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Professional paper

STRESS RESPONSE AND PERFORMANCE CHANGES OF LAW ENFORCEMENT OFFICERS' MARKSMANSHIP UNDER VARIED PHYSIOLOGY STRESS LEVELS

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Abstract

Aim: This study aimed to investigate changes in the stress response and shooting performance of law enforcement officers under varying levels of stress via simulated life-threatening situations. Methods: Thirteen experienced law enforcement officers completed three handgun-shooting trials. Trials included a modified course adopted from the Illinois State Firearms Qualification and two simulated conflicts using a TI Simulator (TI Training, Golden, Colorado). Heart rate, blood pressure, alpha-amylase, cortisol, and shooting performance data were collected around each trial. Results: Compared with the qualification course, the results showed a significant reduction in the percentage of shots hit during the simulated conflicts. No correlation was found between physiological variables measured in this study and marksmanship performance. Conclusions: Simulated encounters can be used to expose law enforcement officers to stressful situations where marksmanship skills can be trained and evaluated. While no physiological variables changed between simulation scenarios, the shots that hit the targets was significantly lower for the T1 simulator compared to a modified course adopted from the Illinois State Firearms Qualification. Further research is necessary to determine whether such training can create enough stress response to cause adaptation for training effect.

Keywords: Law Enforcement, Marksmanship, Stress, Cortisol, Blood Pressure, Heart Rate

Introduction

Fine motor skill performance under stress is commonly demonstrated by competitive athletes during game-time situations in challenging environments. However, law enforcement officers, and occasionally civilians who find themselves in a self-defense situation, physically performing under stress can mean the difference between life and death for themselves and for those around them. Law enforcement is characterized by high levels of stress with a simultaneous high expectation of performance (Groer et al. 2010), and if a law enforcement officer is called upon to use deadly force in the defense of themselves or others, the precise movement patterns used in the process of marksmanship skills could be affected by the high levels of stress.

Currently, law enforcement officers receive a varied duration of training on marksmanship skills, using several different modes of training and professional qualifications. According to Charles and Copay (2003), regarding specific marksmanship training, traditional line officers receive 48 hours of training over a 480-hour police academy curriculum. Further training may take place at individual police departments on top of the required firearms qualification, but as Charles and Copay (2003) point out, "The typical police training and qualification test, supposedly sanctioning police firearms proficiency, are not sufficiently related to the skills

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required to perform in real-life shooting incidents." Taverniers and Boeck (2014) believe that the current firearms training for law enforcement officers (dominated by traditional carboard-style targets) is insufficient, and Thomasson et al. (2014) believes that firearm training is one of the most important aspects of training because of several factors related to safety and the public's expectation of protection and liability.

When an individual is subjected to a high stress situation, many actions of the body are governed by the sympathetic branch of the autonomic nervous system (Martini, 1998). Depending on the severity of the situation, the sympathetic branch of the autonomic nervous system may take a varying degree of control, and at its highest level of control, the individual could experience a "fight-or-flight" response which, according to Martini (1998), "prepares the body for a crisis that may require sudden, intense physical activity" (p. 514). In response to increased stress, the hypothalamus initiates the fight-or-flight response by causing a cascading release of chemical messengers, leading to the secretion of hormones from the adrenal glands. Activation of the adrenal glands results in the release of stress hormones into the bloodstream, including cortisol, released from the adrenal cortex, and catecholamines epinephrine (E) and norepinephrine (NE), released from the adrenal medulla (Amerman, 2016). The purpose of these hormonal responses to stressful situations is to allow individuals to experience them the fight for survival or flight from danger to avoid harm. However, with the heightened potential for physical ability seen in a fight-or-flight response, researchers, including Thompson et al. (2015), witnessed diminished capacities in other mental and physical variables, including fine motor skill performance.

Based on this idea, it can be extrapolated that when law enforcement personal perform physical activity at its greatest sympathetic stimulus potential that the heightened stress could result in a diminished level of performance, and the officer may exceed the optimal level of stimulus and ultimately perform marksmanship activities with reduced technical proficiency or marksmanship. Physiological variables must be quantified before, during, and after a stressful situation to determine how an individual subject responds and if any fine motor skills are affected during a fight or flight response. Current technology demonstrates the opportunity to assess stress responses through the measurement of enzymes and hormones released into salivary gland secretions after exposure to a stress-inducing situation. (Hellhammer, et al 2009) (Nater and Rohlander, 2009) (Granger, et al 2007), and these increases in hormonal changes have been documented to mirror increases in cardiovascular functioning as quantified through heart rate and changes in systolic blood pressure. Thus, Hellhammer et al. (2009) suggested the use of salivary cortisol measurement as an assessment of stress response owing to its simplicity in collection and its link to HPA axis activity.

Therefore, this investigation was set to build upon the existing knowledge of how the performance of fine motor skills, which are related to pistol marksmanship, can be altered by increasing levels of stress or anxiety. Accordingly, the purpose of this examination was to determine how increased levels of stress affect the performance of fine motor skills related to pistol marksmanship among law enforcement officers.

Methods:

Thirteen police officers between the ages of 25-55 were recruited to participate in this simulation-based study. The subjects included police and/or officers from Special Weapons and Tactics (SWAT) teams from municipal police departments and county Sheriff departments with varying lengths of service. Identifying officers with SWAT experience may be particularly relevant, as in most cases, SWAT officers receive additional training in skills related to this investigation. Exclusion criteria for this investigation were uncontrolled hypertension and/or cardiac arrhythmias. Only male subjects were eligible to participate in this investigation due to hormonal differences between male and female subjects, as well as possible risks to unborn

children due to loud noises and any risk of falling during experimental activities. All participants in this experiment were full-time, active-duty law enforcement officers with at least one prior firearm qualification experience within their respective departments.
All subjects were informed of the risks and benefits associated with this investigation and provided written consent prior to participation in accordance with the Northern Illinois University's Institutional Review Board and Institution Biosafety Committee. Permission to conduct this study was approved by the departmental review boards at the testing locations.
This study employed a counterbalanced quasi-experimental design. Each subject participated in two different conditions, separated by at least 48 h, with different levels of complexity and stress. After initial baseline data were collected at rest, subjects were randomized between two different assessments: (1) basic pistol qualification procedures (operating their standard duty firearm against static simulation targets within the time limit adopted from the Illinois Law Enforcement Training and Standards Board), and (2) a simulated conflict (involving complex problem solving and challenging marksmanship activities, including encounters with simulated aggressive assailants). The basic pistol qualification course was adopted from Illinois Law Enforcement Training and Standards. Short-distance shooting required the participants to draw the pistol from a holster and fire two rounds in six seconds, repeated six times for a total of 12 possible shots. Middle-distance shots continued the pattern of two shots fired in 6 s, repeated six times, for a total of 12 shots. The longest distance stages included drawing from the holster and firing one shot in 6 s for six total rounds during this portion of the course. This format allowed 30 shots to be captured across three distances.
Participants began the virtual reality condition after receiving a situational report on how to approach their scenario as a real-life call in the line of duty. A state-certified range master was on-site at all times during the experience and was able to provide feedback to the participants in relation to law enforcement procedures, as would be the case in a live training exercise.

Preliminary Screening and Study Protocol

Each subject wore a heart rate monitor for the duration of the investigation, with data collected between each course of the fire adopted by the Illinois Law Enforcement Training and Standards Board. Initial measurements included resting heart rate, blood pressure, and saliva samples with each subject seated quietly. Once the initial screening was completed, subjects rested for 10 min and then had their baseline saliva samples taken for cortisol and salivary alpha-amylase.

Assessment of Heart Rate and Blood Pressure

Each subject was given a Polar FT60 heart rate monitor (Polar Electro, Lake Success, NY, USA) to wear over the entire course of data collection. The heart rate monitor display watches were worn by each participant on their wrists to be read by investigators between the courses of fire. Heart rate data were collected immediately before the beginning and between each section of the course of fire. Final heart rate data were collected immediately after the conclusion of the course of fire. Blood pressure data were collected by the same master's-level exercise physiologist prior to beginning any condition, with the subjects resting in a seated position for baseline. Immediately after completion of each condition, once the subjects had made safe and holstered their firearms, their blood pressure was measured and recorded again in a seated position.

Assessment of Salivary Biomarkers

To ensure that proper collection took place, subjects were asked not to eat, drink beverages other than water, or smoke within 1 h of the testing time. Baseline salivary samples were collected 5 min after the completion of the initial screening. At the termination of each marksmanship scenario, saliva samples were collected at the 10-minute post-termination point to ensure that samples were taken at the greatest possible concentration level for both cortisol and salivary alpha-amylase. Samples were frozen and sent to Salimetrics (State College, PA, USA) for analysis. The analysis included enzyme-linked immunosorbent assays for cortisol and enzymatic reactions performed with alpha-amylase reagents. The samples were thawed to room temperature, vortexed, and centrifuged for 15 min at approximately 3,000 RPM (1,500 × g) immediately before performing the assay.
The samples were tested for salivary cortisol using a high-sensitivity enzyme immunoassay (Cat. No. 1-3002). The sample test volume was 25 µl of saliva per determination. The assay has a lower limit of sensitivity of 0.007 µg/dL, a standard curve range from 0.012-3.0 µg/dL, an average intraassay coefficient of variation of 4.60%, and an average inter-assay coefficient of variation 6.00%, which meets the manufacturer's criteria for accuracy and repeatability in salivary bioscience, and exceeds the applicable NIH guidelines for enhancing reproducibility through rigor and transparency.

Assessment of Marksmanship Scoring

Initial marksmanship scores were determined on a flat simulated shooting range within a TI Training Simulator (TI Training, Golden, Colorado) against the static overlay/center mass of targets, with each subject using a battery-operated pistol with a marking laser. Prior to each round of data collection, the TI Training Simulator was calibrated using the same laser-marking pistol to ensure the accuracy of the shots placed by each subject. Each participant was asked to follow the course of fire adopted from the Illinois Law Enforcement Training and Standards Board. Scoring data included number of shots taken and counted as either "Hit" or "No-Hit" in accordance with the standard qualification procedure. The second condition required each participant to engage in two simulated dangerous encounters with virtual suspects using a TI Training Simulator (TI Training, Golden, Colorado, USA). This activity required the participants to perform duties as they would in a real-life situation, including discharging their firearms at various intervals against an unknown number of assailants. Hit percentage scores were collected for each participant, including those against multiple targets in succession and simultaneously. Scoring data included the number of shots taken and counted as either "Hit" or "No-Hit" in accordance with the standard training procedure.

Results

Marksmanship Performance

After data collection was completed, a paired-samples *t*-test was performed to determine whether a significant difference existed in the accuracy of shooting between the modified Illinois Firearms Qualification Course-of-Fire (IFQC) and the two simulated conflicts (SimCon1, SimCon2). During the modified IFQC, participants fired 390 rounds at targets, with 387 falling within the target area, resulting in a 99.23% hit rate. During the first simulated conflict (SimCon1), participants fired 56 shots, 27 of which were recorded as hits to the intended targets. This yielded a 47.48% average hit rate, with an individual range of 100% hit rate to 0% hit rate across participants. The median hit percentage for Simulated Conflict 1 is 37.50%.

During the second simulated conflict (SimCon2), the participants fired 41 shots, 23 of which hit their intended target. This yielded a 50.13% hit rate, with an individual range of 100% hit rate to 0% hit rate across participants. The median hit percentage for Simulated Conflict 2 is 50.00%.

A paired sample *t*-test comparing the hit percentage of the modified IFQC to SimCon1 showed a mean difference between the two tests of 51.75% with a standard deviation of 28.19%. The *t* statistic between the modified IFQC and SimCon1 was 6.62 with a significance level of p = .000025. A paired sample *t*-test comparing the hit percentage of the modified IFQC to SimCon2 showed a mean difference between the two tests of 49.10% with a standard deviation of 34.74%. The *t* statistic between the modified IFQC and SimCon2 was 5.01 with a significance level of p = 0.000263. With both tests showing statistical significance at $p<0.05$, the null hypothesis is rejected. To further illustrate the effect size, a Cohen's *d* test was performed between means of the modified IFQC and SimCon1 which resulted in a score of 2.5598; the same test for the modified IFQC and SimCon2 resulted in a score of 1.9415. According to Rice and Harris (2005), Cohen's D scores of .2, .5, and .8 represent small, medium, and large effects, respectively. With the results from this study yielding much larger scores of over 2.5 and 1.94, we conclude that there is a very large effect size between the modified IFQC tests and both simulated conflicts.

Salivary Cortisol and Alpha-Amylase

The saliva samples analyzed for the biomarker alpha-amylase yielded insufficient results and were not included in the analysis portion of this experiment. Because one sample provided insufficient saliva for both cortisol and alpha-amylase, one sample of cortisol was missing from the dataset and labeled as QNS (quantity not sufficient). In this case, we were able to impute the mean from the remaining data to provide a data point for a single missing cortisol level. Salivary cortisol was measured at rest and again after completion of the modified IFQC and the two simulated conflicts (SimCon1 and SimCon2). With the known decrease in accuracy as shown above, Pearson's *r* correlation was used to assess any relationship between the change in salivary cortisol and performance in the two simulated conflicts. By including the hit percentages of both simulated conflicts together, as they were completed collectively before the salivary cortisol level was measured, the Pearson statistics showed no relationship between the two variables. The Pearson correlation between salivary cortisol and hit percentages recorded during the simulated conflicts yielded .010 and a significance of $p = .975$. A scatter plot of the simulated conflict total hit percentage and salivary cortisol change from resting state is shown in Figure 4.3.

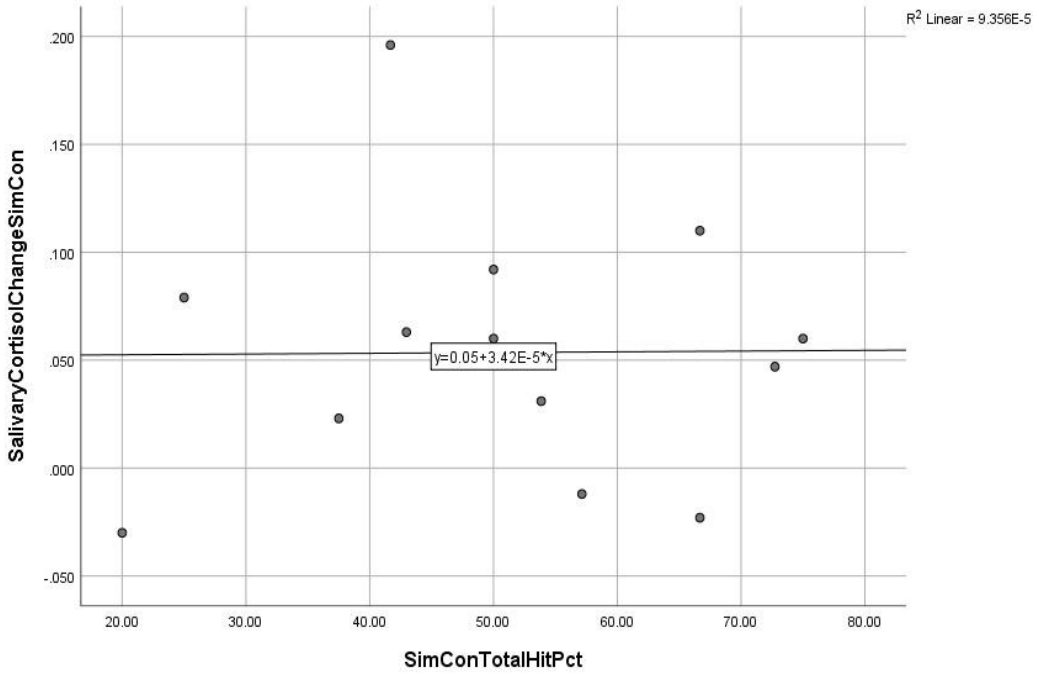


Figure 4.3: Relationship Between Change in Salivary Cortisol and Shot Hit Percentage of Simulated Conflict

Heart Rate

To determine the greatest possible effect of the shooting experience on heart rate, statistical analysis was performed on the data representing the change from resting heart rate to the data collected immediately after the shooting activities. In recognition of the significantly decreased accuracy taking place during the simulated conflict in comparison to the modified IFQC, the analysis focused on the simulated conflict to find any correlation between change in heart rate from resting and decreased shooting accuracy. The Pearson correlation between the heart rate and hit percentages recorded during the first simulated conflict (SimCon1) yielded .022 and a significance level of $p = .943$. When the test was repeated after the second simulated conflict (SimCon2), the Pearson correlation yielded −.35, with a significance level of $p = .909$.

Blood Pressure

Blood pressure data were collected at rest, immediately prior to beginning any course of fire, and once each simulation was completed. To determine the greatest possible effect of the shooting experience on blood pressure, statistical analysis was conducted on the data representing the change from resting heart rate to data collected immediately after the shooting activities. Once again, with the significantly decreased accuracy taking place during the simulated conflicts in comparison to the modified IFQC, the analysis focused on the simulated conflicts to determine any correlation between the change in blood pressure and decreased shooting accuracy. During Simulated Conflicts 1 and 2, the average changes in participants' systolic blood pressure were 18.77 mmHg and 23.08 mmHg, respectively. Diastolic blood pressure had an average change for the same tests of 4.15 mmHg and 5.54 mmHg. When comparing the change in systolic blood pressure to shooting performance, a Pearson correlation for SimCon1 showed a correlation of −.104 and a significance level of $p = .735$. See Figure 4.4. For SimCon2, the same statistical approach showed a correlation of −.429 and a significance level of $p = .144$. See Figure 4.5.

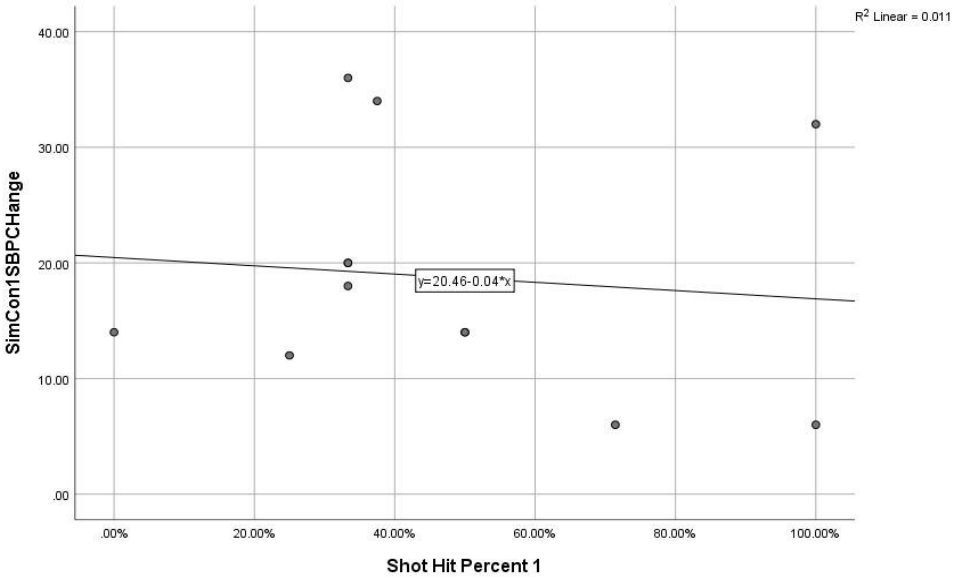


Figure 4.4: Relationship Between Change in Systolic Blood Pressure and Hit Percentage During Simulated Conflict 1

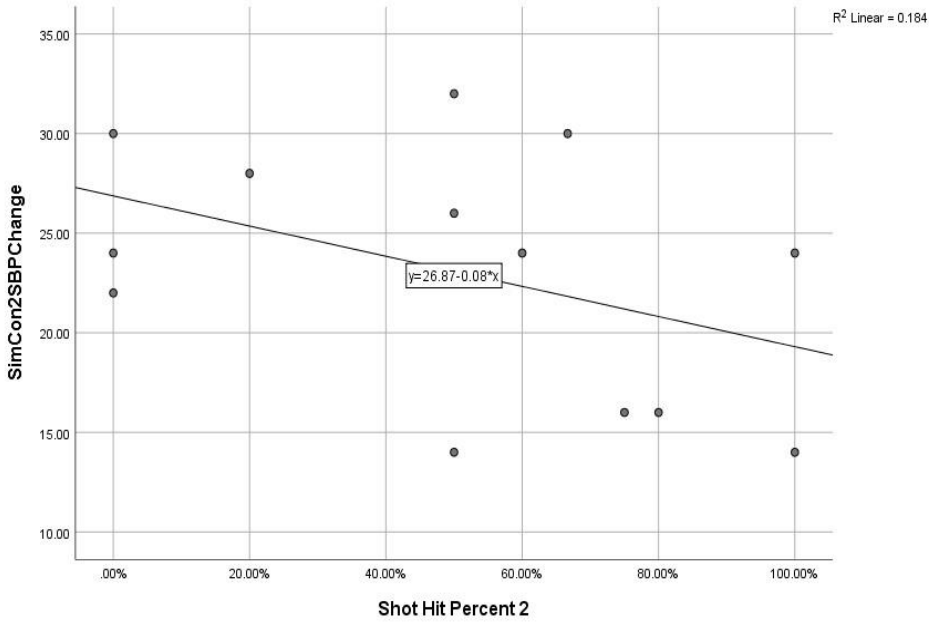


Figure 4.5: Relationship Between Change in Systolic Blood Pressure and Hit Percentage During Simulated Conflict 2

Discussion

This study investigated how the shooting performance of trained active-duty law enforcement officers changed when they experienced varying levels of stress. When compared to a standard firearms qualification course of fire, simulated conflicts will show a decrease in marksmanship performance with a loss of shooting accuracy. Across the three differing scenarios used in this study, heart rate, blood pressure and cortisol levels can increase in some individuals, suggesting a stress response, but this study showed no relationship between the measured stress response and altered marksmanship performance. Earlier literature suggests that acute stress response

can have a detrimental effect on fine motor skills (Thompson, 2015). Additionally, Wegner (2014) provides additional support for the stress response and diminished performance. However, from this study, authors were not able to find a specific stress response which closely related to a decrease in physical performance of marksmanship skills.

Based on the results of this investigation, it should be noted that the type of simulation used in this study elicited a physiological response by the participants, including a mean heart rate increase of 16.46 beats per minute after SimCon1 and 19.70 beats per minute after SimCon2, and an increased mean systolic blood pressure of 18.77 mmHg and 23.08 mmHg across the two simulated conflict trials. As Thompson et al. (2015) noted, several studies have shown that increased arousal during stressful situations can influence psychomotor tasks, including marksmanship skills. Authors Oudejans (2008) and Nieuwenhuys and Oudejans (2010) found results from similar studies where shooting performance during stressful situations was significantly diminished in both military personnel and law enforcement officers. However, although a physiological response was noted during this investigation, it did not statistically correlate with the change in shooting performance of the group

A couple of other factors must be considered when physiological responses do not appear to be related to diminished fine motor skills, as was the case in this investigation. The first consideration included whether the simulation was creating enough of a physiological response to drive the participants to a state of arousal where diminished performance would consistently occur over a greater number of participants. As Wegner et al. (2014) pointed out, differing levels of stimulation may cause changes in performance, both positive and negative, in relation to the desired outcome.

Finally, with the widespread use of simulation training and other real-life analogs, future investigations should compare the effects of detrimental feedback to the participants, such as pain from marker ammunition, as a further enhancement to understanding how officers respond to stressful situations, which may necessitate more consistent use of these tools in officer training protocols.

Conclusion

Simulation technology can be a useful tool for marksmanship training and skill refinement. With scenario-based training options available, law enforcement officers can be exposed to a wide range of skills and tactics not found on a standard flat range during typical target style practice. During this training, acute stress response can become elevated, exposing officers to physiological challenges to marksmanship performance. If repeated exposure to stressful encounters can create an adaptation resulting in improved motor control, marksmanship skills under stress may be enhanced through regular use of this technology.

Limitations

This study has limitations that must be acknowledged. Although each participant served as their own control, the number of participants who provided complete data for this study should be increased to better represent the population. However, with research of this type, it was necessary to recruit subjects who were current law enforcement officers, and due to departmental needs, they must be on duty to participate. This creates challenges for participants as their occupation requires attention and total time commitment while on duty. Future research should collect repeated saliva samples for additional processing when determining biomarker concentrations.

Author Contributions

B.M. conceived the presented idea. B.M and P.C. wrote the manuscript with support from J.L and D.W.
B.M. and P.C. assisted with data collecting and carrying out the experiment. All authors reviewed the manuscript.

Conflict of Interest Statement

We have no conflicts of interest to disclose.

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