The Risk of Being Shot At: Stress, Cortisol Secretion, and Their Impact on Memory and Perceived Learning During Reality-Based Practice for Armed Officers

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*A field experiment was organized during a handgun shooting workshop for armed officers (*N *= 36). In-depth stress analyses involved anticipatory distress, subjective stress, and salivary cortisol reactivity triggered by reality-based handgun shooting practice and, more specifically, by being in an uncontrollable situation with the risk of being shot at. Subsequently, the study examined to what extent exposure to reality-based stress affected working memory performances and self-perceived active learning. As expected, the risk of being shot at caused more anticipatory distress, subjective stress, and increasingly triggered cortisol secretion. Further results showed that, although stress endurance deteriorated working memory performance, participants in the high-realism group simultaneously self-perceivably learned more (i.e., acquired task-relevant*

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We thank the organizers of the Interdepartmental Forum for the opportunity to conduct the research; the members of the research team, Werner Lebon and Aurélie Delonghie, without whom the study would not have been possible; and Welko Tomic for his appreciated comments that helped to improve the article.

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International Journal of Stress Management
2011, Vol. 18, No. 2, 113–132

1072-5245/11/$12.00 DOI: 10.1037/a0023742

skills and competencies). The dual stress effect may result from the professional appreciation of reality-based practice and increased self-efficacy toward hazardous real-life situations. Balancing the intersection between occupational psychology, cognitive psychology, and psychoneuroendocrinology, this study performed stress research in an important and rarely accessible professional setting.

Keywords: active learning, digit span test, glucocorticoids, NASA TLX, working memory

Stress management capabilities and appropriate cognitive functioning under dangerous, nonroutine circumstances are key issues in so-called "high-reliability occupations" (Flin, 2002, p. 255). These professions are characterized by high demands and fatal outcomes in case of failure. As a consequence, the ability to effectively cope with stress and calmness in crisis are commonly required performance characteristics. In their line of duty, police officers and military personnel can reasonably be expected to encounter hazardous situations in which errors can have life-threatening consequences. These situations require the best knowledge available for appropriate cognitive functioning during stressful events (Bartone, Roland, Picano, & Williams, 2008; Delahaij, Van Dam, Gaillard, & Soeters, 2011). Empirical work, however, in this domain is very limited, particularly when it involves in-depth stress analyses with endocrinological markers (e.g., cortisol secretion; Dickerson & Kemeny, 2004) and outcome measures such as information processing, working memory, skill acquisition, and learning in operational settings (Harris, Ross, & Hancock, 2008).

Whereas traditional handgun training has focused primarily on cardboard-target practice (e.g., Murray, 2004), recent developments increasingly involve simulation-based instruction and reality-based programs (Fletcher, 2009; Oudejans, 2008). Reality-based handgun programs simulate real-life confrontations that oblige armed officers to perform under increased pressure and anxiety. Pressure and anxiety are the core dimensions of acute stress (Warr, 1990) and may lead to officers who underperform under threat (e.g., Keinan & Friedland, 1996). For instance, Morrison and Vila (1998) found no relationship between traditional handgun training and shooting in the line of duty; they suggested that traditional training doctrines "provide poor preparation for the challenges posed by armed confrontations" (p. 527). Oudejans (2008) examined the effects of reality-based handgun training on a perceptual–motor task and found that police officers' shooting performances degraded significantly when they "choked" under pressure. Similarly, Nieuwenhuys and Oudejans (2010) demonstrated that pressure and anxiety negatively affect officers' handgun shooting accuracy, situational awareness (increased eye blinking), and effective bodily posture. At present, there is—to the current authors' knowledge—no empirical work that has investigated combined stress effects, cognitive alterations, and self-reported learning during reality-based practice.

STRESS AND CORTISOL SECRETION

Stress is a multifaceted phenomenon that comprises diverse reactions toward tangible or mentally evoked threats. Beside subjective experiences, stressful events also trigger a number of psychophysiological reactions. Karasek and Theorell (1990) neatly formulated the complexity of stress induction: "Stress is a systemic concept referring to a disequilibrium of the system as a whole, in particular of the system's control capabilities. Biological control systems include the brain, the heart muscle, and psychoendocrine systems. Control systems also occur at the level of cognitive functioning . . ." (p. 87). From a psychological perspective, many of these psychoendocrine reactions are related to the stress-responsive hypothalamic–pituitary–adrenal axis, which secretes glucocorticoids (primarily cortisol in humans) in reaction to factual or apparent hazardous events (e.g., Wolf, 2009). However, psychoendocrinological research on acute naturalistic stressors is rare, and a meta-analysis by Dickerson and Kemeny (2004) concluded that there has been "surprisingly little empirical work in humans that has examined the relationship between acute, uncontrollable psychological situations and cortisol responses" (p. 359).

Cortisol regulation is a protective bodily response mechanism that mobilizes energy to cope with stressors and prevents the system from overshooting and damaging vital functions (Munck, 2000). Besides providing protection, ample neuropsychological research has shown that cortisol readily enters the brain and may modulate cognitive performances. Whereas the direction of the modulation is influenced by the envisaged memory phase (De Quervain, Aerni, Schelling, & Roozendaal, 2009; Smeets, 2010), the relationship between stress and cognitive performances resembles an inverted U curve (Joëls, Pu, Wiegert, Oitzl, & Krugers, 2006). That is, whereas moderate stress levels provoke moderate cortisol reactivity and usually result in positive effects of improved memory (Wolf, 2009), stress research during strenuous military training has found both robust cortisol increases and significant decreases in cognitive performances (Morgan, Doran, Steffian, Hazlett, & Southwick, 2006; Morgan et al., 2000, 2001, 2002; Taverniers, Van Ruysseveldt, Smeets, & von Grumbkow, 2010; Taylor et al., 2007).

WORKING MEMORY AND ACTIVE LEARNING

An important cognitive brain system is working memory (WM). WM supports human thought processes by providing an interface between perception, long-term memory, and action-related information (Baddeley, 2003). Accordingly, its key characteristics are the capacity to store, manipulate, and process information (Unsworth & Engle, 2007). Although a theoretical concept derived from cognitive psychology, appropriate WM functioning in daily life is very important as demonstrated by its positive relationships with problem-solving capabilities, arithmetic, and overall academic achievement (Dehn, 2008; Hoffman & Schraw, 2009). WM's processing capacity, however, is limited, and disproportioned storage or excessive demands can have severe consequences for ongoing cognitive activities (Alloway, 2006; Alloway, Gathercole, Kirkwood, & Elliot, 2009) or for filtering relevant and irrelevant information (Ahw & Vogel, 2008). They may even lead to a permanent loss of information that is prevented from reaching long-term memory (Medina, 2008). WM is also sensitive to intense stress (Morgan et al., 2006; Taverniers, et al., 2010), and a better understanding of the way naturalistic stressors affect WM is important because many operational errors have been related to dysfunctional WM performances. For instance, limited WM capacity in threatening environments has been significantly related to increased risk of police officers' aggressive shooting behavior toward unarmed bystanders (Kleider & Parrott, 2009). Kleider, Parrott, and King (2010) additionally found an increased overall error risk and a higher likelihood of reaction failures against armed opponents for police officers with reduced WM processing capacity.

Whereas WM is unambiguously a cognitive construct, self-reported active learning is a task-related outcome that "occurs in situations that require both individual psychological energy expenditure (demands or challenges) and the exercise of decision-making competence" (Karasek & Theorell, 1990, p. 92). Most occupational learning outcomes are tacit and broadly regarded as part of a person's general capability in a job context (e.g., Streumer & Kho, 2006). Accordingly, individual perception of what is learned and its work-related relevance are key issues in active learning (i.e., perceived acquisition of skills and competencies; Doornbos & Krak, 2006). Active learning can occur during training and may develop into a feeling of mastery, self-efficacy, and increased motivation (Karasek & Theorell, 1990). Past work has provided some evidence that anxiety provokes nontask activities and reduces the efficacy of information processing. Information processing is a crucial step in the early stages of skill acquisition (Colquitt, LePine, & Noe, 2000; Warr & Downing, 2000). Conversely, findings in the domain of military PC-based training revealed that participants performed better and became more motivated by training realism and increased context-relevant stress (Morris, Hancock, & Shirkey, 2004). Reality-based practice also induces context-relevant stress and, simultaneously, provides ample opportunities to encounter new situations and to develop new skills and competencies. Karasek and Theorell (1990) predicted that such a situation would lead to more active learning. Moreover, if what is learned can be used during job performance, reality-based programs may trigger constructive reinforcements of learned skills in situations that resemble stressful real-life events, thus improving the transfer of training and enhancing a feeling of mastery and self-efficacy (Goldstein & Ford, 2002; Karasek & Theorell, 1990).

THE CURRENT STUDY

Reality-based handgun practice is a relatively new evolution in the training curriculum of armed officers (Nieuwenhuys & Oudejans, 2010; Oudejans, 2008). The current study is, to our knowledge, the first to perform in-depth analyses of the added stress effects of reality-based practice. More specifically, we compared the experienced stress during high-realism practice with the stress of a control group that practiced in identical circumstances but, explicitly, without “the risk of being shot at” (i.e., not with a control group that performed cardboard-target practice). Empirical work that combines naturalistic stressors, psychoneuroendocrinological stress markers, and cognitive outcomes is limited in itself (Dickerson & Kemeny, 2004; Harris et al., 2008; Orasanu & Backer, 1996), and few if any studies have compared factual WM capacities with self-reports of active learning (i.e., the perceived acquisition of skills and competencies relevant for work; Doornbos & Krak, 2006). The current study integrated these research features and examined them in a venue ideal for conducting naturalistic stress research while being in full accordance with the appropriate ethical standards.

In accordance with the above argumentation, we hypothesized that the high-realism group (vs. the control group) would report more anticipated distress before running the workshop (i.e., preceding any action involved; Hypothesis 1). After execution of the workshop, the risk of being shot at in the high-realism group (vs. the control group) would lead to more self-reported subjective stress (Hypothesis 2) and trigger significantly more cortisol reactivity (Hypothesis 3). Subsequently, we assumed that the stress caused by high-realism practice (vs. the control group) would impede WM processing (Hypothesis 4) and simultaneously would increase self-reported active learning (i.e., the perceived acquisition of task-relevant skills and competencies; Hypothesis 5).

METHOD

Participants

Participants were 36 healthy male armed officers with body mass indexes (BMIs) ranging from 20.8 to 28.7 kg/m^2. Ages ranged from 22 to 59 years ($M = 38.17$ years, $SD = 9.57$), and all were in active service. Participants were controlled for endocrine disorders and the use of medication on location. Data from six participants were excluded from the analyses because their BMIs exceeded 29 kg/m^2; a too-elevated BMI could distort hormonal results (Nicolson, 2008). Seven participating officers had previously been involved in real-life shooting incidents (control: $n = 3$; high-realism: $n = 4$, randomly assigned).

Measures and Materials

Anticipated Distress

Immediately after the workshop's briefing (and the announcement of the experimental condition), participants' anticipated stress was measured with the Subjective Units of Distress Scale (SUDS). The SUDS is a well-anchored one-item Likert scale that is often used in this type of research (e.g., Morgan et al., 2006). Scoring possibilities ranged from 0 (*no distress*) to 10 (*extremely high distress*).

Saliva Sampling and Cortisol Analyses

Salivary cortisol is a valid, reliable, and noninvasive index of unbound fractions of cortisol in the blood (Kirschbaum & Hellhammer, 1989, 1994; Nicolson, 2008). Increases of cortisol concentrations are measurable within 5 to 20 min following the onset of the stressor (e.g., Nicolson, 2008). Samples were collected by synthetic roll devices (Salivette; Sarstedt, Etten-Leur, the Netherlands) and stored at −20 °C after collection. The samples were thawed, numbered, and centrifuged at 3,000 rpm, 4 °C for 5 min at the Dresdner Technical University LabServices. Salivary free cortisol was analyzed using a commercial chemiluminescence immunoassay (IBL, Hamburg, Germany). Samples from the same subjects were analyzed in a single run to reduce error variance. Inter- and intra-assay coefficients of variation were below 10%.

Subjective Stress

Subjective allostatic task load was assessed as a proxy of stress by the NASA task load index (TLX). The TLX is a self-report scale that encompasses six task load-related subscales (Mental Demands, Physical Demands, Time Demands, Own Performance, Effort, and Frustration; Hart & Staveland, 1988). The TLX is considered a highly sensitive assessment technique of subjective stress that allows stress estimates during or shortly after a task (Rubio, Díaz, Martín, & Puente, 2004). Total scores were obtained by summing raw scores of the six subscales, each ranging from 0 to 20. High TLX scores represent high stress levels.

Working Memory

WM capacity was measured with the digit span (DS) test's digits backward (DB) paradigm. The DB paradigm requires participants to repeat a string of digits in reverse order and is often applied as a pure and free-standing performance measure in WM research (Axelrod, Fichtenberg, Millis, & Wertheimer, 2006; Schoofs, Preuss, & Wolf, 2008). A computer-adapted version of the DS test (Wechsler, 1987) was used and participants were presented with three to nine digits for immediate recall (one-by-one, at a rate of one per second). Total scores were obtained by summing raw component scores.

Perceived Active Learning

Given the importance of the individual perception of learning (i.e., the task-related relevance of the learned material; e.g., Doornbos & Krak, 2006), self-reported active learning was measured with four items that specifically addressed the executed workshop. Ad hoc items were obtained from two independently questioned subject matter experts and translated into proximate learning outcomes, the acquisition of new skills and competencies (Karasek & Theorell, 1990). The items were "By executing this workshop, I have . . ." (a) "improved my competencies to appreciate a potentially dangerous situation," (b) "improved my competencies to safely manage a potentially dangerous situation," (c) "effectively trained my communication skills with my teammate," and (d) "improved my skills to move appropriately in accordance with my teammate." Answering possibilities ranged from 1 (*not at all*) to 6 (*very much*). Cronbach's alpha of the current scale was .83.

Control Measures

The degree to which stress is perceived can show considerable individual variation that often depends on character profiles and past experiences (e.g., Kudielka, Hellhammer, & Wüst, 2009). The current study introduced two relevant personality profiles and job experience (number of years) as control variables. Emotional stability and openness to new experiences were assessed with the Ten-Item Personality Inventory, a short and reliable measure of the Big-Five personality traits that is often used when personality is not the primary research interest (test–retest reliability = .72; Gosling, Rentfrow, & Swann, 2003). A sample item was "I see myself as: anxious, easily upset . . . ." Answering possibilities ranged from 1 (*disagree strongly*) to 7 (*agree strongly*).

Procedure

Testing protocols were submitted to and approved by the standing ethics committee of the Open University of the Netherlands; no institutional review board protocols were required. The experiment was conducted in full accordance with the standing operating safety procedures of Belgian Defense.

The field experiment was embedded within an annually organized forum for armed officers. In the course of 3 days, about 400 officers subscribed for specialized handgun practice spread over eight workshops. All participants were fully established, active duty officers; some had more than 25 years of experience in their jobs (no students or cadets were involved).

Recruitment and Attrition

Participants for the experiment were recruited on arrival at the forum's staging area. All arrived in teams of two. When approached by members of the research team, potential participants received a brief explanation about the ongoing experiment and were explicitly informed (in French or Dutch, according to the officers' mother tongue) about the procedures and that participation was voluntary. Subsequently, during a general briefing, all were again group-wise informed about the forum's general setup, the reality-based practice workshop, and the ongoing experimental activities (both in French and Dutch). Those who volunteered to participate were then invited to sign a written informed consent that once more expressed the voluntary participation at any time before and during the experiment. It is important to note that given participants' status as experienced and fully established armed officers, ethical concerns about voluntary participation were never an issue—any pressure exerted from either the research team or the organization would have been counterproductive. Dropout rates were low (four officers declined to participate during recruitment because of other obligations) and the large majority of the participants were genuinely interested in the experiment. There was no attrition during the experiment proper.

Experimental Procedure

Participants performed the workshop in teams of two and were randomly assigned to a control ($n = 17$) or a high-realism ($n = 19$) condition for a between-subjects field experiment. The order of the eight workshops was fixed to avoid too divergent an activity spectrum at the onset of the experiment. Participants were instructed not to eat and not to smoke 1 hr prior to the beginning of the exercise (Nicolson, 2008). When controlled, none of the participants self-reportedly violated these instructions. Participants were individually tested and all experimental procedures were conducted between 1300 and 1700 hours to control for circadian cortisol rhythms (Nicolson, 2008). At arrival at the workshop, cortisol baseline measurements (C_0) were obtained after a relaxation phase of approximately 20 min. Next, all participants were briefed that they would have to enter and search the house of an "aggressive arms collector with a history of violent behavior" (see Figure 1).

Participants in the control group were told that they would be evaluated for their tactical work but, explicitly, that they would not be shot at. To

Figure 1. Picture of the "aggressive opponent," on location and in full safety gear.

reinforce the perception of a nonthreatening environment, this group was provided with an inert (rubber) “blue gun.” Participants in the high-realism condition received exactly the same briefing, except that they were explicitly told that they “might be shot at, given the arms collector’s history of violence.” These participants were issued a small arms marker ammunition system (SAMAS) adapted FN GP 9-mm gun. Participants were informed that the “aggressive opponent” possessed a similar gun. In effect, after the briefing, participants in the high-realism group knew that they could be shot at by a role player who used SAMAS training ammunition—low-velocity colored soap cartridges in reduced caliber that were specially designed for this type of handgun practice. At this point, two important remarks are that (a) preceding the experiment, all participants were enabled to observe colleagues undergoing a shot in the buttocks (as part of another workshop), and (b) the experimental procedure did not impose additional stress to the existing workshop (e.g., given the installment of a control group on behalf of the experiment, 17 participants were in fact exposed to a less stressful procedure than initially foreseen).

Immediately following the experimental briefing, participants were instructed to dress in safety gear and asked to complete the SUDS to assess anticipated distress. Next, the actual workshop started with the opening of the opponent’s door (T) and lasted from 3 to 7 min ($M = 5$ min), depending on the groups’ execution mode. All timings were meticulously registered and cortisol samples were taken at T + 5 (immediately after the workshop) and during the interval T + 15 to T + 20; the latter timing coincided with the start of the cognitive tests and was based on previous findings that revealed the most important cortisol concentrations after 15 to 20 min (e.g., Kudielka et al., 2009). Besides the experimental treatment, all testing procedures were identical for both conditions; while one participant completed questionnaires (control measures, active learning, and the TLX), his teammate performed the DS test. Figure 2 depicts the experimental setup for both conditions.

Statistical Analyses

Subjective stress effects (TLX) were analyzed by an independent samples *t* test (two-tailed). For each participant, we computed individual cortisol reactivity (ΔC) as $\Delta C = C_{Max} - C_0$ and analyzed it by two-tailed independent samples *t* tests. Subsequently, cortisol levels were analyzed with a 2 × 3 repeated measures analysis of variance (ANOVA), with time (C_0, C_1, C_2) as a repeated measure factor and group (control vs. high-realism) as a between-groups factor. Greenhouse–Geisser-corrected *p* values are reported when appropriate. Results on the DS test and the active learning scale

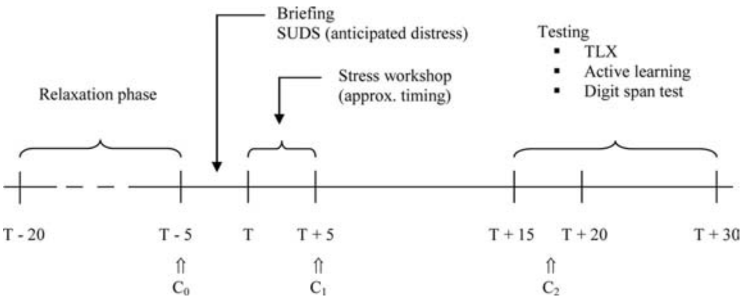

Figure 2. Experimental timeframe (min) for both groups (control vs. high-realism), including a relaxation period, baseline salivary cortisol (C) sampling (C_0 at T – 5), experimental briefing, Subjective Units of Distress Scale (SUDS) completion, execution stress workshop, salivary cortisol sampling (C_1 at T + 5 and C_2 between T + 15 and T + 20), and assessment of subjective stress, working memory performance, and active learning. TLX = NASA task load index.

were analyzed by separate two-tailed independent samples *t* tests (control vs. high-realism). Control measures were analyzed by separate two-tailed independent samples *t* tests. For all above analyses, alpha was set at .05.

RESULTS

Both groups did not differ with respect to the control measures: (a) job experience, $M_{\text{Control}} = 19.24$, $SE = 2.48$, $M_{\text{High-realism}} = 16.05$, $SE = 1.59$, $t(34) = 0.76$, $p = .45$; (b) emotional stability, $M_{\text{Control}} = 4.88$, $SE = 0.32$, $M_{\text{High-realism}} = 4.26$, $SE = 0.30$, $t(34) = 1.43$, $p = .16$; and (c) openness to new experiences, $M_{\text{Control}} = 9.00$, $SE = 0.44$, $M_{\text{High-realism}} = 9.47$, $SE = 0.45$, $t(34) = -0.75$, $p = .46$. Cortisol data were log-transformed because of excessive skewness. Although further reported means reflect the untransformed values to facilitate interpretability, all cortisol-related analyses were conducted with log-transformed data. Salivary cortisol baseline levels (C_0) did not differ between the control ($M = 9.55$, $SE = 4.57$) and high-realism ($M = 11.36$, $SE = 6.85$) groups, $t(34) = -0.81$, $p = .42$.

Immediately after the briefing (and the announcement of the experimental condition), participants in the high-realism group reported significantly more anticipated distress on the SUDS ($M = 4.00$, $SE = 0.18$) than those in the control ($M = 3.24$, $SE = 0.18$) group, $t(34) = -2.91$, $p < .01$, confirming Hypothesis 1.

After execution of the workshop, participants in the high-realism group ($M = 58.58$, $SE = 2.86$) reported significantly higher levels of subjective stress on the TLX than those in the control ($M = 43.71$, $SE = 4.12$) group, $t(34) = -3.02$, $p < .005$, confirming Hypothesis 2. It is interesting that the results demonstrated an important variability in scores on the six TLX subscales. The absence of a clear trend indicates the highly individual experience of reality-based practice as a stressor. Results for ΔC were well in line with the subjective stress assessment. The high-realism group ($M = 5.67$, $SE = 6.19$) showed significantly higher levels of cortisol reactivity than those in the control ($M = 2.44$, $SE = 3.80$) group, $t(28) = -2.33$, $p < .05$. Moreover, the 2 (group: control, high-realism) × 3 (time: C_0, C_1, C_2) mixed model ANOVA for cortisol reactivity also yielded a significant Group × Time interaction effect, Wilks's $\Lambda = .16$, $F(2, 33) = 3.99$, $p < .05$, partial $\eta^2 = .11$, and a significant effect of time, Wilks's $\Lambda = .65$, $F(2, 33) = 9.93$, $p < .001$, partial $\eta^2 = .23$, but no main effect of group. Post hoc tests showed no differences between the cortisol levels for the control group over time. In the high-realism group, however, cortisol concentrations did differ significantly between C_0 and both C_1 ($M_{0-1} = -3.35$, $SE = 0.84$, $p < .001$) and C_2 ($M_{0-2} = -5.25$, $SE = 1.29$, $p < .001$), and between C_1 and C_2 ($M_{1-2} = 1.90$, $SE = 0.74$, $p < .05$), confirming Hypothesis 3. Figure 3 depicts untransformed cortisol means. Note that mean C_0 levels for both conditions (and all three control measures) were relatively high ($M = 10.42$ nmol/L). Given the time of day when testing took place (i.e., when the cortisol circadian rhythm stabilizes toward the lower values; Nicolson, 2008), these concentrations indicate relatively high levels of arousal (e.g., Kirschbaum & Hellhammer, 1989, p. 154).

Figure 4 shows that the mean DS scores in the DB paradigm for WM performances for the control ($M = 6.82$, $SE = 0.19$) and the high-realism

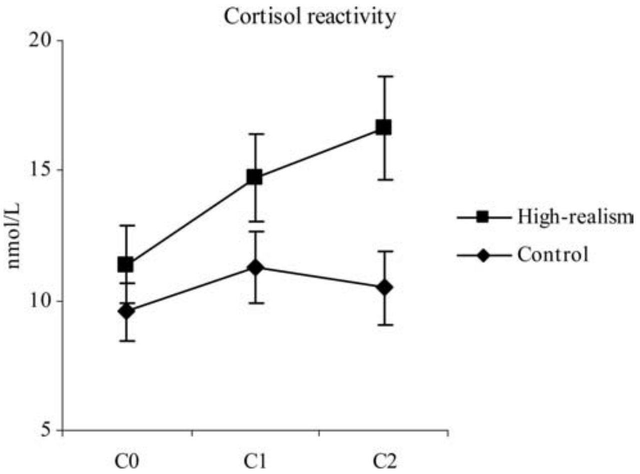

Figure 3. Mean cortisol (C) reactivity (±1 SEM) for the control ($n = 17$) and the high-realism ($n = 19$) groups. Baseline salivary cortisol sampling (C_0) at T – 5 min, C_1 at T + 5 min, and C_2 in between T + 15 and T + 20 min.

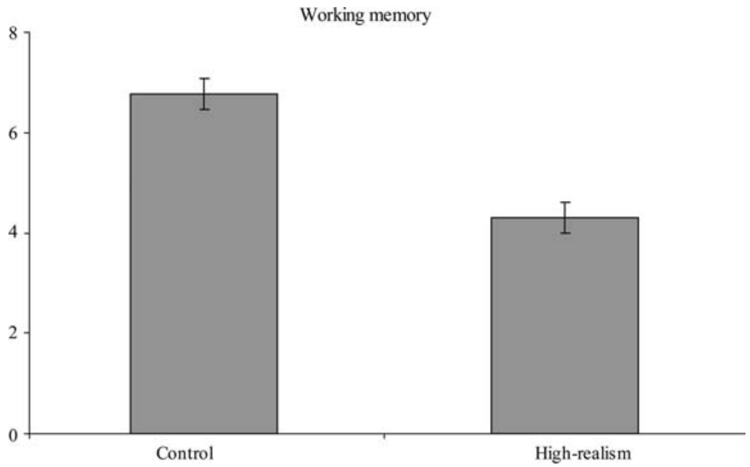

Figure 4. Representation of the mean scores (±1 SEM) on the digit span test for working memory performance for the control ($n = 17$) and the high-realism ($n = 19$) groups. Group means differ significantly ($p < .001$).

($M = 4.37$, $SE = 0.22$) groups differed significantly, $t(34) = 8.69$, $p < .001$, confirming Hypothesis 4.

Figure 5 represents mean scores for self-reported active learning for the control ($M = 13.82$, $SE = 0.90$) and high-realism ($M = 16.89$, $SE = 1.13$)

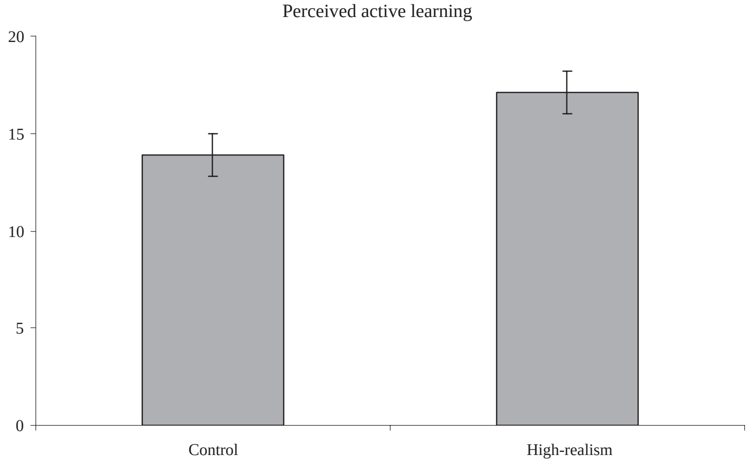

Figure 5. Representation of the mean performance scores (±1 SEM) for perceived active learning (i.e., perceivably acquired task-related skills and competencies) behavior for the control ($n = 17$) and the high-realism ($n = 19$) groups. Group means differ significantly ($p < .05$).

groups, $t(34) = -2.09$, $p < .05$, which also differed significantly but, relative to WM, in the opposite direction, confirming Hypothesis 5.

DISCUSSION

The first aim of the current field experiment was to perform stress analyses during reality-based handgun practice and, more specifically, to examine the added stress effect of the uncontrollable "risk of being shot at" (in a high-realism group). It is important to note that, besides the "risk of being shot at," both groups figured in identical scenarios. The second objective was to investigate to what extent stress during reality-based practice affected WM processing and self-reported active learning (Doornbos & Krak, 2006; Harris et al., 2008). As expected, the high-realism group reported more anticipatory distress, which occurred even before the actual practice. After running the workshop, the risk of being shot at caused more subjective stress and increased cortisol reactivity. The scoring variability on the six TLX subscales and the lack of a tendency accentuated the individual nature of stress perception during reality-based practice. After stress exposure, WM processing deteriorated significantly in the high-realism group that, in spite of the experienced stress and apparent memory deterioration, reported more active learning. An important point of consideration regarding these findings is that the participants were not familiar with the pain effect of the SAMAS ammunition. Hence, the a priori appreciation of the effect of the marker ammunition was entirely psychological.

The increased anticipatory distress and subjective stress experiences were well in line with the results of previous reality-based practice research (Nieuwenhuys & Oudejans, 2010; Oudejans, 2008) and with those of studies that provided information on the criterion stressor without prescriptive details on coping possibilities (see Keinan & Friedland, 1996; Orasanu & Backer, 1996). The risk of being shot at also caused significant increases in cortisol secretion. It is interesting that the maximally observed cortisol concentrations were halfway between those often found under lab conditions (Dickerson & Kemeny, 2004) and those observed during high-intensity military training (Morgan et al., 2000, 2001, 2002; Taverniers, Van Ruysseveldt, Smeets, & von Grumbkow, 2010; Taylor et al., 2007). The interposition confirms the elevated levels of stress exposure during reality-based practice and accords well with the notion that exposure to more intense stressors triggers increased cortisol secretion (Dickerson & Kemeny, 2004). The absence of an actual no-stress control group within the ongoing activity resulted in relatively high cortisol baseline measures. Accordingly, there is reason to assume that the high baseline level attenuated the overall results on cortisol reactivity and veiled that the control group too performed under (moderate) stress given the opponent's equally aggressive behavior and the risk of negative evaluation by the instructors (Dickerson, Mycek, & Zalivar, 2008). Accordingly, the magnitude of the baseline levels—and in fact all three levels for the control group—seems to be comparable to the maximal cortisol concentrations that are often observed in laboratory research (Dickerson & Kemeny, 2004).

WM is an important human brain system that provides an interface between perception, long-term memory, and action-related information (Ahw & Vogel, 2008; Baddeley, 2003; Dehn, 2008; Kleider et al., 2010). Its processing capacity becomes particularly salient in operational circumstances and many operational errors have been linked to a decline in WM performance (Harris et al., 2008; Kleider & Parrott, 2009; Kleider et al., 2010). As expected, the current findings demonstrate that reality-based practice causes a substantial deterioration of WM processing (e.g., Joëls et al., 2006). The measured differences in WM processing capacity, however, were stronger than expected and were comparable to those observed after exposure to extreme military stressors (Morgan et al., 2006; Taverniers, et al., 2010). This could be explained by the above-mentioned moderate cortisol concentrations in the control group that usually lead to improved memory performances (as compared with no-stress conditions; Dickerson & Kemeny, 2004). The comparison between moderate and high stress levels may explain the statistically larger differences and are in line with the hypothesized inverted U curve between cortisol secretion and memory performances (Joëls et al., 2006).

In spite of the significantly higher subjective and objective stress levels, the participants in the high-realism group reported more active learning. These results contradict previous experimental work that found a negative relationship between anxiety and skill acquisition (Colquitt et al., 2000; Warr & Downing, 2000), which may depend on the skills of interest in the respective studies. An alternative explanation could be related to the self-reported operationalization of "active learning" in the current study. Individual perceptions of what is learned and its relevance for work are important features from an occupational perspective (Doornbos & Krak, 2006). The current results support the idea that reality-based practice enhances individual perception in terms of acquired skills and competencies that are relevant for the work of armed officers. Following predictions by Karasek and Theorell (1990), officers would become more motivated by realistic practice because it gradually prepares them for job performance in hazardous real-life circumstances (e.g., Keinan & Friedland, 1996). Constructive reinforcements of learned skills in situations that resemble stressful real-life events improve the transfer of training and may lead to a feeling of mastery and self-efficacy (Goldstein & Ford, 2002; Karasek & Theorell, 1990). This reasoning also accords well with results found in military research where participants performed better and became more motivated by increased training realism and context-relevant stress (Morris et al., 2004).

Limitations

This study has some limitations that need to be addressed before interpreting its results. Given that the research was embedded within an existing application, the study lacked an actual "no-stress" control group. The installation of a no-stress control group could provide a more complete picture of stress effects during reality-based practice. Second, theories such as cognitive narrowing and the need for early closure (e.g., Kruglanski & Webster, 1996) would have provided a social–psychological enlargement of the current study. Follow-up research could envisage the introduction of the Need for Closure Scale as a control measure for individual differences (e.g., Roets & Van Hiel, 2007; Webster & Kruglanski, 1994) and the integration of social–psychological paradigms in the experimental setup.

Next, although the current study combined a cognitive (WM) and an occupational outcome (perceived active learning, assessed with a reliable though nonvalidated ad hoc scale), the latter was self-reported and its results could not be compared with measures of actual acquisition of skill and competencies. Although self-perceived acquisition of skills and competencies is a highly valuable work-related learning asset (e.g., Doornbos & Krak, 2006), the self-reported nature of the scale makes it impossible to exclude alternative explanations such as cognitive dissonance theory (Festinger, 1957). Therefore, follow-up research could address these shortcomings in combining behavioral, cognitive, and occupational outcomes to complete the overall picture. The use of multifaceted data could lead to the discovery of alternative associations. For example, mediation analyses could explore path processes between stress, stress markers, and the respective outcome measures (MacKinnon & Fairchild, 2009; Taverniers, Van Ruysseveldt, & von Grumbkow, 2010). Evidently, a larger and more heterogeneous (e.g., male/female) sample would be desirable. Finally, it remains unclear whether the stress effects during reality-based practice are caused by the anticipated physical pain, the psychological effect of "being hit," or a combination of both. A focused assessment of the use of SAMAS ammunition, combining pain analyses, and subjective and psychophysiological stress markers, could further clarify this issue.

Practical Implications and Future Research

In spite of the above limitations, the current findings may have useful practical implications for an important occupational field. Such implications could involve armed officers' stress management capabilities, coping strategies, and information processing under stress. More specifically, the findings may provide support for (a) selection applications for armed officers, aimed at the early identification of individuals with increased risk for cognitive decline or who lack inherent coping abilities to function appropriately under stress (Delahaij et al., 2011; Flin, 2002; White, 2008); and (b) the gradual or phased incorporation of reality-based practices within handgun shooting training to improve stress management capabilities under pressure (see Keinan & Friedland, 1996; Shipley & Baranski, 2002). Relative to this, Oudejans (2008) demonstrated that the effects of reality-based practice on perceptual-motor performance disappear after three training sessions. Accordingly, preliminary interventions based on theories such as terror management and the mortality salience hypothesis (e.g., Burke, Martens, & Faucher, 2010; Greenberg, Pyszczynski, & Solomon, 1986) might provide a solution to render the reality-based stress effects longer lasting than those of novelty and (anticipated) pain have shown to produce. In addition, findings may provide support for (c) cognitive–behavioral interventions aimed at improving cortisol regulation (Hammerfald et al., 2006), which are straightforward psychoneuroendocrinological extensions of the latter implication, however, with a potentially important impact on cognitive reliability (e.g., Joëls et al., 2006; Wolf, 2009); and (d) the ergonomic design of communication interfaces that enable operators to split attention when high levels of acute stress can be anticipated (Ahw & Vogel, 2008; Wickens, Lee, Liu, & Becker, 2004; Yuan, Steedle, Shavelson, Alonzo, & Oppezzo, 2006). Evidently, the above implications diverge strongly in terms of "present applicability"; whereas some are immediately applicable, others—although promising—will require major future research efforts.

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