participant. As noted earlier, reported here are data from the cognitive measures of a larger research manipulation that also included a motor task (rifle aiming). Coincident with the ninth effector, the other participant fired an air-soft rifle, the sound of which distracted the participant in the control panel task.

Mediation Analyses

The mediating role of approach-avoidance motivation in control panel performance was evaluated. Impulsive avoidance served a meaningful mediating role when evaluating the effect of effector exposure on control panel accuracy. Effector exposure significantly affected impulsive avoidance relative to the control trial (Figure 5, pathway a1; $\beta = 1.71$, $SE = 0.72$, $p = 0.04$). Impulsive avoidance was higher after effector exposure relative to the

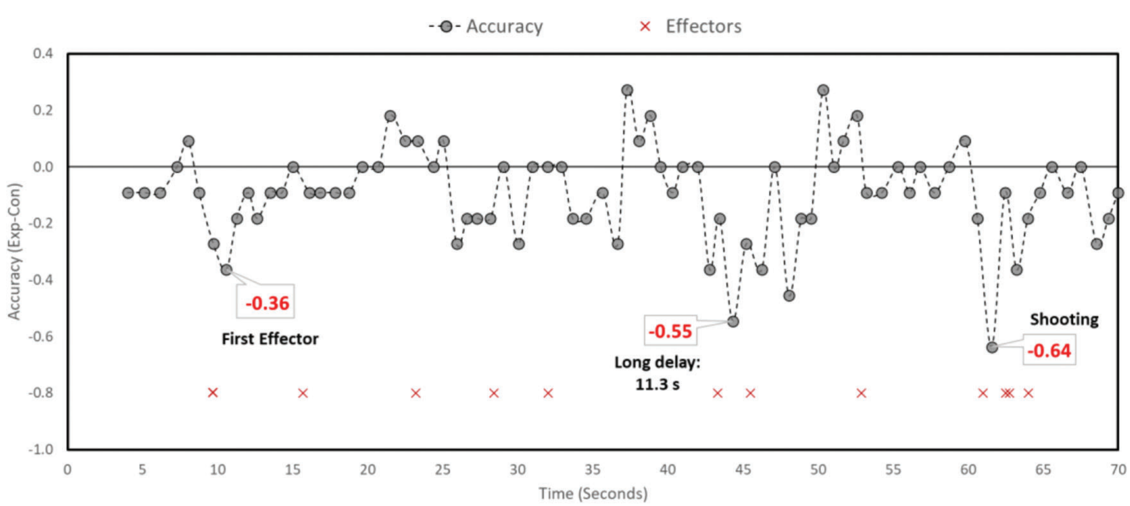

Figure 4. Individual response control panel accuracy scores (experimental − control) throughout the experiment.

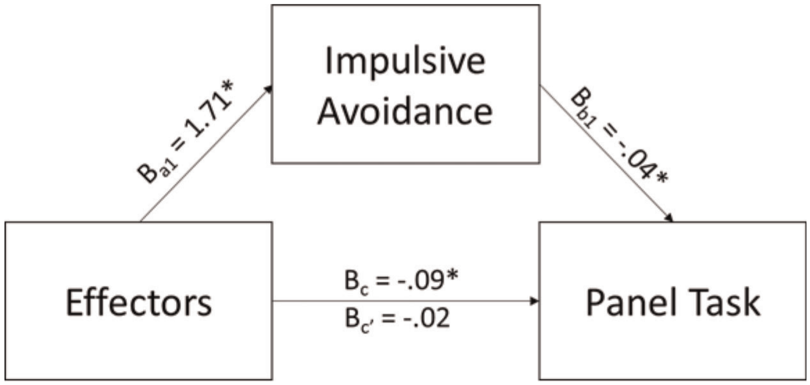

Figure 5. Mediational model representing the effect of effectors on the control panel task through impulsive avoidance.

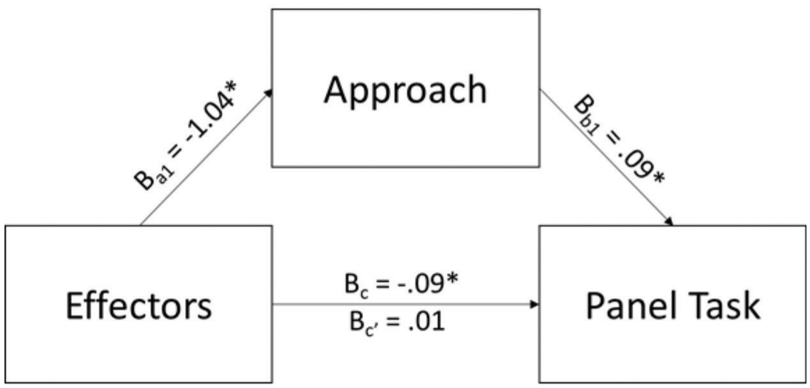

Figure 6. Mediational model representing the effect of effectors on the control panel task through approach.

control condition. The omnibus test of total effects indicated that effector exposure significantly predicted performance degradation (Figure 5, pathway c; $\beta = -0.09$, $SE = 0.04$, $p = 0.06$). When impulsive avoidance was included in the mediation model, the omnibus test of the direct effect of effector exposure on performance degradation was reduced to a nonsignificant level (Figure 5, pathway c′; $\beta = -0.02$, $SE = 0.04$, $p = 0.67$). However, impulsive avoidance still significantly affected performance degradation in the mediational model (Figure 5, pathway b1; $\beta = -0.04$, $SE = 0.01$, $p = 0.01$). Furthermore, because the confidence interval for the impulsive avoidance indirect effect (Figure 5, pathways a1 $\times$ b1) did not contain zero, it can be determined that effector exposure significantly predicted control panel accuracy through impulsive avoidance ($\beta = -0.08$, $SE = 0.05$, 95% CI [−0.19, −0.01]). Overall, this analysis suggested that impulsive avoidance fully mediated the effect of effector exposure on control panel accuracy.

Approach served a meaningful mediating role when evaluating the effect of effector exposure on control panel accuracy. Effector exposure significantly affected approach relative to the control trial (Figure 6, pathway a1; $\beta = -1.04$, $SE = 0.42$, $p = 0.03$). The omnibus test of total effects indicated that effector exposure significantly predicted performance degradation (Figure 6, pathway c; $\beta = -0.09$, $SE = 0.04$, $p = 0.06$). When approach was included in the mediation model, the omnibus test of the direct effect of effector exposure on performance degradation was reduced to a nonsignificant level (Figure 6, pathway c′; $\beta = 0.01$, $SE = 0.02$, $p = 0.81$). However, approach still significantly affected performance degradation in the mediational model (Figure 6, pathway b1; $\beta = 0.09$, $SE = 0.01$, $p = 0.00007$). Furthermore, because the confidence interval for the approach indirect effect (Figure 6, pathways a1 $\times$ b1) did not contain zero, it was determined that effector exposure significantly predicted accuracy on the control panel through approach ($\beta = -0.10$, $SE = 0.05$, 95% CI [−0.23, −0.02]). Overall, this analysis suggested that approach fully mediated the effect of effector exposure on control panel accuracy.

Moderation Analysis

A simple slopes analysis with the MEMORE macro (Montoya, 2018) indicated that reflective avoidance interacted with effector exposure to predict control panel accuracy, $M = -0.06$, $SD = 0.02$, $p = 0.01$. Moderation of the effect of effector exposure on control panel accuracy means that the difference between the effector exposure and control condition effects on the control panel task depends on reflective avoidance. Simple slopes analyses

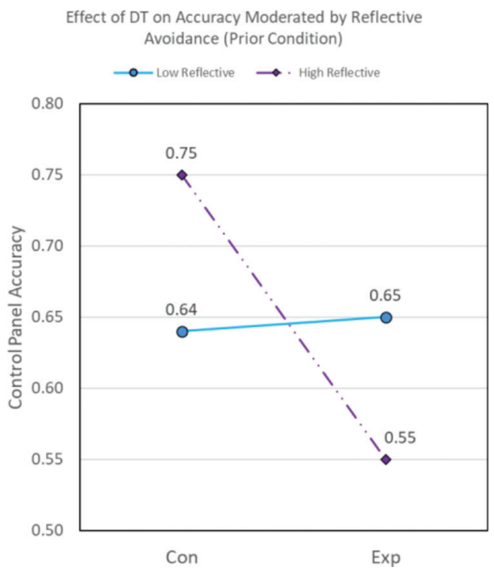

Figure 7. Effect of effectors on control panel task scores as moderated by reflective avoidance predicted scores plotted 1 *SD* above and below the mean.

probed the conditional effect of effector exposure on the control panel task at different values of reflective avoidance (see Figure 7) and revealed that participants with high reflective avoidance (i.e., at 1 *SD* above the mean) made more errors on the control panel task when exposed to effectors than the control condition, $b = -0.19$, $SE = 0.04$, $p = 0.002$, but participants with low reflective avoidance (i.e., at 1 *SD* below the mean) did not, $b = 0.01$, $SE = 0.04$, $p = 0.82$.

Discussion

It was proposed that people's goals initially influence their behavior (e.g., the goal to acquire valuable resources leads one to break into an abandoned warehouse). When people encounter dissuasive technology, they evaluate the experience by engaging in information processing (Figure 1).

The first stage in information processing is *Evaluation*, which includes but is not limited to processing sensory and perceptual information. In order for information processing to proceed beyond this stage (to *Comparison*), it is necessary to observe a significant increase in heart rate or some other physiological variable as a function of effector exposure. Conversely, if a change during *Evaluation* is not observed, dissuasive technology would not be expected to impede operationally relevant behavior. The analyses suggest that participant heart rate increased significantly after effector exposure and, thus, the first stage in information processing was completed successfully. These data support past research in which blast overpressure produced by effectors generated a rise in heart rate (e.g., Madhavan & Dobbins, 2018).

The next stage in the information processing model is *Comparison*. During this stage, the relative strengths of approach and avoidance indexes are compared. It was proposed that much of the operationally relevant behavior caused by NLWs is the consequence of a targeted person comparing the relative strength of these two indexes. This approach-avoidance motivational framework can be further separated into impulsive and reflective systems (Mojica et al., 2019). A significant increase in avoidance was expected during the *Comparison* stage as a function of effector exposure. The observance of an increase in avoidance would suggest that the *Comparison* information processing stage successfully occurred. If avoidance motivation does not increase after encountering dissuasive technology, it is anticipated that the NLW(s) under investigation would be ineffective at deterring operationally relevant behavior. The data suggest that the second stage in the information processing model was verified. Relative to the control trials, all participants experienced increased avoidance motivation (impulsive and reflective) after effector exposure. These data complement previous research (Mojica et al., 2019), in which avoidance increased when people encountered dissuasive technology.

According to the model (Figure 1), two information processing avoidance routes affect motor and attentional behavior. Hypothetically, ineffective dissuasive technology produces nonsignificant changes during *Evaluation* and *Comparison* and nonsignificant performance degradation effects. However, significant changes were observed during the *Evaluation* (elevated heart rate) and *Comparison* (increased impulsive and reflective avoidance) stages, and performance was affected. Thus, two information processing routes were possible.

1. If impulsive avoidance is high, performance degradation on the control panel will be high.
2. If reflective avoidance is high, the predicted outcomes are different for the two tasks, but performance degradation on the control panel will be high.

Thus, according to the theoretical model (Figure 1), impulsive and reflective avoidance were expected to degrade performance on the control panel task. Processing aversive consequences of dissuasive technology diverts cognitive resources away from attentional tasks. The mediation analysis revealed that impulsive avoidance fully mediates dissuasive technology's effect on control panel accuracy. Thus, effector exposure led to increased impulsive avoidance, which resulted in performance degradation. These data also replicate past research that found that loud, potentially dangerous sounds degrade performance on cognitively demanding tasks (e.g., Staal, 2004; Thackray & Touchstone, 1970; Vlasek, 1969; Woodhead, 1958, 1959).

The moderation analysis supported the hypothesis that reflective avoidance interacted with dissuasive technology to degrade performance on an attentional task. Reflective avoidance functioned as a moderating variable because after effector exposure, performance degradation effects on the control panel task varied across levels of reflective avoidance, such that participants high in reflective avoidance became less accurate than participants low in reflective avoidance (see Figure 7). A possible explanation for why reflective avoidance functioned as a moderator instead of a mediator is that extraneous factors outside of the immediate experimental manipulation may have contributed to reflective avoidance assessments. People naturally vary in their capacity to tolerate distress from unpleasant situations (e.g., Harmon-Jones et al., 2003). Moreover, in previous research (see Mojica et al., 2019), motivational levels were more variable for reflective avoidance than impulsive avoidance, suggesting that individual differences drawn from prior experiences may affect these ratings in addition to the immediate experience of the dissuasive technology. In contrast, impulsive avoidance is viewed as a visceral experience informed by the immediate situational context. Thus, reflective avoidance in this study may represent a high-level cognitive assessment of avoidance (e.g., ability to cope after encountering dissuasive technology) reflecting individual differences drawn from prior experiences to some extent, and it is this aspect of the factor that is believed to have interacted with dissuasive technology to affect performance.

Whether people habituated to the negative sensations they experienced when encountering dissuasive technology was also tested. Habituation reduces behavioral responsiveness to a stimulus presented repeatedly or over a prolonged presentation (Thompson, 2015). Habituation was observed on the control panel task at an individual trial level. Figure 4 represents control panel accuracy for all 79 recorded trials. Control accuracy was subtracted from experimental accuracy to quantify performance degradation associated with effector detonation for each trial. This method allowed the evaluation of performance changes.

After the first effector, performance dropped 36%. Performance was close to zero (difference score: experimental − control trials) during the second to the fifth effector detonations. These data support previous research on habituation, in that effectors had weaker effects on performance over time (Foss et al., 1989; May & Rice, 1971; Thackray & Touchstone, 1970; Vlasak, 1969). Thus, the habituation hypothesis is supported because performance rebounded during the second to fifth effector detonations. However, when the sixth effector detonated, performance fell again to 55%. This drop in performance likely occurred because the time gap between E5 and E6 is 11.3 seconds, the longest time between successive effector detonations. Participants may have come to believe that they would not experience any more effectors and were thus taken off guard by the new effector. The more unpredictable and uncontrollable stressors are (e.g., loud noise), the more people experience stress (see Cohen, 1980). Finally, there was a sharp but brief decline when the ninth effector was denoted. This event coincided with the other participant firing an air-soft rifle. This change likely contributed to the decrease in control panel accuracy. In summary, habituation occurred when performance was evaluated at an individual trial level but discontinued when effector detonations became more unpredictable.

Conclusions

The present study evaluated if approach-avoidance motivation is an essential mechanism underlying why effector exposures (6g concussion pack pyrotechnic devices) produce performance degradation effects. An information processing model was used to understand how performance degradation effects on a cognitively demanding task occur when people encounter dissuasive technology. The model was supported in several ways. First, participants exhibited an elevated heart rate. Second, mediation and moderation analyses confirmed that performance degradation caused by effector exposures was produced through impulsive avoidance and approach, and was especially likely to occur for individuals high in reflective avoidance.

Future research exploring the effects of dissuasive technology on performance degradation should consider applying this approach-avoidance information processing model to best capture the intricacies of dissuasive technology effects. By noting the nature of their respective performance task and assessing approach-avoidance motivation variables, researchers can better predict how participants will perform at their task or if they may abandon the task entirely. This information could inform military and civilian operations regarding which NLWs to use for a particular situation or improve the effectiveness of using specific dissuasive technologies.

The data that support the findings of this study are available from the corresponding author (A.J.M.) upon reasonable request.

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References

Baddeley, A. D. (2000). Selective attention and performance in dangerous environments. *Journal of Human Performance in Extreme Environments*, *5*, 86–91. https://doi.org/10.7771/2327-2937.1010

Bartak, C. P., Mojica, A. J., Mitchell, J. N., Williams, G. C., Tellez, M. A., Mathis, R., Collins, K. R., Burdell, G. P., & Ashworth, A. (2021). *Approach-avoidance framework for differing levels of adversarial motivation across multiple non-lethal weapons, part 2* (AFRL-RH-FS-TR-2022-0001). United States Air Force Research Laboratory.

Carver, C. S. (2001). Affect and the functional bases of behavior: On the dimensional structure of affective experience. *Personality and Social Psychology Review*, *5*, 345–356. https://doi.org/10.1207/S15327957PSPR0504_4

Carver, C. S., & Harmon-Jones, E. (2009). Anger is an approach-related affect: Evidence and implications. *Psychological Bulletin*, *135*, 183–204. https://doi.org/10.1037/a0013965

Cohen, S. (1980). Aftereffects of stress on human performance and social behavior: A review of research and theory. *Psychological Bulletin*, *88*, 82–108. https://doi.org/10.1037/0033-2909.88.1.82

Corsi, P. M. (1972). *Human memory and the medial temporal region of the brain* [Doctoral thesis, McGill University, Canada].

Deutsch, R., Gawronski, B., & Strack, F. (2006). At the boundaries of automaticity: Negation as reflective operation. *Journal of Personality and Social Psychology*, *91*, 385–405. https://doi.org/10.1037/0022-3514.91.3.385

Deutsch, R., & Strack, F. (2006). Duality models in social psychology: From dual processes to interacting systems. *Psychological Inquiry*, *17*, 166–172. https://doi.org/10.1207/s15327965pli1703_2

Deutsch, R., & Strack, F. (2010). Building blocks of social behavior: Reflective and impulsive processes. In B. Gawronski & K. Payne (Eds.), *Handbook of implicit social cognition: Measurement, theory, and applications.* Guilford Press.

Elliot, A. J. (2008). *Handbook of approach and avoidance motivation*. Psychology Press. https://doi.org/10.4324/9780203888148

Foss, J. A., Ison, J. R., Torre Jr, J. P., & Wansack, S. (1989). The acoustic startle response and disruption of aiming: II. Modulation by forewarning and preliminary stimuli. *Human Factors*, *31*(3), 319–333. https://doi.org/10.1177/001872088903100306

Frijda, N. H. (2007). *The laws of emotion*. Lawrence Erlbaum Associates.

Goodie, J. L., Larkin, K. T., & Schauss, S. (2000). Validation of Polar heart rate monitor for assessing heart rate during physical and mental stress. *Journal of Psychophysiology*, *14*, 159–164. https://doi.org/10.1027//0269-8803.14.3.159

Gray, J. A. (1987). *The psychology of fear and stress* (2nd ed.). Cambridge University Press.

Harmon-Jones, E., Sigelman, J., Bohlig, A., & Harmon-Jones, C. (2003). Anger, coping, and frontal cortical activity: The effect of coping potential on anger-induced left frontal activity. *Cognition and Emotion*, *17*, 1–2. https://doi.org/10.1080/02699930302278

Hayes, A. F. (2009). Beyond Baron and Kenny: Statistical mediation analysis in the new millennium. *Communication Monographs*, *76*, 408–420. https://doi.org/10.1080/03637750903310360

Hennecke, M. (2019). What doesn't kill you…: Means for avoidance goal pursuit are less enjoyable than means for approach goal pursuit. *Motivation Science*, *5*, 1–13. https://doi.org/10.1037/mot0000104

Higgins, E. T. (1997). Beyond pleasure and pain. *American Psychologist*, *52*, 1280–1300. https://doi.org/10.1037/0003-066X.52.12.1280

Kahneman, D. (2011). *Thinking, fast and slow*. Allen Lane.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. Griffin, & D. Kahneman (Eds.), *Heuristics of intuitive judgment: Extensions and applications* (pp. 49–81). Cambridge University Press.

Kirchner, W. K. (1958). Age differences in short-term retention of rapidly changing information. *Journal of Experimental Psychology*, *55*, 352–358. https://doi.org/10.1037/h0043688

Lang, P. J. (1995). The emotion probe. Studies of motivation and attention. *American Psychologist*, *50*, 372–385. https://doi.org/10.1037/0003-066X.50.5.372

Lewin, K. (1935). *A dynamic theory of personality. Selected papers*. McGraw-Hill Book Company.

Madhavan, P., & Dobbins, C. (2018). *Path analysis of human effects of flashbang grenades* (No. IDA-D-9270, IDA-18-000393). Institute for Defense Analyses.

Madhavan, P., & Srinivasan, R. (2018). *Analysis of the startle response to effector grenades* (No. IDA-D-8945, IDA-18-000043). Institute for Defense Analyses.

May, D. N., & Rice, C. G. (1971). Effects of startle due to pistol shot on control precision performance. *Journal of Sound and Vibration*, *15*, 197–202. https://doi.org/10.1016/0022-460X(71)90534-7

Mojica, A. J., Bartak, C. P., Dalton, P. H., Maute, C. D., Mitchell, J. N., Williams, G. C., Tellez, M. A., Mathis, R. J., Collins, K. R., Willard, F. D. C., & Ashworth, A. (2019). *Approach-avoidance framework for differing levels of adversarial motivation across multiple non-lethal weapons, part 1* (AFRL-RH-FS-TR-2019-0031). United States Air Force Research Laboratory.

Montoya, A. K. (2018). Moderation analysis in two-instance repeated measures designs: Probing methods and multiple moderator models. *Behavior Research Methods*, *51*, 61–82. https://doi.org/10.3758/s13428-018-1088-6

Montoya, A. K., & Hayes, A. F. (2017). Two-condition within-participant statistical mediation analysis: A path-analytic framework. *Psychological Methods*, *22*, 6–27. https://doi.org/10.1037/met0000086

Parmentier, F. B., Elford, G., Escera, C., Andrés, P., & San Miguel, I. (2008). The cognitive locus of distraction by acoustic novelty in the cross-modal oddball task. *Cognition*, *106*, 408–432. https://doi.org/10.1016/j.cognition.2007.03.008

Schneirla, T. C. (1959). An evolutionary and developmental theory of biphasic processes underlying approach and avoidance. In. M. R. Jones (Ed.), *Nebraska symposium on motivation*. University of Nebraska Press.

Staal, M. A. (2004). *Stress, cognition, and human performance: A literature review and conceptual framework*. NASA/TM—2004–212824.

Stanovich, K. E., & West, R. F. (2000). Individual differences in reasoning: Implications for the rationality debate. *Behavioral and Brain Sciences*, *23*(5), 645–665. https://doi.org/10.1017/S0140525X00003435

Strack, F. (1999). Beyond dual-process models: Toward a flexible regulation system. *Psychological Inquiry*, *10*, 166–169. https://doi.org/10.1207/S15327965PL100213

Strack, F., & Deutsch, R. (2004). Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review*, *8*, 220–247. https://doi.org/10.1207/s15327957pspr0803_1

Strack, F., Deutsch, R., & Krieglmeyer, R. (2009). The two horses of behavior: Reflection and impulse. In E. Morsella, J. A. Bargh, & P. M. Gollwitzer (Eds.), *Oxford handbook of human action*. Oxford University Press.

Thackray, R. I., & Touchstone, R. M. (1970). Recovery of motor performance following startle. *Perceptual and Motor Skills*, *30*, 279–292. https://doi.org/10.2466/pms.1970.30.1.279

Thompson, R. F. (2015) *International encyclopedia of the social & behavioral sciences*. Elsevier.

Vlasak, M. (1969). Effect of startle stimuli on performance. *Aerospace Medicine*, *40*, 124–128. https://doi.org/10.1136/oem.15.2.120

Woodhead, M. M. (1958). The effects of bursts of impulse noise on a continuous visual task. *British Journal of Industrial Medicine*, *15*, 120–125.

Woodhead, M. M. (1959). Effect of brief impulse noise on decision making. *Journal of the Acoustical Society of America*, *31*, 1329–1331. https://doi.org/10.1121/1.1907629