


# Sleep Deprivation and Racial Bias in the Decision to Shoot: A Diffusion Model Analysis

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David J. Johnson<sup>1,2</sup> , Michelle E. Stepan<sup>2</sup>, Joseph Cesario<sup>2</sup> ,  
and Kimberly M. Fenn<sup>2</sup>

## Abstract

The current study examines the effect of sleep deprivation and caffeine use on racial bias in the decision to shoot. Participants deprived of sleep for 24 hr (vs. rested participants) made more errors in a shooting task and were more likely to shoot unarmed targets. A diffusion decision model analysis revealed sleep deprivation decreased participants' ability to extract information from the stimuli, whereas caffeine impacted the threshold separation, reflecting decreased caution. Neither sleep deprivation nor caffeine moderated anti-Black racial bias in shooting decisions or at the process level. We discuss how our results clarify discrepancies in past work testing the impact of fatigue on racial bias in shooting decisions.

## Keywords

decision to shoot, racial bias, sleep deprivation, caffeine, diffusion decision model

An important question in understanding racial disparities in fatal police shootings concerns the role of sleep deprivation in officers' decisions. Although it has been hypothesized that sleep deprivation is a cause of both errors in fatal shootings and racial disparity in those shootings (e.g., the shooting of Botham Jean; Shepherd, 2019), direct data on this issue have been equivocal. In the current study, we examined whether sleep deprivation increases errors and racial bias in decisions to shoot and whether caffeine mitigates these effects.

## Fatigue and Policing

Although work hours are federally regulated in many professions, police officers often work long shifts, secondary jobs, and overtime (Vila & Kenney, 2002). Overtime is often not evenly distributed; officers in high-crime areas work on average more than 20 hr overtime per month, with some working up to 70 hr per month (Vila, 1996). In one survey, officers reported working over 60 hr per week, and 70% reported getting only 3–6 hr of sleep (Senjo, 2011). Another survey found 29% of officers reported excessive sleepiness (Rajaratnam et al., 2011) and 40% had a sleep disorder. These officers were more likely to fall asleep while driving, have safety violations, or show anger toward suspects (Rajaratnam et al., 2011).

Laboratory research on officer fatigue has found similar results. After 5 days of 10 hr shifts, night-shift officers were more likely to deviate from their lanes in a simulated driving task (S. M. James & Vila, 2015). Similarly, L. James et al.

(2018) employed a use-of-force simulator, where officers interacted with civilians in scenarios that could either escalate or deescalate. Fatigued night-shift officers were more likely to respond in ways that resulted in deadly outcomes compared to fatigued day-shift officers.

## Fatigue and Shooting Decisions

Although the relationship between fatigue and deficits in police performance generally is robust, research on simulated shooting decisions has shown only weak fatigue effects. Studies using an immersive shooting simulator have shown no impact of fatigue (i.e., 5 days of 10-hr shifts) on officer decision accuracy (L. James et al., 2017). Research on shooting decisions with students has also not found a main effect of fatigue on decision making (Ma et al., 2013). A related issue concerns the impact of fatigue on racial bias in shooting decisions. Police officers did not show more racial bias in a shooting simulator when fatigued (L. James et al., 2017), whereas fatigued students and police recruits have shown more racial bias in shoot/don't shoot tasks (Ma et al., 2013). Thus, it

<sup>1</sup> Department of Psychology, University of Maryland at College Park, MD, USA  
<sup>2</sup> Michigan State University, East Lansing, MI, USA

## Corresponding Author:

David J. Johnson, Department of Psychology, University of Maryland at College Park, 4094 Campus Dr., College Park, MD 20742, USA.  
Email: djjohnson@smcm.edu

remains unclear whether fatigue increases racial bias in shooting decisions.

Resolving these conflicting results is difficult because of methodological differences across studies. L. James et al. (2017) used a shooting task with high external validity and recruited officers under realistic fatigue conditions. However, their design had low internal validity; the simulator did not fully cross race, armed status, and scenario. In contrast, Ma et al. (2013) used a fully crossed set of less externally valid stimuli (i.e., static images) and recruited students or police recruits instead of trained officers. They also employed weak fatigue manipulations (a 15-min Stroop task; Study 1) or measured self-reported sleep (Study 2). As self-reported sleep is only moderately correlated with actual sleep, these results should be interpreted with caution (Lauderdale et al., 2008).

A major weakness of these studies is that officers did not make poorer decisions when fatigued. This is unexpected because sleep deprivation causes performance deficits across many domains. L. James et al. (2017) attribute this lack of an increase in errors to sympathetic nervous system activation, mitigating the impact of sleep deprivation. Another possibility is that these manipulations were not strong enough to impact performance. Thus, in the current study, participants completed a shooting task after 24 hr without sleep or a full night of sleep.

### Reducing Fatigue With Caffeine

Another unexplored area concerns ways to mitigate the risks of fatigue on the decision to shoot. One strategy to combat fatigue is consuming caffeine, a widely used central nervous system stimulant (Donovan & DeVane, 2001). Caffeine mitigates the negative effects of sleep deprivation on alertness, attention, and vigilance (Beaumont et al., 2001; N. Wesensten et al., 2002). Vigilant attention of sleep-deprived individuals who consume caffeine sometimes does not significantly differ from performance of rested individuals who do not consume caffeine (McLellan et al., 2005; Stepan et al., under review), suggesting caffeine may reverse impairments in attention due to sleep deprivation.

The effects of caffeine on higher order cognition are more mixed. Caffeine can mitigate sleep-deprived performance on tasks assessing reasoning and strategy development (N. J. Wesensten et al., 2005) and some tasks assessing problem-solving (Killgore et al., 2009). In contrast, caffeine may not benefit performance on tasks assessing inhibitory control (N. J. Wesensten et al., 2005), working memory (N. Wesensten et al., 2002), placekeeping (Stepan et al., under review), or some problem-solving tasks (Killgore et al., 2009). Thus, it remains unclear the degree to which caffeine might impact shooting decisions.

Although research has not investigated the impact of caffeine on law enforcement performance, researchers have examined the impact of caffeine on military performance. McLellan et al. (2005) observed soldiers during a 55-hr field exercise. Soldiers were not allowed to sleep and were given either caffeine or placebo. Caffeinated soldiers maintained marksmanship vigilance and accuracy at higher rates than the placebo

**Table 1.** Parameters of the Diffusion Decision Model.

Parameter	Interpretation
Threshold separation ( $\alpha$ )	The separation between the two thresholds, determining the amount of evidence required to decide, with $0 < \alpha$ .
Relative start point ( $\beta$ )	Initial bias to shoot at the start of the evidence accumulation process, with $0 < \beta < 1$ . Values above .50 indicate a bias to shoot.
Drift rate ( $\delta$ )	Average quality of evidence extracted from a stimulus at each unit of time, with $-\infty < \delta < \infty$ . Higher absolute values indicate stronger evidence. Positive values indicate evidence to shoot.
Nondecision time ( $\tau'$ )	Proportion of the minimum response time spent on processes unrelated to decision making, with $0 < \tau' < 1$ .

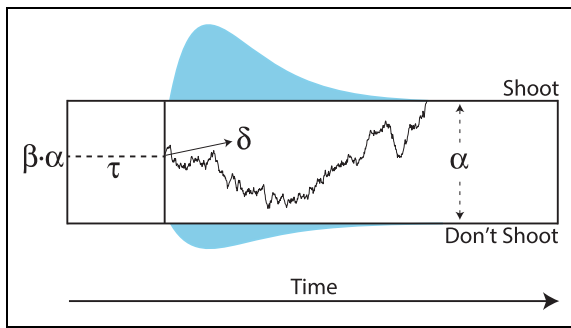
group. Insofar as the processes underlying marksmanship and shoot/don't shoot decisions are similar, sleep-deprived decision makers may benefit from caffeine. Administering caffeine also provides an opportunity to test whether caffeine might moderate racial bias in shooting decisions, perhaps by mitigating any negative effects due to sleep deprivation.

In sum, the effects of fatigue on shooting decisions and racial bias are inconsistent across studies. In addition, no work has studied how caffeine might moderate sleep deprivation. We address these gaps by studying the impact of sleep deprivation on civilian shooting decisions using a static shooting task. This design is a trade-off favoring internal validity at the cost of generalizing the findings to more realistic contexts. This design allowed us to collect more data, so we could examine the factors impacting shooting decisions using cognitive modeling. We now discuss how we used these models to examine *how* fatigue and caffeine consumption impact performance.

### Modeling Shooting Decisions

Use of lethal force is typically studied experimentally by having participants make fast decisions to shoot or not shoot targets. These decisions have been studied using sequential sampling models such as the diffusion decision model (DDM; Ratcliff, 1978; Ratcliff et al., 2016). According to the DDM, people begin with an initial bias to shoot or not. They accumulate evidence for each option by repeatedly sampling information from the environment. When the evidence reaches a threshold, the corresponding option is chosen (see Table 1 for descriptions of model parameters and Figure 1 for a graphic representation).

The DDM can help to identify how race and other factors impact the decision process (see Johnson et al., 2017). In the first-person shooter task (FPST; Correll et al., 2002), civilians accumulate evidence faster to shoot armed Black targets and to not shoot unarmed White targets (Correll et al., 2015; Pleskac et al., 2018). Although applications of the DDM to understand how race impacts shooting decisions are increasing (see Pleskac et al., under review), no work has examined how sleep



**Figure 1.** The decision diffusion model as applied to the decision to shoot. Individuals start with an initial bias  $\beta$  to shoot or not. Noisy information is accumulated to shoot or not with average strength  $\delta$ . The amount of information needed to make a decision is indicated by the distance between the threshold boundaries  $\alpha$ . The length of nondecision processes is indicated by  $\tau$ . The model predicts the distribution of response times for shoot and don't shoot decisions (in blue).

deprivation and caffeine might impact decisions to shoot. As such, we consider how these factors might impact the decision process parameters.

**Threshold separation.** Threshold separation ( $\alpha$ ) measures how much participants favor accuracy over speed. Larger values indicate greater preference for accuracy over speed and will correspond behaviorally with more accurate but slower decisions. We predicted that sleep deprivation would increase errors and reduce the threshold separation, with caffeine mitigating these effects.

Research is mixed as to whether civilians favor accuracy more for Black than White targets (Pleskac et al., 2018) or whether there is no difference (Johnson et al., 2018). However, changes in the threshold separation symmetrically affect the speed and accuracy of decisions to shoot and not shoot and thus cannot explain typical patterns of racial bias reflected by an *asymmetric* change in error rates and/or response times.

**Relative start point.** The relative start point ( $\beta$ ) indicates an initial bias to shoot or not shoot. It is one mechanism by which race can produce an asymmetric change in decisions and response times indicative of racial bias, although this is typically not found in civilian samples (Johnson et al., 2018; Pleskac et al., 2018). We predicted that race would not impact the relative start point, although we explored whether sleep deprivation and caffeine might change initial biases to shoot due to target race.

**Drift rate.** Drift rate ( $\delta$ ) refers to the average strength of evidence participants extract from a scene. This primarily reflects whether a person is armed but can also be influenced by the race of a target (Correll et al., 2015; Pleskac et al., 2018) and police experience (Johnson et al., 2018). We predicted that sleep deprivation would reduce participants' ability to identify weapons, increasing errors and weakening drift rates. Because

caffeine reduces fatigue, we predicted that these deficits would diminish for those taking caffeine.

In the FPST, the impact of target race among civilians is typically evident in the drift rate (Correll et al., 2015; Pleskac et al., 2018). Whether armed or unarmed, evidence to shoot Black targets is greater than evidence for White targets. This is consistent with the idea that race is accumulated as evidence relevant to the decision to shoot. We expected to replicate this finding and test whether it would be exacerbated by sleep deprivation or mitigated by caffeine.

**Nondecision time.** Nondecision time ( $\tau$ ) indicates the length of response time spent on processes unrelated to decision making. We did not make predictions about this parameter as past studies have not found consistent effects across predictor variables (Correll et al., 2015; Pleskac et al., 2018).

## Method

### Participants

Participants were undergraduate students at Michigan State University who did not have memory disorders, reported moderate caffeine use (up to 400 mg daily), slept a minimum of 6 hr the night before the study, and woke by 9:00 a.m. on the first day of the study. They did not have strong time-of-day preferences (48–52 on the Morningness–Eveningness Questionnaire; Horne & Östberg, 1976) or major sleep disturbances (0–10 on the sleep disturbances section of the Pittsburgh Sleep Quality Index; Buysse et al., 1989). Participants refrained from napping the day of the study and from consuming caffeine, alcohol, or drugs 24 hr prior to the study.

Participants ( $N = 378$ ) completed the study in groups of up to 11. To maximize statistical power, we recruited as many students as possible during the 2017–2018 academic year. Because this study was conducted at the end of a larger project, some participants did not have time to complete the FPST ( $n = 27$ ). Other participants' data were not saved due to a software error ( $n = 24$ ). Five participants' data were lost due to experimenter error, three participants withdrew from the study, and one admitted prior knowledge of the experimental design. Our final sample was 318. Participants were 71% women, 81% White, 8% Black, 4% Asian, and 4% Hispanic. The average age was 19 ( $SD = 1$ ).

### Measures

This study was a part of a larger project examining the effects of sleep deprivation on cognition using a battery of tasks (see Supplemental Materials). The relevant tasks for this study include the psychomotor vigilance task (PVT; Dinges & Powell, 1988; Lim & Dinges, 2008) and the FPST (Correll et al., 2002).

**PVT.** The PVT is a measure of vigilant attention (Lim & Dinges, 2008). It was used as a manipulation check of the effect of sleep deprivation and caffeine (Dinges & Powell, 1988; Lim &

Dinges, 2008). Participants monitored a blank computer screen for a large red circle. They were instructed to click the mouse as quickly as possible when the circle appeared. Clicking the mouse triggered response time feedback for 0.5 s. The circle appeared at random intervals between 1 and 10 s. The task lasted 10 min. The dependent variable was response time.

**FPST.** The FPST was used to measure the impact of race on shooting decisions. Stimuli from Correll et al. (2002) were presented with PsychoPy (Version 1.83.01; Peirce et al., 2019). On any given trial, participants saw one to four neutral background scenes, presented for a random interval between 500 and 1,000 ms each. A target then appeared in background at a random location holding a handgun or a harmless object (e.g., cell phone). Participants were instructed to press “shoot” if the target was armed or “don’t shoot” if the target was unarmed. Participants received feedback about their accuracy and were told to speed up if they responded outside the 650-ms response window.

Targets were 20 White men and 20 Black men, each photographed holding a handgun and a harmless object for a total of 80 pictures. Participants saw each picture twice, completing 160 trials. The dependent variables were decisions and response times.

## Procedure

Participants arrived at the laboratory at 10:00 p.m. knowing they would be assigned to stay awake all night or go home and sleep. Participants completed all tasks and measures in the larger project except the FPST. Afterward, participants were randomly assigned to condition varying in sleep deprivation (rested and sleep deprivation) and caffeine administration (placebo, acute, and sustained).

In the acute caffeine condition, participants were given a single dose of caffeine in the morning. In the sustained condition, participants were given three smaller doses of caffeine overnight. Dosages were designed, so both groups would have similar levels of caffeine during morning assessments (Ritter & Yeh, 2011). We collapsed across caffeine administration as preliminary tests revealed both groups performed similarly (Stepan et al., under review).

Sleep-deprived participants were monitored by trained experimenters. Participants were allowed to engage in any activity that did not activate the autonomic nervous system, including consuming noncaffeinated food and beverages. Caffeine or placebo pills were administered in a double-blind fashion according to the schedule provided in Table 2. Participants were sleep deprived for approximately 24 hr before morning tasks.

Rested participants returned to the lab at 8:30 a.m. and were randomly given placebo or caffeine. At 9:00 a.m., all participants completed the same measures as the night before as well as the PVT and FPST. They were then debriefed and dismissed. Sleep-deprived participants were given a ride home.

**Table 2.** Experimental Conditions and Caffeine Administration.

Sleep Condition	Caffeine Condition	N	Caffeine		
			12:30 a.m.	4:30 a.m.	8:30 a.m.
Rested	Placebo	60	—	—	Placebo
Rested	Acute	60	—	—	200 mg
Sleep deprivation	Placebo	70	Placebo	Placebo	Placebo
Sleep deprivation	Acute	62	Placebo	Placebo	200 mg
Sleep deprivation	Sustained	66	100 mg	100 mg	100 mg

Note. Data from the acute and sustained caffeine conditions were combined as the effect of caffeine did not depend on administration schedule.

## Analytic Approach

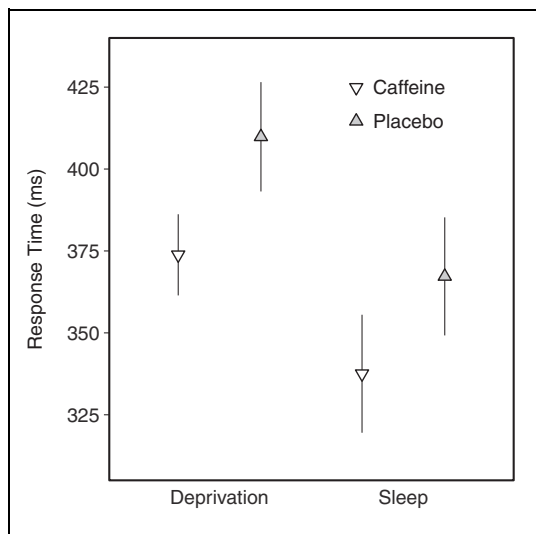
Decision accuracy and correct response times were analyzed using multilevel regression using the lme4 package in R (Version 1.1-21; Bates et al., 2015). Intercepts varied by participants in the PVT and by participants and targets in the FPST (Judd et al., 2012). PVT trials faster than 100 ms and slower than 3,000 ms were removed (Basner & Dinges, 2011). FPST trials faster than 300 ms and slower than 3,000 ms were removed (Ratcliff et al., 2018). This excluded 1.3% of trials from the PVT and 2.4% of trials from the FPST. We report condition means and 95% confidence intervals.

FPST decision and response time data were simultaneously analyzed with the DDM using multilevel Bayesian methods (Johnson et al., 2017; Kruschke, 2014; Vandekerckhove et al., 2011) in JAGS (Version 4.3; Plummer, 2003; Wabersich & Vandekerckhove, 2014). We make inferences using a parameter estimation approach (Gelman et al., 2013; Kruschke, 2014). We report the most credible value of a parameter and its 95% highest density interval (HDI) in brackets. When testing condition differences and interactions, we report the most credible estimate, the effect transformed to Cohen’s *d*, and its 95% HDI.

Given our research questions, we allowed all DDM parameters to vary by target race, sleep deprivation, and caffeine. The drift rate was additionally allowed to vary by object type. We used uninformative priors for the parameters and their correlations (Klauer, 2010; Matzke et al., 2015). We did not estimate trial-by-trial variability in parameters (e.g., Ratcliff et al., 2016, 2018) due to the small number of trials per condition (40). Posterior predictive model fits predicted shooting rates and the shape of response time distributions well. However, the model does overestimate response times for slower trials (i.e., in the .9 response time quantile). Model fits, code, diagnostics, parameter estimates, and correlations are provided in the Supplemental Materials.

## Results

Data, analyses, and materials for this study are available on the Open Science Framework: <https://osf.io/t4p3r/>. We used the simr package (Version 1.05; Green & MacLeod, 2016) in R to simulate what higher order size effects the experimental design was sufficient to detect in decision accuracy. This analysis revealed that we had 82% [76, 87] power to detect a



**Figure 2.** Response time on the psychomotor vigilance task as a function of sleep deprivation and caffeine. Points are predicted means, and bars are 95% confidence intervals.

three-way interaction of  $b = 0.25$  and 81% [74, 86] power to detect a four-way interaction of  $b = 0.50$ .

### PVT

We used data from the PVT to validate the fatigue and arousal manipulations. We analyzed response times using multilevel regression, with trial, cue delay, sleep deprivation, caffeine, and the interaction between the latter two as predictors. As shown in Figure 2, sleep-deprived participants were slower to respond than rested participants,  $b = 39$  ms [23, 56]. Participants who took caffeine were faster to respond than participants who took placebo,  $b = -33$  ms [-49, -16]. There was no interaction between sleep and caffeine,  $b = -6$  ms [-39, 27]. Sleep-deprived participants who took caffeine were not slower than rested participants who took placebo,  $b = 6$  ms [-15, 28]. Thus, sleep deprivation decreased vigilant attention and caffeine increased vigilant attention, supporting the effectiveness of these manipulations.

### FPST

**Behavior analyses.** We analyzed FPST decision accuracy and correct response times using multilevel modeling, with race, object, sleep deprivation, caffeine, and their interactions as predictors (see Figure 3). As predicted, sleep-deprived participants made more errors ( $M = 0.30$  [0.28, 0.33]) than rested participants ( $M = 0.26$  [0.23, 0.29]),  $b = 0.22$  [0.11, 0.33]. Participants who consumed caffeine ( $M = 572$  ms [559, 585]) responded faster than those who took placebo ( $M = 585$  ms [572, 599]),  $b = -13$  ms [-24, -2], but caffeine did not reduce errors,  $b = -0.05$  [-0.16, 0.05]. In contrast with our predictions, caffeine consumption did not mitigate the effect of sleep deprivation on errors,  $b = -0.04$  [-0.25, 0.17].

Participants made fewer errors for armed ( $M = 0.26$  [0.23, 0.28]) than unarmed targets ( $M = 0.31$  [0.28, 0.34]),  $b = -0.28$  [-0.32, -0.23] and were faster to shoot armed targets ( $M = 547$  ms [534, 558]) than to not shoot unarmed targets ( $M = 611$  ms [599, 623]),  $b = -64$  ms [-68, -60]. Consistent with past research, there was also an interaction between race and object,  $b = -0.30$  [-0.39, -0.22]. Unarmed Black targets ( $M = 0.34$  [0.30, 0.37]) were shot more than unarmed White targets ( $M = 0.29$  [0.25, 0.32]),  $b = 0.25$  [0.02, 0.47]. Decisions to shoot armed targets did not vary by race,  $b = -0.06$  [-0.28, 0.16]. This interaction was not moderated by sleep deprivation, caffeine, or their interaction.

Finally, the effect of sleep deprivation varied by object type,  $b = -0.17$  [-0.25, -0.09]. Sleep-deprived participants missed armed targets ( $M = 0.27$  [0.24, 0.29]) more than rested participants ( $M = 0.24$  [0.22, 0.27]),  $b = 0.13$  [0.02, 0.25] but made even more errors for unarmed targets ( $M = 0.34$  [0.32, 0.37]) than rested participants ( $M = 0.28$  [0.25, 0.31]),  $b = 0.30$  [0.19, 0.42].

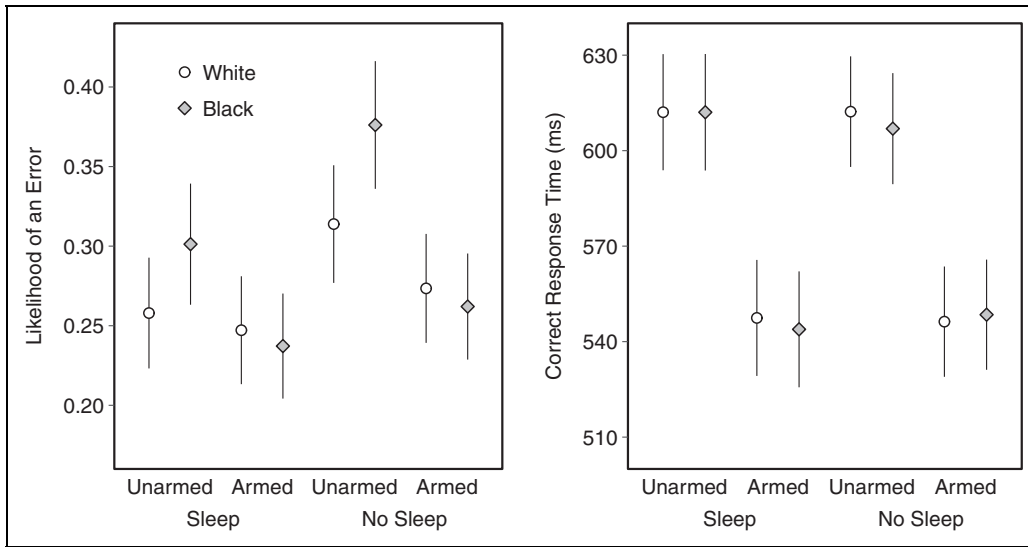
In sum, sleep-deprived participants were more likely to make errors than rested participants, and participants who took caffeine responded faster than those who took placebo. Caffeine, however, did not mitigate the negative effects of sleep deprivation. Participants also shot unarmed Black men more than unarmed White men, and this bias was not moderated by sleep deprivation or caffeine consumption. To better understand how these manipulations affected the decision process, we next analyzed data with the DDM.

**Process analyses.** Figure 4 displays all DDM parameters by condition.

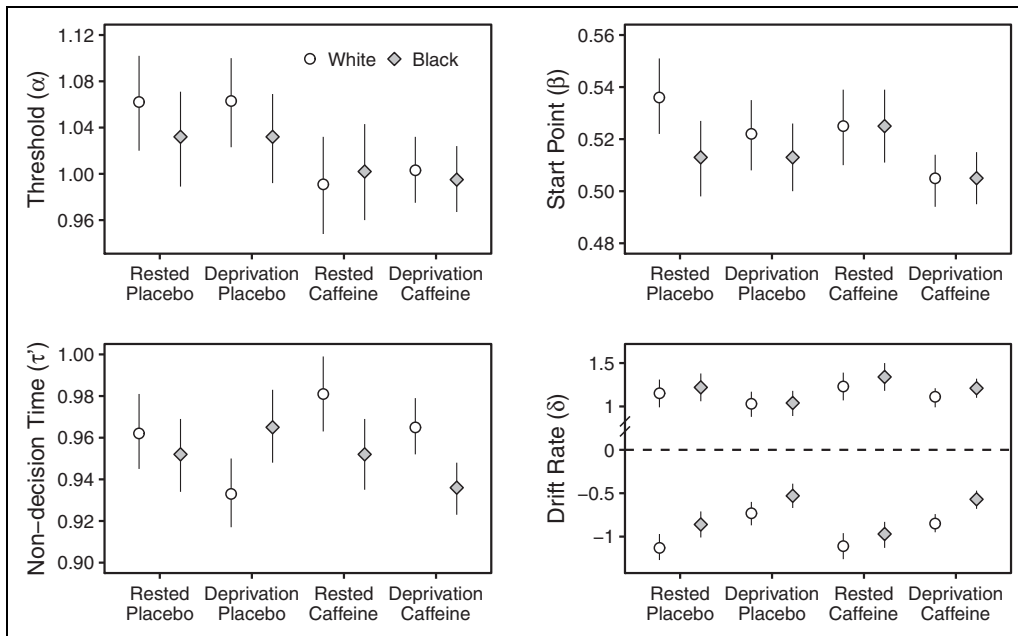
**Sleep deprivation.** Contrary to our threshold separation hypothesis, sleep deprivation did not decrease the threshold separation,  $b = 0.00$ ,  $d = 0.02$  [-0.23, 0.27], nor did caffeine moderate the effect of sleep deprivation,  $b = 0.00$ ,  $d = -0.01$  [-0.48, 0.52]. However, rested participants' relative start point favored the shoot decision more than sleep-deprived participants,  $b = -0.014$ ,  $d = -0.40$  [-0.72, -0.07].

Our hypothesis that drift rates would be lower for sleep-deprived participants was partially supported, although this depended on whether a target was armed,  $b = -0.51$ ,  $d = -1.07$  [-1.55, -0.55]. For unarmed targets, drift rates were weaker (closer to zero) for sleep-deprived ( $M = -0.76$  [-0.83, -0.69]) than rested participants ( $M = -0.93$  [-1.00, -0.86]),  $b = -0.18$ ,  $d = -0.37$  [-0.52, -0.23]. For armed targets, drift rates were not weaker for sleep-deprived ( $M = 1.18$  [1.11, 1.25]) than rested participants ( $M = 1.15$  [1.07, 1.22]),  $b = -0.03$ ,  $d = -0.07$  [-0.21, 0.08]. However, caffeine did not moderate this interaction,  $b = 0.05$ ,  $d = .11$  [-0.87, 1.10].

**Caffeine.** Although caffeine did not moderate the predicted effects of sleep deprivation, it affected the decision process in other ways. Participants' threshold separation was narrower when they took caffeine versus placebo,  $b = -0.048$ ,  $d = -0.32$  [-0.57, -0.07], reflecting a preference for speed over accuracy.



**Figure 3.** (Right) Probability of making an error in the first-person shooter task (FPST) as a function of race, object, and sleep deprivation. (Left) Response times for correct decisions in the FPST as a function of race, object, and sleep deprivation. Points are predicted means, and bars are 95% confidence intervals.



**Figure 4.** Effect of race, sleep deprivation, and caffeine on the threshold (top left), the relative start point (top right), nondecision time (bottom left), and drift rate (bottom right). Drift rates for armed targets appear above zero, drift rates for unarmed targets appear below zero. Points are predicted means, and bars are 95% highest density interval.

Caffeine further interacted with target race in the threshold separation,  $b = 0.034$ ,  $d = 0.22$  [0.03, 0.41]. When participants consumed placebo, they set wider thresholds for White targets ( $M = 1.060$  [1.035, 1.088]) than Black targets ( $M = 1.031$  [1.005, 1.057]),  $b = 0.031$ ,  $d = 0.20$  [0.06, 0.34]. The difference was not credible when participants consumed caffeine,  $b = -0.002$ ,  $d = -0.01$  [-0.14, 0.11]. Sleep deprivation did not moderate this interaction,  $b = -0.02$ ,  $d = -0.13$  [-0.50, 0.25].

Caffeine also interacted with target race in the relative start point,  $b = 0.017$ ,  $d = 0.48$  [0.04, 0.94]. When participants took placebo, they showed a higher initial bias to shoot White targets ( $M = 0.529$  [0.519, 0.538]) versus Black targets ( $M = 0.513$  [0.503, 0.523]),  $b = 0.016$ ,  $d = 0.45$  [0.14, 0.82]. The difference was not credible when participants consumed caffeine,  $b = -0.001$ ,  $d = -0.03$  [-0.32, 0.27]. Sleep deprivation did not moderate this interaction,  $b = -0.015$ ,  $d = -0.44$  [-1.31, 0.48].



Finally, there was an interaction between race and caffeine in nondecision times,  $b = -0.040$ ,  $d = -0.89 [-1.44, -0.41]$ , moderated by deprivation,  $b = -0.047$ ,  $d = -1.00 [-2.07, -0.05]$ . The race–caffeine interaction was not credible for rested participants,  $b = -0.017$ ,  $d = -0.39 [-1.17, -0.35]$ , but was for deprived participants,  $b = -0.061$ ,  $d = -1.40 [-2.14, -0.78]$ . Focusing on deprived participants, those taking placebo spent a smaller proportion of time on nondecision processes for White ( $M = 0.933 [0.917, 0.950]$ ) than Black targets ( $M = 0.965 [0.948, 0.983]$ ),  $b = -0.031$ ,  $d = -0.75 [-1.29, -0.21]$ . Those taking caffeine spent a larger proportion of time on nondecision processes for White ( $M = 0.965 [0.952, 0.979]$ ) than Black targets ( $M = 0.936 [0.923, 0.948]$ ),  $b = 0.031$ ,  $d = 0.71 [0.31, 1.09]$ .

**Race.** Based on past research with civilians, we predicted target race would impact the drift rate and not the relative start point (Correll et al., 2015; Pleskac et al., 2018). As reported above, participants did show a relative start point favoring the shoot decision for White versus Black targets, but only those who took placebo,  $b = 0.016$ ,  $d = 0.45 [0.14, 0.82]$ . However, this pattern does not explain the behavioral findings that Black targets are more likely to be shot than White targets. The other way target race could produce this pattern is through the evidence accumulation process.

As predicted, we found an interaction between target race and object type in the drift rate,  $b = -0.15$ ,  $d = -0.29 [-0.49, -0.13]$ . For unarmed targets, drift rates were weaker (closer to zero) for Black ( $M = -0.74 [-0.80, -0.67]$ ) than White targets ( $M = -0.96 [-1.02, -0.89]$ ),  $b = -0.22$ ,  $d = -0.46 [-0.61, -0.33]$ . For armed targets, drift rates were stronger for Black ( $M = 1.20 [1.13, 1.28]$ ) than White targets ( $M = 1.12 [1.05, 1.20]$ ),  $b = -0.08$ ,  $d = -0.16 [-0.32, -0.01]$ . The race–object interaction was not moderated by sleep deprivation, caffeine, or their interaction.

## Discussion

Sleep deprivation decreased vigilant attention and increased errors on the FPST, which corresponded with decreases in the rate at which participants extracted evidence from stimuli. It had an especially pernicious effect for unarmed targets; participants were more likely to shoot unarmed targets after sleep deprivation than to miss armed targets. Although individuals rely on stimulants to reduce negative effects of sleep deprivation, caffeine did not decrease shooting decision errors. In fact, participants favored speed over accuracy more after taking caffeine than placebo as indexed by the threshold separation.

Despite credible effects of sleep deprivation, it did not moderate the impact of race in evidence accumulation or in initial biases. Regardless of fatigue, participants accumulated target race (i.e., being Black) as evidence to shoot. Thus, our findings are largely consistent with past civilian research; race leads to anti-Black bias through the weapon

identification process (Correll et al., 2015; Johnson et al., 2018; Pleskac et al., 2018).

Our findings also clarify past work on fatigue in shooting decisions. This work has been split about whether fatigue exacerbates racial bias (L. James et al., 2017; Ma et al., 2013). Currently, the only significant evidence fatigue increases racial bias is based on a study using a Stroop task to manipulate fatigue via ego depletion (Study 1; Ma et al., 2013). Given recent concerns about whether ego depletion is possible in such short time periods (Friese et al., 2019), our null results should increase skepticism about the claim that fatigue increases racial bias in laboratory shooting decisions.

We also found participants who consumed placebo had wider thresholds and higher relative start point for White than Black targets. These effects indicate favoring speed over accuracy coupled with an initial bias to favor the shoot decision for White versus Black targets. Given that past research found *larger* threshold separations for Black versus White targets (Pleskac et al., 2018), or no effect of race (Johnson et al., 2018), we refrain from making strong statements about the cause or robustness of these race effects.

## Strengths and Limitations

Despite the documented negative relationship between sleep deprivation and real-world police performance (Rajaratnam et al., 2011), past research has not found participants make poorer shooting decisions when fatigued. We addressed this shortcoming by using a stronger sleep deprivation manipulation and found participants showed lower vigilant attention and made poorer decisions after 24 hr without sleep. Thus, our null results with regard to the impact of fatigue on racial bias cannot be attributed to an insufficiently strong manipulation. However, if sleep deprivation or caffeine consumption have a small effect on racial bias (i.e., less than  $b = 0.25$ ), our design may have had insufficient power to detect them.

Another strength of our approach is the ability to identify how fatigue impacted the decision process. Fatigued participants had a decreased ability to extract evidence from stimuli. This decline in ability to extract evidence was especially large for unarmed targets. At its core, the FPST is a visual search task, where participants must identify an object within a scene. Our results are consistent with an explanation, where fatigue-induced shooting performance deficits are driven by visual search impairment, a possibility to be examined in future work.

One issue with studying shooting decisions is the trade-off between internal and external validity. We studied decisions using a computer task, where only the race and armed status of targets were manipulated to ensure high internal validity. Similarly, we used a 24 hr sleep deprivation manipulation to ensure high fatigue. These benefits come at the cost of external validity. The FPST does not provide participants with prior information about who they are encountering or allow

interactions with targets, both of which impact shooting decisions (Johnson et al., 2018; Pleskac et al., under review). Similarly, responding by pressing buttons to shoot is clearly different from firing a gun during a high-threat encounter.

A final limitation is our use of student samples. In this study and prior FPST work, students typically show racial bias in the evidence accumulation process, whereas officers typically show racial bias in the relative start point (Johnson et al., 2018; Pleskac et al., 2018). While we cannot rule out that sleep deprivation could impact officers differently than students, our results suggest sleep deprivation has a selective impact on evidence accumulation. Thus, officers may also show deficits in their ability to collect evidence under sleep deprivation.

## Conclusion

Accidents where actions of sleep-deprived officers result in the death of civilians often become high-profile events (Vila & Kenney, 2002), as do fatal shootings of unarmed Black Americans (Peeples, 2019). The current study clarifies that sleep-deprived individuals are more likely to shoot unarmed individuals in a simulated shooting task and that caffeine does not mitigate these harmful effects. However, sleep deprivation does not seem to impact racial bias in those decisions. We caution direct applications of these data to real-world police shootings given the artificial nature of the task and the greater complexity involved in those decisions.

## Author Contributions

David J. Johnson, Kimberly M. Fenn, and Joseph Cesario conceptualized the article; Michelle E. Stepan collected the data; David J. Johnson analyzed the data and drafted the original article; and all authors reviewed and edited the article.


## Declaration of Conflicting Interests


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## ORCID iD

David J. Johnson  <https://orcid.org/0000-0003-4537-1748>

Joseph Cesario  <https://orcid.org/0000-0002-1892-4485>

## Supplementary Material

The supplemental material is available in the online version of the article.

## References

Basner, M., & Dinges, D. F. (2011). Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. *Sleep, 34*(5), 581–591.

- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Beaumont, M., Batejat, D., Pierard, C., Coste, O., Doireau, P., Van Beers, P., Chauffard, F., Chassard, D., Enslin, M., Denis, J. B., & Lagarde, D. (2001). Slow release caffeine and prolonged (64-h) continuous wakefulness: Effects on vigilance and cognitive performance. *Journal of Sleep Research, 10*(4), 265–276.
- Buysse, D. J., Reynolds, C. F., III, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213.
- Correll, J., Park, B., Judd, C. M., & Wittenbrink, B. (2002). The police officer's dilemma: Using ethnicity to disambiguate potentially threatening individuals. *Journal of Personality and Social Psychology, 83*(6), 1314–1329.
- Correll, J., Wittenbrink, B., Crawford, M., & Sadler, M. (2015). Stereotypic vision: How stereotypes disambiguate visual stimuli. *Journal of Personality and Social Psychology, 108*(2), 219–233. <https://doi.org/10.1037/pspa0000015>
- Dinges, D., & Powell, J. (1988). Sleepiness is more than lapsing. *Sleep Research, 17*, 84.
- Donovan, J., & DeVane, C. (2001). A primer on caffeine pharmacology and its drug interactions in clinical psychopharmacology. *Psychopharmacology Bulletin, 35*(3), 30–48.
- Friese, M., Loschelder, D. D., Gieseler, K., Frankenbach, J., & Inzlicht, M. (2019). Is ego depletion real? An analysis of arguments. *Personality and Social Psychology Review, 23*(2), 107–131.
- Gelman, A., Stern, H. S., Carlin, J. B., Dunson, D. B., Vehtari, A., & Rubin, D. B. (2013). *Bayesian data analysis*. Chapman and Hall/CRC.
- Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution, 7*(4), 493–498.
- Horne, J. A., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International journal of Chronobiology, 4*, 97–110.
- James, L., James, S., & Vila, B. (2017). Does the “reverse racism effect” withstand the test of police officer fatigue? *Policing: An International Journal of Police Strategies & Management, 40*(2), 184–196.
- James, L., James, S., & Vila, B. (2018). The impact of work shift and fatigue on police officer response in simulated interactions with citizens. *Journal of Experimental Criminology, 14*(1), 111–120.
- James, S. M., & Vila, B. (2015). Police drowsy driving: Predicting fatigue-related performance decay. *Policing: An International Journal of Police Strategies & Management, 38*(3), 517–538.
- Johnson, D. J., Cesario, J., & Pleskac, T. J. (2018). How prior information and police experience impact decisions to shoot. *Journal of Personality and Social Psychology, 115*(4), 601–623. <https://doi.org/10.1037/pspa0000130>
- Johnson, D. J., Hopwood, C. J., Cesario, J., & Pleskac, T. J. (2017). Advancing research on cognitive processes in social and personality psychology: A hierarchical drift diffusion model primer. *Social Psychological and Personality Science, 8*(4), 413–423.



- Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology, 103*(1), 54–69. <https://doi.org/10.1037/a0028347>
- Killgore, W. D., Kahn-Greene, E. T., Grugle, N. L., Killgore, D. B., & Balkin, T. J. (2009). Sustaining executive functions during sleep deprivation: A comparison of caffeine, dextroamphetamine, and modafinil. *Sleep, 32*(2), 205–216.
- Klauer, K. C. (2010). Hierarchical multinomial processing tree models: A latent-trait approach. *Psychometrika, 75*(1), 70–98.
- Kruschke, J. (2014). *Doing Bayesian data analysis: A tutorial with R, JAGS, and Stan*. Academic Press.
- Lauderdale, D. S., Knutson, K. L., Yan, L. L., Liu, K., & Rathouz, P. J. (2008). Self-reported and measured sleep duration: How similar are they? *Epidemiology, 19*(6), 838–845.
- Lim, J., & Dinges, D. F. (2008). Sleep deprivation and vigilant attention. *Annals of the New York Academy of Sciences, 1129*(1), 305–322.
- Ma, D. S., Correll, J., Wittenbrink, B., Bar-Anan, Y., Sriram, N., & Nosek, B. A. (2013). When fatigue turns deadly: The association between fatigue and racial bias in the decision to shoot. *Basic and Applied Social Psychology, 35*(6), 515–524. <https://doi.org/10.1080/01973533.2013.840630>
- Matzke, D., Dolan, C. V., Batchelder, W. H., & Wagenmakers, E. J. (2015). Bayesian estimation of multinomial processing tree models with heterogeneity in participants and items. *Psychometrika, 80*(1), 205–235.
- McLellan, T. M., Kamimori, G. H., Bell, D. G., Smith, I. F., Johnson, D., & Belenky, G. (2005). Caffeine maintains vigilance and marksmanship in simulated urban operations with sleep deprivation. *Aviation, Space, and Environmental Medicine, 76*(1), 39–45.
- Peeples, L. (2019). What the data say about police shootings. *Nature, 573*, 24–26.
- Peirce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., Kastman, E., & Lindeløv, J. K. (2019). Psychopy2: Experiments in behavior made easy. *Behavior Research Methods, 51*(1), 195–203.
- Pleskac, T. J., Cesario, J., & Johnson, D. J. (2018). How race affects evidence accumulation during the decision to shoot. *Psychonomic Bulletin & Review, 25*, 1301–1330. <https://doi.org/10.3758/s13423-017-1369-6>
- Pleskac, T. J., Johnson, D. J., Cesario, J., Terrill, W., & Gagnon, G. (under review). Modeling police officers' deadly force decisions in an immersive shooting simulator.
- Plummer, M. (2003). *JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling*. In *Proceedings of the 3rd international workshop on distributed statistical computing* (Vol. 124, No. 125.10, pp. 1–10).
- Rajaratnam, S. M. W., Barger, L. K., Lockley, S. W., Shea, S. A., Wang, W., Landrigan, C. P., O'Brien, C. S., Qadri, S., Sullivan, J. P., Cade, B. E., Epstein, L. J., White, D. P., Czeisler, C. A., & Harvard Work Hours, Health and Safety Group. (2011). Sleep disorders, health, and safety in police officers. *Journal of the American Medical Association, 306*(23), 2567–2578.
- Ratcliff, R. (1978). A theory of memory retrieval. *Psychological Review, 85*(2), 59–108. <https://doi.org/10.1037/0033-295X.85.2.59>
- Ratcliff, R., Huang-Pollock, C., & McKoon, G. (2018). Modeling individual differences in the go/no-go task with a diffusion model. *Decision, 5*(1), 42–62.
- Ratcliff, R., Smith, P. L., Brown, S. D., & McKoon, G. (2016). Diffusion decision model: Current issues and history. *Trends in Cognitive Sciences, 20*(4), 260–281. <https://doi.org/10.1016/j.tics.2016.01.007>
- Ritter, F. E., & Yeh, K. C. M. (2011). Modeling pharmacokinetics and pharmacodynamics on a mobile device to help caffeine users. In: Schmorow, D. D., & Fidopiastis, C. M. (eds) *International conference on Foundations of augmented cognition. Directing the Future of Adaptive Systems. FAC 2011. Lecture Notes in Computer Science, vol 6780*. (pp. 528–535). FAC Springer, Berlin, Heidelberg.
- Senjo, S. R. (2011). Dangerous fatigue conditions: A study of police work and law enforcement administration. *Police Practice and Research: An International Journal, 12*(3), 235–252.
- Shepherd, K. (2019). 'Not racist but . . .': White police officer who killed innocent black man in his home sent offensive texts. Retrieved October 2, 2019, from [www.washingtonpost.com](http://www.washingtonpost.com)
- Stepan, M. E., Altmann, E. M., & Fenn, K. M. (under review). Caffeine selectively mitigates cognitive deficits associated with sleep deprivation.
- Vandekerckhove, J., Tuerlinckx, F., & Lee, M. D. (2011). Hierarchical diffusion models for two-choice response times. *Psychological Methods, 16*(1), 44–62. <https://doi.org/10.1037/a0021765>
- Vila, B. (1996). Tired cops: Probable connections between fatigue and the performance, health and safety of patrol officers. *American Journal of Police, 15*(2), 51–92.
- Vila, B., & Kenney, D. J. (2002). The prevalence and potential consequences of police fatigue. *NIJ Journal, 248*, 17–21.
- Wabersich, D., & Vandekerckhove, J. (2014). Extending JAGS: A tutorial on adding custom distributions to JAGS (with a diffusion model example). *Behavior Research Methods, 46*(1), 15–28. <https://doi.org/10.3758/s13428-013-0369-3>
- Wesensten, N., Belenky, G., Kautz, M. A., Thorne, D. R., Reichardt, R. M., & Balkin, T. J. (2002). Maintaining alertness and performance during sleep deprivation: Modafinil versus caffeine. *Psychopharmacology, 159*(3), 238–247.
- Wesensten, N. J., Killgore, W. D., & Balkin, T. J. (2005). Performance and alertness effects of caffeine, dextroamphetamine, and modafinil during sleep deprivation. *Journal of Sleep Research, 14*(3), 255–266.

## Author Biographies

**David J. Johnson** is a postdoctoral researcher at the Lab for Applied Social Science Research at the University of Maryland. His research employs computational models and secondary data analyses to study the psychological processes that underlie decisions.

**Michelle E. Stepan** recently received her PhD in cognition and cognitive neuroscience at Michigan State University. Her research focuses on how sleep and sleep deprivation affect memory, attention, and processes related to problem-solving.

**Joseph Cesario** is an associate professor of psychology at Michigan State University. He studies social cognition and decision making.

**Kimberly M. Fenn** is an associate professor of psychology at Michigan State University. Her research focuses broadly on learning and

memory and factors that either facilitate or impair these processes. Her primary area of expertise is in how a period of sleep or sleep deprivation affects cognition, learning, and memory.

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