Heliyon 9 (2023) e17871

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

The effects of expected and unexpected stress on inappropriate aggression in simulated police interventions

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ARTICLE INFO

Keywords:
Aggression
Stress
Impulsive behavior
Police

ABSTRACT

Here we performed a before-after ABA-design study in police cadets (N = 82) to compare the effects of unexpected (event-triggered) and expected (anticipatory) stressors on aggression. On the first day of the study, participants filled in the Buss-Perry Aggression Questionnaire (BPAQ) and the Barratt Impulsiveness Scale (BIS) and were fitted with heart rate (HR) monitors, which remained attached till the end of the study. On day 2, they were instructed to perform a police intervention in a realistic training environment. The intervention was preceded either by a warning or by a reassuring audio recording that forecasted violent or routine interventions, respectively. Both groups encountered hostile suspects at the intervention site, the behavior of which, however, did not justify the use of force e.g., aggression. The warning resulted in a gradually developing anticipatory stress as shown by HRs. Cadets exposed to the reassuring audio recording showed minimal anticipatory stress but responded to the hostile suspects by an abrupt increase in HRs, which was missing in the warned group. The magnitude of HR responses was similar in the two groups, only their temporal evolution differed. Although aggression showed some associations with BPAQ and BIS scores, the main predictors of behavior were HR changes according to a Multiple Regression analysis. The gradually developing anticipatory stress was associated with low, whereas the abrupt increase in HRs was associated with high aggression. Our findings suggest that the anticipation of a stressful event improves behavioral control whereas an unexpected stress strongly promotes aggression.

1. Introduction

Aggression depends on both anticipatory and event-triggered stress, which precede and accompany, respectively, social encounters. While the effects of acute stressors on aggression are rather well understood, the impact of anticipatory stress is less clear in humans, and even less is known about the interactive effects of the two stressors.

The role of frustration in aggression was hypothesized first by Dollard et al. [1] and Miller [2]. The hypothesis was reformulated and adapted to new discoveries by Berkowitz [3] whereas Henry [4] corroborated it with the biological concepts of stress. The hypothesis was later enriched by new findings concerning the relationship between diurnal and momentary increases in stress hormone

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https://doi.org/10.1016/j.heliyon.2023.e17871
Received 24 February 2023; Received in revised form 12 June 2023; Accepted 29 June 2023
Available online 30 June 2023

production [5], the impact of stress types on aggression types [6], the neural mechanisms underlying behavioral responses [7], etc. Currently it is widely accepted that stress promotes aggressive behavior in both animals and humans [8]. For instance, the administration of the stress hormone corticosterone increases, whereas the lowering of corticosterone production inhibits aggression [9,10]. Moreover, there seems to be a positive feed-back loop between the brain mechanisms that control aggression and the stress response [11]. Likewise, aggression associates with increased production of the stress hormone cortisol in humans, which positively controls aggression as shown by cortisol manipulations [12,13]. The temporal evolution of the stress response received little attention in these studies, not lastly because they focused on glucocorticoid stress responses, which develop relatively slowly, and persist over half an hour without additional stressors.

In many instances, the stress response is elicited by the conflict *per se*, yet in other cases there are signs that anticipate a forthcoming conflict and result in anticipatory stress responses [14,15]. These are especially important in real-life situations, where the individual is influenced by a variety of information regarding the nature of forthcoming social encounters. For instance, police officers may receive reassuring or warning messages by dispatch, which may prove false in the field [16]. How does such information affect the development of stress responses and ultimately behavior during interventions? Earlier human findings are conflicting in this respect. Part of the studies suggest that pre-task stressors deteriorate decision-making and increase aggression [17,18], whereas others suggest that anticipatory stress improves the ability of the individual to cope with the situation, and to control aggressive impulses [19–21]. On a theoretical level, understanding the role of event-related and anticipatory stress would clarify an important aspect of the stress-aggression relationship, particularly the role of contextual factors. On a practical level, such studies may help developing new strategies for preparing individuals, e.g., police officers for potentially aggressive encounters.

The objective of this study was to investigate how correct and false information regarding the aggressive nature of a forthcoming social encounter influenced stress responses and behavior. Particularly, we aimed at comparing the effects of unexpected (event-triggered) and expected (anticipatory) stressors on aggression. Participants were cadets of the Faculty of Law Enforcement of the University of Public Service (Budapest, Hungary) who completed their second year of study and participated in a summer internship program. They were recruited at the end of the second year and were studied during the summer at the International Training Center

Table 1
Participant characteristics.

Variable	Pre-intervention stress		No stress		Group comparisons
	Partner	Leader	Partner	Leader	
Age (years)	21.6 ± 0.3	20.9 ± 0.2	21.9 ± 0.3	21.3 ± 0.2	$F_{stress}(1,78) = 0.63$; $p > 0.4$; $F_{role}(1,78) = 0.19$; $p > 0.1$ $F_{interaction}(1,78) = 1.08$; $p > 0.2$
Residence					$\chi^2 = 1.44$; $p < 0.7$
Village	35.0	35.0	28.6	42.9	
Town	30.0	55.0	42.9	28.6	
City	30.0	5.0	14.3	9.5	
Budapest	5.0	5.0	14.3	19.0	
Source of subsistence					$\chi^2 = 1.42$; $p < 0.7$
Parent	40.0	40.0	42.9	33.3	
Scholarship	5.0	0.0	0.0	0.0	
Self	0.0	0.0	0.0	4.8	
Mixed	55.0	60.0	52.4	57.1	
Economic status					$\chi^2 = 4.38$; $p < 0.2$
Below average	5.0	5.0	14.3	0.0	
Average	80.0	75.0	57.1	85.7	
Above average	15.0	20.0	23.8	9.5	
Outstanding	0.0	0.0	4.8	4.8	
Education					$\chi^2 = 3.13$; $p < 0.4$
High school	100.0	100.0	100.0	100.0	
College (current)	100.0	100.0	100.0	100.0	
University (prior)	5.0	0.0	9.5	0.0	
Physical illness					$\chi^2 = 3.71$; $p < 0.3$
Yes	0.0	5.0	0.0	9.1	
Mental disorder					Not quantifiable
Yes	0	0	0	0	
Prior knowledge of training					$\chi^2 = 1.94$; $p < 0.6$
Detailed	10.0	25.0	14.3	9.5	
Approximate	40.0	40.0	23.8	42.9	
Little	50.0	30.0	52.4	42.9	
None	0.0	5.0	9.5	4.8	
Prior expectations regarding the training experience					$\chi^2 = 1.85$; $p > 0.6$
None	15.0	0.0	4.8	9.5	
Anxiety	0.0	5.0	4.8	4.8	
Excitement	55.0	75.0	71.4	61.9	
Desire to prove	20.0	20.0	9.5	19.0	

Data were shown as percent share of participants belonging to various variable categories except for age, which was shown as mean ± standard error of the mean and was evaluated by ANOVA. Frequency distributions were compared by crosstabulation.

(Budapest, Hungary). On the first day of the study, they completed the Buss-Perry Aggression Questionnaire and the Barratt Impulsiveness Scale [22,23] and were fitted with heart rate monitors that remained secured to their body until the end of the study. The next day, cadets were submitted to a training procedure preceded either by a correct warning on a difficult training situation or a false assurance regarding its nature. Note that aggression as a trait and impulsiveness interactively control the display of aggression under conditions of challenge and stress whereas heart rate changes allow a minute-by-minute monitoring of stress responses [24–26]. We hypothesized that a correct warning would lead to a gradually developing anticipatory stress, whereas false reassurances would lead to an abrupt event-related stress response at the start of the intervention. We also hypothesized that the latter would be associated with larger aggression than the former.

2. Materials and methods

2.1. Participants

Participants (N = 82) were students of the Faculty of Law Enforcement, University of Public Service (Budapest, Hungary). Eligibility criteria were as follows: (i) The student successfully completed the second year of studies. Note that by the end of this year, students were qualified to participate in police interventions including qualifications for lawful gun use. (ii) The student enrolled in the regular summer internship program. (iii) The student was physically and mentally healthy. Note that all students were checked in this regard before their summer internship program by a trained physician. (iv) The student signed the informed consent form required by participation. These criteria resulted in a rather homogeneous sample, who were familiar to each other, which was useful during patrol formation. For the sociodemographic characteristics of participants see Table 1.

The recruitment process developed as follows. Students were informed about the study by the end of the semester (early June) when they were familiarized with the project by a briefing of about 1h. Those showing interest were formally invited to participate when their internship program started in July. Those who wanted to participate at this stage were transferred to the International Training Centre, where they were briefed again. Those who declined to participate at this stage (8 students) remained in the facility and acted as helpers for the study personnel, without participating in the study. The rest, e.g., 82 students signed a consent form that contained ample information on data management, risks and procedures.

The study was approved by the Police Education and Training Centre (Budapest, Hungary; decision No. ROKK 2017/1622-1/2017). The approval covered the ethical aspects of the training. The study was performed according to the guidelines of the 2013 Helsinki Declaration for research involving human subjects and to local rules concerning the management of personal data and the safety of study participants. Participation was voluntary and was based on a signed informed consent form.

The sample size for this study was calculated from the findings of a previous one [27]. This observational study was in many respects similar to the present one. One of the training scenes studied earlier was similar to the one studied here, and there also were overlaps in physiological and behavioral variables. Sample sizes for discrete variables were calculated based on formula $N = [(p^*)(1-p^*)(Z_\beta + Z_{\alpha/2})^2]/(p_1-p_2)^2$, where p* is the average proportion exposed (proportion of exposed cases + proportion of control exposed/2), Z_β is the standard normal variate for power, $Z_{\alpha/2}$ is the standard normal variate for significance, whereas p1 – p2 is the effect size (p_1 is proportion in cases and p_2 in control) [28]. Power requirement was established at 0.8 whereas significance level at 0.05. The minimum necessary sample size for discrete variables was 38. The sample size for continuous variables was calculated based on formula $N = [2\ (z_{1-\alpha/2} + z_{1-\beta})2\ S_p^2]/\delta^2$, where $z_{1-\alpha/2}$ and $z_{1-\beta}$ are the ordinates for the standard normal distribution, S_p is the variance, whereas $\delta = \mu2 - \mu1$ is the mean difference between the two groups [29]. The two-sided significance level was set at $\alpha = 0.05$, and power at 0.8. The minimum necessary sample size was 34 per group. Based on these calculi, the target sample size per group was 40–45. The number of females was lower than that required by these calculi; therefore, only males were studied.

2.2. Design

We performed the study at the International Training Centre (ITC, Budapest, Hungary; https://www.nokitc.hu/koltozeseng/itc), where participants spent approximately 24h. On the first day, they were fitted with HR monitors, which remained attached throughout their stay, and filled in the Buss-Perry Aggression Questionnaire (BPAQ) and the Barratt Impulsiveness Scale (BIS). Sociodemographic variables were also recorded on this day.

Participants spent the night in the dormitories of the ITC. The training took place the next day, in a building that resembled a floor of an apartment house, including a fully furnished apartment with a living room, bedroom, kitchen, and bathroom. After arrival, participants were equipped with Glock 17T training handguns with Simunition FX ammunition (General Dynamics-Ordnance and Tactical Systems-Canada Inc., Canada), rubber sponge-coated truncheons, radio transceivers, protective clothing, and masks. They formed patrols of two and elected a leader for each. The mission of patrols was to investigate the above-mentioned apartment from where the neighbor reported noises despite that its inhabitants were away on a holiday trip.

After briefing, patrols waited 10 min in a room adjacent to the apartment, where they heard an audio recording. They were made to believe that they listened to noises that filtered out from the adjacent apartment. The “assured” group (N = 40) listened to a peaceful and successful police intervention (reassuring recording). The “warned” group (N = 42) heard loud shouts, people fighting, and gunshots (warning recording). A whistle started the intervention after 10 min. Cadets could reach the mission target through a passageway that resembled the corridor of an apartment house. In the apartment, they met two foreign journalists acted by disguised training officers. They spoke only English (foreign language for cadets), proved themselves with journalist IDs, but were unfriendly to the intruding police, tried to call their embassy, and recorded events on video. Although unmistakably angry and hostile, their behavior did not justify the use of force against them. A whistle ended the intervention.

2.3. Variables and data collection

Stress responses were evaluated via HRs recorded by Firstbeat Bodyguard 2™ monitors (Firstbeat Technologies, Jyväskylä, Finland), which record R-to-R intervals with 1 ms resolution. Recordings showed 99.9% similarity with standard clinical ECG under diverse physical activities [30], and was used earlier in various experimental paradigms [31]. The instrument remained secured to the body even during intense physical activity and caused minimal discomfort.

The BPAQ [22] (Hungarian version: [32]) is a self-report instrument that evaluates aggression on four subscales e.g., anger, physical aggression, hostility, and verbal aggression. It consists of 29 items to be rated on a 5-point Likert scale. The BIS [23] (Hungarian version: [33]), is a 30-item inventory that assesses attentional impulsiveness (poor attention focus), motor impulsiveness (acting without thinking), and non-planning (lack of forethought).

Behavior during intervention was recorded by three video cameras that covered the mission target from three angles. Two independent researchers (IK and JH) examined all recordings and listed the behaviors they observed. Thereafter, the lists were compared, unified, behaviors were defined, and the scoring of behaviors begun by means of the H77 behavior recording system amply used earlier in both animal and human research [27]. We recorded both the frequency and duration of behaviors. The two showed high correlation; therefore, only the most representative was shown here, e.g., frequency for gunshots and duration for physical aggression. Scoring was continuous from the start to the end of the intervention. Behaviors recorded were non-overlapping and contiguous. When the behavior was not clearly visible, the researcher coded "unclear." This represented less than 5% of total time; consequently, it had a minimal impact on the findings.

The intervention started when cadets entered the apartment and lasted 4 min on average. The following behaviors were recorded: *gun use*, shooting at suspects. *Inactivity/assistance*, inactivity and/or assisting the partner by presence; *loss of control*, unresponsiveness to the whistle that signaled the end of the intervention; *physical aggression*, wrestling, hitting, or kicking; *procedural activity*, searching the apartment, identifying suspects, etc.; *surrender*, allowing suspects to gain control; *verbal aggression,* verbally intimidating the

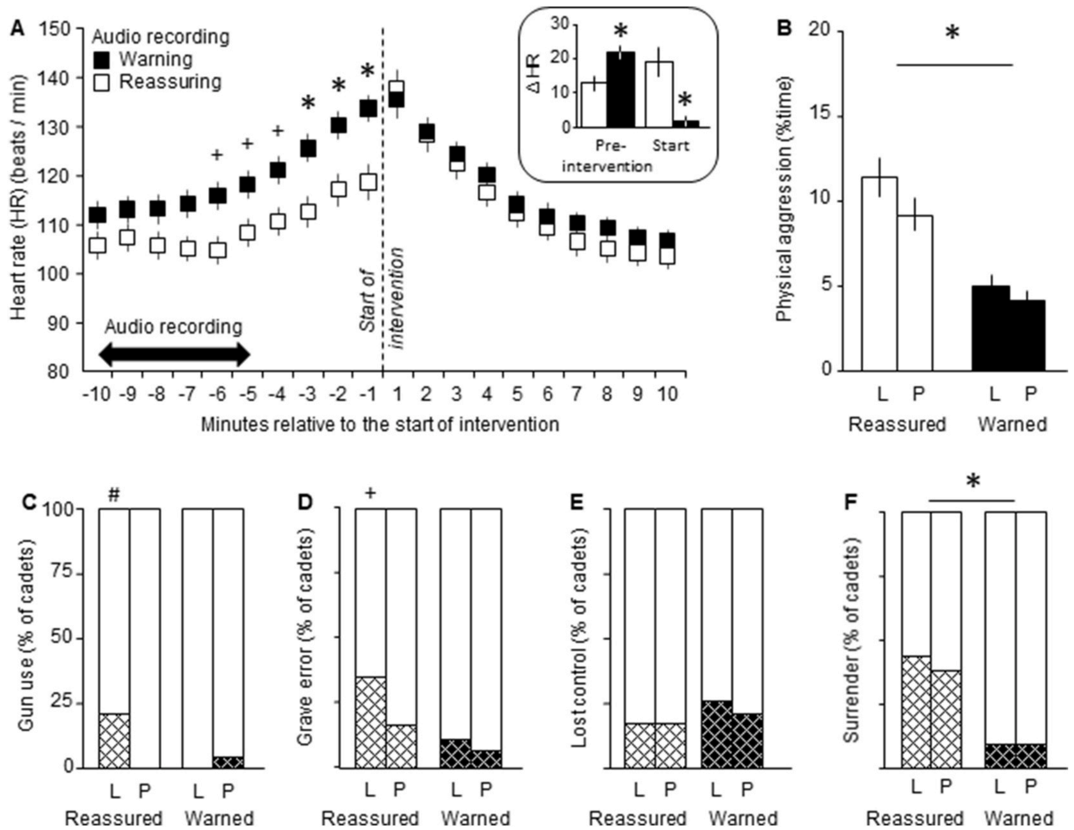

Fig. 1. The effects of warning on heart rates and behavior. (**A**) The effects of the audio recordings on heart rates (HRs). (**A, insert**) Summed heart rate changes in the preparatory phase, when cadets listened to the audio recordings in the adjacent room (preparation; difference between min −10 and −1), and changes elicited by the start of intervention (start; difference between min +1 and −1). (**B–F**) Various indices of aggressiveness in the two groups. *L*, leader; *P*, partner; +, marginally significant group differences; *, significant group differences; #, significant difference from all other groups ($p < 0.05$ at least after Bonferroni correction).

suspect; *verbal control,* calls to suspects. Note that the behavior of "journalists" did not require aggression by participants. Suspects readily identified themselves, informed the cadets that they rented the apartment and avoided physical provocation. As such, participants self-initiated aggression, which was illegitimate under the conditions of the scene, despite the clear hostility of suspects. Our police experts (IF and JV) inspected the recordings and confirmed that the behavior of "journalists" did not justify the use of force against them. Police experts also evaluated the professionalism of the intervention. They rated the infliction of physical injuries and shooting as "grave errors." Note that both were virtual as the practicing weapons could accomplish neither.

The primary dependent variable of the study was the share of the time spent with physical aggression. This was selected as the primary dependent variable because most participants did show physical aggression, which allowed a detailed analysis. Other aggression-related behaviors, e.g., gun use, grave errors, loss of control and surrender) were secondary dependent variables. Independent (predictor) variables were HR changes, as well as BPAQ and BIS scores. Regarding HRs, we focused on changes preceding the intervention, which were indicative of anticipatory stress and those following the start of intervention, which were indicative of event-induced stress. Regarding the former, we considered HRs from −10 min (10 min before the encounter) to −1 min. The former coincided with the start of the audio recording that was the source of anticipatory stress, whereas the latter was the last pre-intervention HR. For event-related stress we considered the difference between min −1 to min +1 (1 min before and after the start of intervention, respectively) because heart rates were maximal at min +1. Thus, this value was equivalent with the maximal stress response for the whole intervention. This classification was based on the findings of the observational study performed earlier [27].

2.4. Statistics

Statistics were made by the Statistica software (Tulsa, USA). HRs were analyzed by 3-factor repeated measures ANOVA (Factor 1 stress; levels: reassuring and warning audio recordings; Factor 2 role; levels: leader and partner; repeated measures Factor 3: time; levels: the time-points represented in figures). Behaviors were analyzed by 2-factor ANOVA (stress and role). We employed the Dunnett test for post hoc comparisons. Variables providing discrete and categorical values were evaluated by the median test. The frequency distribution of behaviors (e.g., gun use, grave errors, loss of control, and surrender) were evaluated by crosstabulation. In both cases, post-hoc comparisons were made by the 2 × 2 version of crosstabulation, i.e., the expected vs. observed x test. Bonferroni correction was employed throughout. Correlations between variables were evaluated by the Spearman test. Interactions between factors were evaluated by Multiple Regression. In this analysis, the dependent variable was the share of time spent with physical aggression,

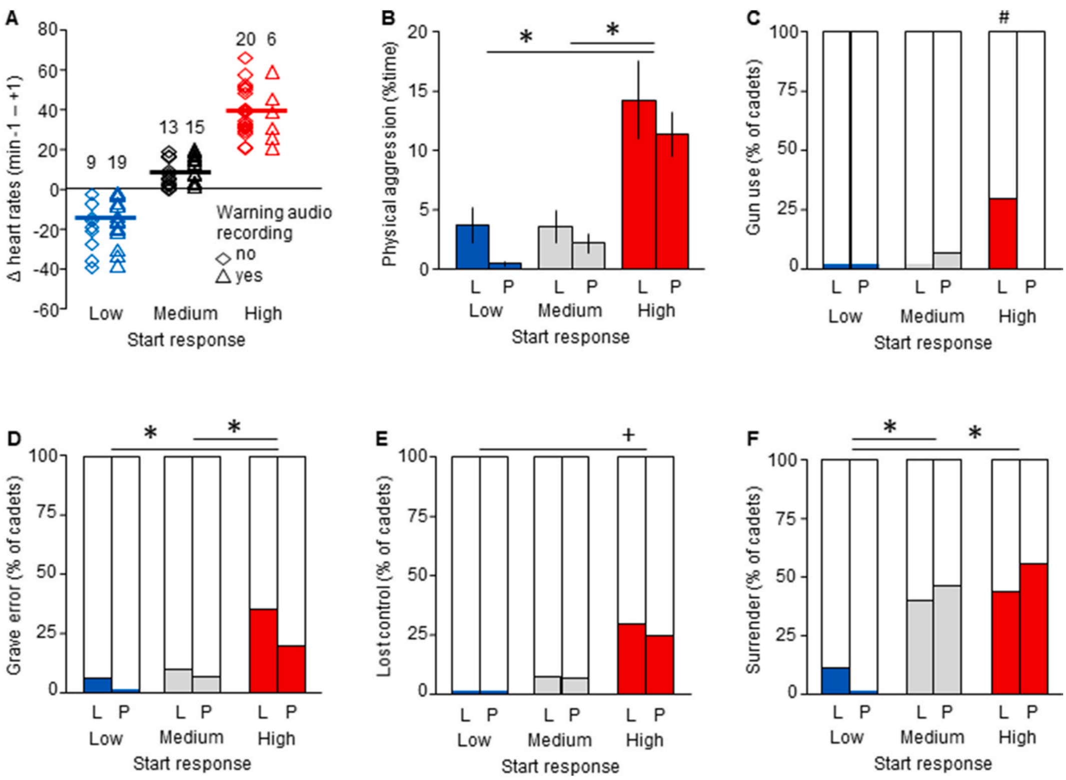

Fig. 2. The impact of start responses on behavior. (A) The grouping of participants into start response groups. Note that the original group assignment did not entirely predict start responses. Numbers above marker columns indicate the size of particular categories. (**B–F**) Various aggressive behaviors in start response groups. *L*, leader; *P*, partner; +, marginally significant group differences; *, significant group differences; #, significant difference from all other groups ($p < 0.05$ at least after Bonferroni correction).

whereas the independent variables were those phases of HR changes that were specified above as well as BPAQ and BIS scores. In the case of secondary dependent variables, the number of positive cases was too small to be evaluated by Multiple Regression.

3. Results

The warning audio recording significantly increased HRs before the intervention as compared to the reassuring recording ($F_{time*stress}(19,1482) = 4.45$; $p < 0.0001$) (Fig. 1A). Leaders had slightly larger HRs than partners (116.6 ± 0.6 vs. 110.8 ± 0.7 beats/min; F_{role} (1,78) = 4.72; $p < 0.05$). This, however, depended neither on time nor on group assignment ($F_{stress*role}$ (1,78) = 0.09; $p < 0.8$; $F_{time*stress*role}(19,1482) = 0.35$; $p < 1.0$). The start of intervention induced a sharp increase in HRs in cadets who listened to the reassuring audio recording, but not in those exposed to the warning recording ($F_{stress*time}(2,160) = 8.51$; $p < 0.001$) (Fig. 1 insert). Due to these changes, the HRs of the two groups was similar at the beginning of the encounter. However, increases were gradual in warned cadets, but abrupt in reassured cadets.

Warning was associated with decreased physical aggression ($F_{stress}(1,78) = 10.93$; $p < 0.001$; $F_{role}(1,78) = 1.38$; $p > 0.1$; $F_{interaction}(1,78) = 0.24$; $p > 0.1$), reduced gun use (Chi^2 (3) = 8.85; $p < 0.05$) and lower likelihood of surrender (Chi^2 (3) = 11.82; $p < 0.01$) (Fig. 1B–F). Grave errors underwent marginal changes (Chi^2 (3) = 6.75; $p = 0.08$), whereas loss of control showed non-significant changes (Chi^2 (3) = 0.30; $p > 0.1$).

The gradual increase in HRs (min −10 − min −1) and the sharp increase observed at the start of the intervention (min −1 − min +1) showed a significant negative correlation ($R = -0.603$; $p < 0.0001$). As such, increased aggression may have been induced either by the lack of appropriate preparations associated with anticipatory stress (see Introduction) or to the effects of acute stress. We attempted to separate the two by dividing the sample into three groups of equal sizes based on the magnitude of the response to the start of the intervention (start response, Fig. 2A). As expected, non-stressed controls typically had high, whereas stressed ones had low start responses. However, about 25–30% of the sample deviated from this general rule. When cadets were regrouped based on start responses, high start responses were associated with longer-lasting physical aggression ($F_{start\ response}(2,100) = 22.57$; $p < 0.0001$), increased likelihood of gun use ($Chi^2 = 17.17$; $p < 0.005$), more grave errors ($Chi^2 = 12.19$; $p < 0.03$), more frequent loss of control ($Chi^2 = 8.45$; $p < 0.09$), and increased surrendering ($Chi^2 = 20.26$; $p < 0.005$) (Fig. 2B–F). Roles had no impact except for gun use, which was typical to leaders with high start responses. These findings suggest that the start response associated positively with aggression irrespective to the original group assignment.

Cadets who showed unprovoked physical aggression during the training scored high on the physical aggression subscale of BPAQ (Table 2). The scores of leaders and partners were similar (20.2 ± 0.9 and 19.9 ± 0.8, respectively). Although significant, group differences were small. Non-planning impulsiveness showed a difference at trend level only.

HR changes significantly predicted the duration of physical aggression according to Multiple Regression analysis (Multiple $R = 0.625$; $F(3,78) = 3.99$ $p < 0.01$). BPAQ predicted aggression at trend level (Multiple $R = 0.332$; $F(4,76) = 2.17$ $p < 0.08$), whereas BIS did not provide significant predictions (Multiple $R = 0.118$; $F(3,78) = 0.37$ $p < 0.8$). After combining HR changes with BPAQ, the prediction remained significant, but the combination did not explain more variance than HRs alone. HR changes together with BIS scores increased the share of variance explained in physical aggression from 13.3% (HR alone) to 25.4% (HRs and BIS) (Multiple $R = 0.504$; $F(6,75) = 4.25$ $p < 0.001$). Significant individual predictors were the start response (beta = 0.655; $p < 0.001$) and non-planning impulsiveness (beta = −0.365; $p < 0.01$). We visualized the interaction in Fig. 3. Unfortunately, sample size did not allow the Multiple Regression analysis of all variables together.

Table 2
Psychometric scores of participants who were aggressive or non-aggressive in the training performed one day later.

Psychometric instrument	Subscales	Behavior during training		χ^2 (p <)
		Not aggressive	Aggressive	
Buss-Perry Aggression Questionnaire	Physical aggression	18.2 ±0.9	20.8 ±0.7	6.21 (0.01)
	Verbal aggression	14.2 ±0.4	15.2 ±0.3	n.s.
	Anger	13.5 ±0.8	13.2 ±0.5	n.s.
	Hostility	15.8 ±0.7	16.7 ±0.5	n.s.
Barratt Impulsiveness Scale	Attentional impulsiveness	15.5 ±0.5	15.3 ±0.4	n.s.
	Motor impulsiveness	19.5 ±0.6	18.6 ±0.4	n.s.
	Non-planning	21.8 ±0.6	19.7 ±0.4	3.39 (0.06)
N		24	58	

Data were shown as means ± the standard error of the mean. *n.s.*, differences not significant.

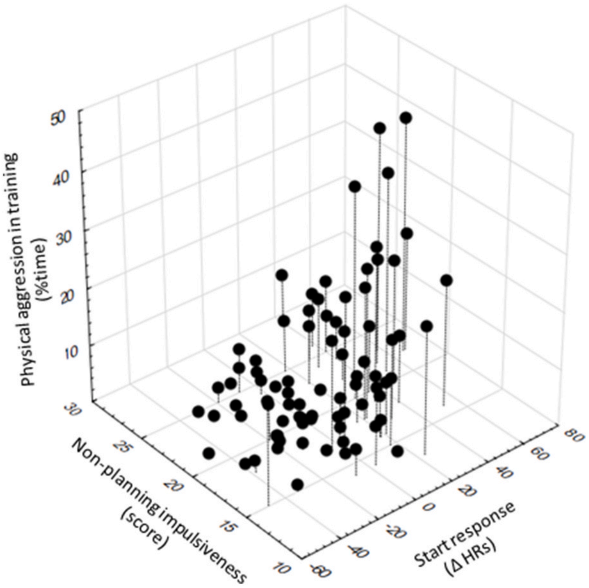

Fig. 3. The dependence of physical aggression on the interaction between non-planning impulsiveness and heart rate start responses. For other explanations, see text.

4. Discussion

4.1. Main findings

Audio recordings that forecasted a violent intervention significantly increased HRs before the intervention as compared to reassuring ones that forecasted a regular intervention. Reassured cadets, however, showed an abrupt increase in HRs when meeting hostile suspects at the intervention site. These findings were in line with our first hypothesis. The warning audio recording was associated with decreased aggression, whereas the abrupt increase in HRs at the start of interventions was associated with high aggression. This finding was in line with our second hypothesis, although the sharp difference between the two conditions was somewhat surprising. The slightly larger HRs of leaders throughout the intervention and the gun use, which was almost exclusively performed by leaders, may suggest that they were influenced by the responsibility of their role. However, the roles voluntarily assumed by participants before the intervention did not affect the interaction between HRs and behavior.

4.2. Comparisons with earlier findings

HRs were frequently used to monitor stress responses elicited by aggression in various circumstances including anticipatory stress and simulated police interventions [34–36] and are considered valid indicators of psychological stress [37]. As such, changes in HRs were interpreted in the more general framework of stress responses.

Stress responses were invariably associated with deficient interventions in earlier policing studies, including poor decisions on lethal force application [38–41], which is at variance with the findings presented here. In our study, however, the interaction between stress and aggression depended on dynamic changes in HRs that were not investigated earlier. In such studies, aggression was studied in conjunction with average or maximal HRs, which precluded the identification of dynamic relationships. In addition, anticipatory stress, although recorded, was not considered when the stress–performance relationship was evaluated.

Our findings support the notion that gradually developing anticipatory stress is protective against uncontrolled outbursts of aggression, likely because it allows individuals to make behavioral, cognitive, and physiological adjustments that facilitate the process of coping with the upcoming stressor [19–21]. Our findings also confirm earlier ones on the aggression-promoting effects of acute stress [8,12,13]. The two lines of evidence are ostensibly conflicting in our case where HRs were similar in the two groups at the start of the intervention. If the stress response *per se* affected aggression, anticipatory and event-triggered stress responses had similar effects. As we observed the opposite, we hypothesize that behavioral consequences were not driven by stress alone but also by its context.

4.3. Overall interpretation

We suggest that the behavior of suspects can be explained within the framework of the biopsychosocial concept of challenge and threat. This concept stipulates that individuals perceive stressors as challenges when their resources are sufficient and as a threat when demands exceed resources [42]. Unpredictability and uncontrollability are considered key factors in this respect [43]. The situation was clearly predicted for the warned cadets but in reassured ones, it was falsely portrayed (unpredicted) by the reassuring recording.

Cadets who were falsely reassured likely considered the situation uncontrollable because there was no time for preparation. Hence the marked behavioral difference between the two groups.

On a theoretical level, our findings suggest that the stress-aggression relationship is not as straightforward as suggested by many earlier studies. Stress may increase or decrease aggression depending on the context. If time was allowed for making decisions, aggression was decreased. Note that aggression was inappropriate to the situation. By contrast, abrupt, unexpected stress strongly promoted aggression even in situations when this was not justified by circumstances. On a more practical level, our findings may be used in the future for selecting individuals suitable for performing interventions under conditions of high stress. It occurs that there were important individual differences in stress responsiveness, with consequences for behavior. For instance, about 30% of individuals showed a dramatic start response despite the fact that they were appropriately warned regarding the difficulties of the forthcoming intervention (see Fig. 2A). It should be established by future studies whether this was an overall individual feature or was due to situational factors not covered here. Our findings also show that warning officers in time may considerably improve the quality of interventions.

4.4. Limitations

One limitation of the study was the modest sample size, which was due to the limited number of cadets available for such studies. Nevertheless, the sample was homogenous because cadets were of the same age and sex and underwent a thorough psychological and physical selection before being admitted to the university. A more important limitation concerns the generalizability of findings, which was influenced by the specifics of participants. Firstly, we studied only males because the number of female cadets was lower than that required by sample size calculi. As a substantial share of active police officers are females, gender is an important factor, and should be studied in the future. Secondly, the experience of our cadets was limited although they did have the qualifications necessary for conducting interventions. As such, studying experienced police officers will also be an important task for the future. Thirdly, participants were classmates, and consequently, the sample was too homogeneous to address important factors such as age, rank, areas of expertise etc. Similar issues may be studied by studying a more diverse sample. Finally, the stress-aggression relationship is relevant for populations other than police officers. For instance, police cadets are trained to control their emotions and aggression, which is not typical to other populations prone to display aggression under stress. Consequently, the aggression-lowering effect of anticipatory stress may be valid only for populations that have similar trainings. The issue may also need further studies in participants with differing degrees of aggression-control training. It is also worth noting that the number of the psychometric tests employed was limited in this study. Aggressiveness and impulsiveness as traits (BPAQ and BIS scores, respectively) had little impact on behavior displayed during training. This naturally does not rule out that other psychological features such as personality had larger roles.

5. Conclusions

We found that warnings regarding the stressfulness of a forthcoming intervention elicited a gradually developing stress response as shown by HRs, which was associated with low aggression during the intervention. A mismatch between the forecast and the actual situation encountered in the field elicited an abrupt stress response, which was associated with high aggression. As judged from HRs, the level of stress was similar in the two groups, suggesting that not stress *per se* but its context was relevant for aggression control.

We observed large individual differences in stress responses, which might be developed into a system of criteria that allows the selection of officers appropriate for conducting operations under stress. In addition, our findings outline the need to inform police officers correctly about the nature of forthcoming interventions.

Funding

This work was supported by the KÖFOP-2.1.2-VEKOP-15-2016-00001. The sponsor did not influence research by any means.

Author contribution statement

István Farkas; József Végh; Erika Malét Szabó: Performed the experiments; Contributed reagents, materials, analysis tools or data.
Krisztián Ivaskevics: Performed the experiments; Analyzed and interpreted the data; Wrote the paper.
József Haller: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

Additional information

No additional information is available for this paper.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgment

The authors thank Tamás Békési, Johanna Farkas, Mihály Fogarasi, László Garamvölgyi and Daniella Kováts for their technical help.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e17871.

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List of abbreviations

ANOVA: analysis of variance
BIS: Barratt Impulsiveness Scale
BPAQ: Buss-Perry Aggression Questionnaire
ECG: electrocardiogram
HR: heart rates
ID: identification document
ITC: International Training Centre, (Budapest, Hungary)
R: coefficient of correlation
ROKK: Police Education and Training Centre (Budapest, Hungary)
R-to-R intervals: the time elapsed between two successive R waves of the QRS signal on the electrocardiogram, which can be used to calculate HRs