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Effect of Experience and Psychophysiological Modification by Combat Stress in Soldier's Memory

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Abstract

The present research aimed to analyze the effect of experience and psychophysiological modification by combat stress in soldier's memory in a simulated combat situation. Variables of rate of perceived exertion, blood glucose, blood lactate, lower body muscular strength manifestation, cortical arousal, specific fine motor skills, autonomic modulation, state anxiety, and memory and attention through a postmission questionnaire were analyzed before and after a combat simulation in 15 experienced soldiers of a special operation unit and 20 non-experienced soldiers of light infantry unit from the Spanish Army. The stress of combat simulation produces a significant increase ($p < 0.05$) in rated perceived exertion, blood glucose, blood lactate, somatic anxiety and a low frequency domain of the heart rate, and a significant decrease of rifle magazine reload time, high frequency domain of the heart rate and somatic anxiety in both groups. The variables of RPE, glucose, CFFT, RMRT, RMSSD, LF/HF, CA, SA and STAI were significantly different in experienced soldiers shown the activation of fight-flight system. The anticipatory anxiety in experienced soldiers shows a cognitive behavioral association by past experiences. The analysis of correct response in the postmission questionnaire show elements more related with the sight and that endanger the physical integrity of soldiers are more remembered, and some significant differences ($p < 0.05$) in the memory performance of experienced soldiers and non experienced soldiers where experienced soldiers shown a better performance. As conclusion, combat stress produce an increase in the psichophysiological response of soldiers independently of experience, but experienced ones presented a lower negative effect on memory than non experienced.

Keywords Military · Combat stress · Memory · Cognitive behavioral association · Military anxiety

Introduction

Exposure of acute stress resulted in alterations of body perception, environment, time, problem-solving deficits and memory [1–3]. These facts have a direct impact in soldiers when they are exposed to combat stress in their operations areas, producing a negative stress coping many battlefield errors as friendly fire incidents, collateral damage… [4]. Also the exposition to combat stress produces a series of psychophysiological alterations as increased sympathetic nervous system modulation, and cardiovascular, muscular and metabolic response, a decreased cortical arousal and processing information and working memory [5–10]. Some research suggest that combat stress exposition could affect the soldiers health when it's becoming chronic, being the maintenance of a high sympathetic nervous system activation a cardiovascular risk factor [11]. Also, the Post Traumatic Stress Disorder (PTSD) has been reported as the effect of a maintained duty stress, producing a hyperarousal state that drives into psychophysiological pathologies and alterations in autonomic modulation, and sleep patterns [12].

The working memory (WM) has a very important role in the decision-making process and tasks that soldiers have to

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carry out in the different theaters of operations [13]. But the proper functioning of the working memory (WM) and explicit memory is negatively affected by stress and anxiety [8, 14–16]. Anxiety typically reduces attentional focus on the current task according to the Attentional Control Theory [17], and also its necessary remembered that explicit memory (EM) and working memory (WM) are stored in a brain region sensitive to changes in the concentration of cortisol induced by stress: the prefrontal cortex [16, 18]. All this, hinders the information processing through explicit memory since due to lack of attention much of the information does not even become part of working memory (WM), and the information that arrives has to deal with cortisol caused by stress in prefrontal cortex. So there are several obstacles that the information that soldiers recieves from outside must overcome to transcend to the long-term memory, and be able to be an information remembered later in the decision-making process. But it is also known that the level of anxiety or arousal is what governs a positive or negative influence of stress on performance [19].

Its knows how training and experience have a direct influence in the psychophysiological response and performance in sports, civil and military parachute jumps, as well as in stressful works as medical or soldiers [20–25], as general adaptation syndrome and habituation process theory explained [26]. Specifically in military area, there are some special units as special operations units that have one of the hardest, extreme, stressful training that prepare them to the most difficult missions in battlefields. The exposition to this continuous extreme and stressful training could produce in these special units a decreased stress response when they are involved in combat becoming this fact in a better operative and memory performance and a lower risk to develop stress disorders. To verify this postulate, we proposed the present research with the aim of to study the effect of experience and psychophysiological modification by combat stress in soldier's memory. The initial hypothesis was that special operations soldiers (SOG) would present a decreased stress response and better memory performance than non-special operations soldiers (NSOG) (Tables 1, 2 and 3).

Methods

Experimental approach to the problem

Psychophysiological response and memory of special operations and non-special operations soldiers were analysed in a combat simulation in order to comply the study objective.

Participants

Thirty-five male soldiers from the Spanish Army belonging to a special operation unit (special operation group (SOG); n: 15; 28.7 ± 3.2 years; 174.8 ± 6.0 cm; 75.3 ± 5.9 kg; 22.9 ± 6.7 body mass index (BMI)); and a light infantry unit (non-special operation group (NSOG); n: 20; 35.4 ± 6.2 years; 179.9 ± 7.0 cm; 83.3 ± 10.5 kg; 25.7 ± 2.6 BMI) were analysed. All participants have a minimum of 8 years of duty service and minimum of 8 month of deployment in international mission in current theatres of operations. For this study, soldiers were equipped with standard uniforms, boots, tactical fighting load carriers, body armour, simulated HK G36c rifle, simulated knives, shackles and a backpack with 12 kg to simulate the equivalent weight of the task force for this type of operation, carrying a total weigh of 23.6 kg. Before the beginning of the research the experimental procedures were explained to all the participants giving their voluntary written informed consent in accordance with the Declaration of Helsinki. In addition all the procedures were approved by the Head Quarter of the Unit.

Combat simulation

For this combat simulation soldiers were divided in operative teams of 4 people. Each team complete the entire manoeuvre alone with no knowledge of the other teams. The team was placed in a waiting area and then started the mission when the previous team completed it. Every soldier performed the same manoeuvre in the same context.

In the manoeuvre the team have to rescue an allied soldier captured by insurgency forced in a village controlled by insurgency forces. During the simulation soldiers have to deal with different incidents as unarmed civil that collaborate with the team, unarmed civil that do not collaborate with the team, terrorism with civil vest with concealed knife that used against the team when they approach him, insurgences warriors armed with a Kalashnikov rifles that shot them, armed friend soldier, armed private security company warriors and simulated death soldiers by an improvised explosive device (IED).

During the manoeuvre the following objects and sounds were placed in strategic point where the team had to pass to analyse different component of attention and memory: I: visual: mobile phone, book, knife, rifle, pistol, animal viscera, animal blood, a corpse, paper documents in three different language than the language team, IED; II: auditory, yell, shot, vehicle motor, a conversation in the same language of native civilian (different that the team language), a conversation in different language of native civilian (different that the team language); III: olfactory: animal viscera, animal blood.

Study variables

Before and immediately after to the simulation the following variables were measured:

I. Rating of perceived exertion (RPE), 6–20 scale [27].

Table 1 Psychophysiological variables obtained before and after the combat simulation by special operation and non-special operation soldiers

	Special Operation Group				Non Special Operation Group				Statistical intergroup results				
												Confidence intervals	
	Pre	Post	t	P	Pre	Post	t	p	moment of analysis	t	p	inf	sup
RPE	6.33 ± 0.49	12.27 ± 1.87	−12.551	.000	6.40 ± 0.60	8.85 ± 2.18	−5.064	.000	pre	−.363	.719	−.44065	−.30732
									post	4.977	.000	2.019	4.814
Glucose (mg/dl)	8.12 ± 1.18	11.12 ± 0.94	−8.950	.000	8.03 ± 0.57	9.85 ± 0.97	−9.333	.000	pre	.272	.789	−.6039	.7839
									post	3.528	.001	.4957	1.8576
Lactate (Mmol/L)	1.27 ± 0.44	4.58 ± 3.45	−4.011	.001	1.56 ± 0.49	4.28 ± 2.30	−6.271	.000	pre	−1.862	.072	−.61440	.02773
									post	.197	.845	−1.8815	2.2782
CFFT (ms)	37.5 ± 3.3	38.3 ± 2.3	−1.585	.135	35.77 ± 2.83	36.06 ± 3.35	−.381	.708	pre	1.677	.105	−.39064	3.91731
									post	2.272	.030	.22682	4.12651
RMRT (s)	30.52 ± 6.12	26.81 ± 4.67	2.555	.023	38.28 ± 6.6	33.10 ± 6.57	2.701	.014	pre	−3.568	.001	−12.18378	−3.32455
									post	−3.555	.001	−10.60715	−2.88485
ABK (w)	1362.94 ± 123.18	1389.90 ± 115.59	−1.289	.218	1225.65 ± 159.92	1359.24 ± 158.84	−10.835	.000	pre	2.911	.006	41.33203	233.25627
									post	.671	.507	−62.34341	123.66201

Between parenthesis *p* values lover than 0.05 between special operation group and non-special operation group. I. Rating of perceived exertion (RPE), Critical Flicker Fusion Threshold (CFFT), rifle magazine reload time (RMRT), Abalakov jump (ABK)

Table 2 Psychophysiological variables obtained before and after the combat simulation by special operation and non-special operation soldiers

	Special Operation Group				Non Special Operation Group				Statistical intergroup results				
												Confidence intervals	
	Pre	Post	t	P	Pre	Post	t	p	moment of analysis	t	p	inf	sup
RMSSD (n.u.)	111.24 ± 14.94	57.31 ± 25.60	8.736	.000	60.76 ± 32.55	18.33 ± 9.84	5.996	.000	pre	6.127	.000	33.60088	67.34279
									post	5.595	.000	24.287	53.667
LF (n.u.)	60.61 ± 6.66	71.98 ± 10.02	−4.353	.001	20.60 ± 16.40	77.70 ± 11.71	−12.585	.000	pre	9.879	.000	31.70105	48.33895
									post	−1.555	.130	−13.21314	1.76981
HF (n.u.)	39.39 ± 6.66	28.02 ± 10.02	4.354	.001	75.10 ± 22.37	22.11 ± 11.58	10.359	.000	pre	−6.749	.000	−46.63674	−24.76759
									post	1.617	.116	−1.53593	13.36926
LF/HF (n.u)	1.60 ± 0.41	3.04 ± 1.55	−3.897	.002	0.40 ± 0.57	5.18 ± 3.63	−6.082	.000	pre	7.294	.000	.870	1.543
									post	−2.367	.025	−3.999	−.286
CA (−)	7.9 ± 4.7	9.7 ± 5.5	−2.606	.021	5.2 ± 4.4	5.6 ± 4.8	−.709	.487	pre	1.705	.099	−.532	5.865
									post	2.367	0.25	.562	7.805
SA (−)	5.7 ± 5.6	8.8 ± 5.3	−2.528	.024	1.4 ± 2.5	3.7 ± 3.6	−2.101	.049	pre	2.792	.012	1.077	7.590
									post	3.268	.003	1.893	8.407
SC (−)	17.7 ± 1.8	18.3 ± 1.8	−1.740	.104	17.9 ± 2.0	17.4 ± 4.5	.510	.616	pre	−.256	.800	−1.493	1.159
									post	.787	.439	−1.401	3.134
STAI (−)	12.33 ± 6.13	15.07 ± 6.58	−2.035	.061	7.95 ± 3.53	9.95 ± 6.34	−1.186	.250	pre	2.480	.022	.706	8.061
									post	2.312	.028	.595	9.639

Between parenthesis p values lower than 0.05 between special operation group and non-special operation group. I. Square root of the mean of the sum of the squared differences between adjacent normal R-R intervals (RMSSD), Low Frecuency Domain of the Heart Rate Variability analysis (LF), High Frequency Domain of the Heart Rate Variability analysis (HF), Cognitive Anxiety (CA), Somatic Anxiety (SA) and Self-Confidence (SC), and State of Anxiety Inventory Test (STAI)

Table 3 Results of the post mission questionnaire parameters in percentage and its significance

	Special Operation Group Response (percentage)			p			Non Special Operation Group Response (percentage)			p			Statistical Intergroup Results p		
	Correct	Wrong	No response	Correct vs wrong	Wrong vs no response	Correct vs no response	Correct	Wrong	No response	Correct vs wrong	Wrong vs no response	Correct vs no response	Correct vs wront	Wrong vs no response	Correct vs no response
Sounds	48.4	51.6	60	.796	.216	.038	61	39	54.7	.016	.001	.235	.136	.001	.029
Objets	78.6	21.4	58.1	.001	.000	.007	62.7	37.3	55.8	.046	.000	.260	.000	.000	.010
Odours	64.3	35.7	40	.271	1.000	.458	83.3	16.7	73.7	.006	.000	.297	.003	.002	.561
Text	90	10	80	.041	.000	.001	72.7	27.3	86	.096	.000	.000	.007	.000	.000
Elements	97.6	2.4	33.3	.000	.004	.096	88.9	11.1	36.8	.000	.003	.231	.000	.000	.037

In some cases, the sum of the percentages of the three types of responses (correct, wrong and no response) is more than 100 because there were several elements

II. Blood glucose concentration by the analysis of 5 μl of capillary finger blood using a portable analyser (One Touch Basic, LifeScan Inc. Madrid).

III. Blood lactate concentration taking a sample of 5 ul capillary blood from a finger of subjects and analysed with the Lactate Pro Arkay, Inc. system (Kyoto, Japan).

IV. Lower body muscular strength manifestation by the Abalakov jump (ABK) measured by the Sensorize FreePowerJump system (SANRO Electromedicina, Madrid. Spain) which recorded flight time (s) to calculate power (W) of jump [28].

V. Cortical arousal trough the Critical Flicker Fusion Threshold (CFFT) in a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12,021) following previous studies [7].

VI. Specific fine motor skills, by the time of reloading a 20 bullet of 5.56 mm calibre into a G36 rifle magazine, rifle magazine reload time (RMRT).

VII. Anxiety response using the CSAI-2R Spanish validated version [29], consisting of 17 items that assess cognitive anxiety (CA), somatic anxiety (SA) and self-confidence (SC), with five, seven and five items respectively. The response scale evaluated the intensity of each symptom on a scale of 1 (not at all) to 4 (very much).

VIII. State anxiety was analysed by the: State-Trait Anxiety Questionnaire. (STAI) [30], which evaluates a transient emotional state, characterized by subjective feelings, consciously perceived, attention and apprehension and hyperactivity of the autonomic nervous system.

After finish the manoeuvre soldiers had to fill a post mission questionnaire in which they were asked by the visual, auditory and olfactory target presented in the previous method point (urban combat simulation). The questionnaire questions consist of different images to try to find the object placed in the simulation, and a list with different sound and odours in which they have to select that they remember, the response of the questionnaire could be correct, wrong or no response.

During the entire manoeuvre, soldiers wore a heart rate (HR) transmitter belt (Polar V800, Kempele, Finland) with RR function to analyse HR and heart rate variability (HRV). We analysed 20 min of HRV while soldier were waiting in waiting area, using this measurement as baseline of HRV and HR parameters. Then we analysed HRV and HR during the manoeuvre with Kubios HRV software (University of Kuopio. Kuopio, Finland). Parameters analysed were HR, high frequency domain of the HRV/low frequency domain of the HRV relation (HF/LF), and square root of the mean of the sum of the squared differences between adjacent normal R-R intervals (RMSSD). Soldiers also wore in their head a SONY HDR-AS30V (Tokio Japon) high definition video camera to confirm that soldiers saw the object and hear the sound placed in the manoeuvre following previous studies [13, 31].

Statistical analysis

Data were analysed using the Statistical Package for the Social Sciences (SPSS) version 21.0 (SPSS Inc., Chicago, Ill., USA). Means and SDs were calculated using traditional statistical techniques. Normality was tested with the Kolmogorov-Smirnov test. A one factor ANOVA for intergroup comparisons and a Student's T test for intragroup comparisons since variables presented a parametric distribution were conducted. The Effect Size was tested by Cohen's D. The significance level was set at $p < 0.05$.

Results

The results of the intragroups analysis shown how RPE, glucose, lactate, RMRT, RMSSD, LF, HF, LF/HF and SA increased significantly ($p < 0.05$) in both groups after the combat maneuver. Values of ABK increased significantly only in NSOG, and values of CA increased significantly only in SOG.

The results of the intergroup analysis shown significant differences between Elite and no Elite groups in the values of RPE, glucose, CFFT, RMRT, RMSSD, LF/HF, CA, SA, STAI.

The results of the post mission questionnaire are shown in percentages of correct, incorrect and unanswered answers, as well as the significance between them. The results shown how the elements more related with the physical integrity (blood, visceras and deceased) are the most correctly remembered since they have the highest percentage of correct answers in SOG (97.6%) and NSOG (88.9%) with a significance level between correct and incorrect answers of 0.000.

Discussion

The aim of this research was to study the effect of experience and psychophysiological modification by combat stress in soldier's memory. The initial hypothesis was partially complied since SOG do not presented a lower psychophysiological activation in all the variables analyzed but shows a better memory performance.

Analysing the psychophysiological response of soldiers we found a similar response independently of the special or non-special operations groups. In both groups the combat simulations demands increased blood glucose and lactate concentrations, showing the increased in energy demands despite the low speed of movements performed by both units. These results is in consonance with previous research conducted with infantry units and reflect the activations of fight to flight system due to the combat stress [7]. Cortical arousal (CFFT) were not modified in both groups, showing an increased tendency as well as previous studies [5] where the CFFT increases revealing the increase in the cortical activation due to the stress in a combat situation where the organism prepares to respond to any stimulus quickly [32]. However, the present combat simulation not supposed an extremely stressful situation as in other studies [6] where CFFT values decreased showing central nervous system fatigue due to the over-stressing situations and the lower experience of the soldiers analyzed. Therefore, special and non-special operations groups maintained a high central nervous system activation. This adequate level of arousal and the activation of the fight to flight system allows soldiers to work at full performance [5, 19, 33] shown a significant increase in leg strength of NSOG and the also increased, but not significantly, of SOG. Even thanks to this activation of the fight to flight system we found an improvement in RMRT where we can say that there is an improvement in fine motor skills of soldiers.

In the HRV analysis HF values decreases significantly which are related with stimulation of parasympathetic nervous system, and in contrast, LF values increases significantly which are related with stimulation of sympathetic nervous system, since this stimulation predominates with states of anxiety, stress or exercise [34]. In terms of anxiety we found that somatic anxiety (SA) increases significantly in both groups, but only in the SOG increases significantly the cognitive anxiety too (CA). These values show how SOG has an anticipatory anxiety due to high LF pre, although during combat they have a lower stress response than NSOG, since it shows higher value of HF and RMSSD. This may be due to the fact that the situations SOG usually faced are more difficult and more demanding than those faced by other military groups like NSOG. Therefore SOG will usually shows higher values of LF whenever it is confronted with a similar situation due to a cognitive behavioral association by past experiences, regardless of the stress tolerance shown during the carry out of the maneuver and their memory performance [32].

Regarding the analysis of the post-questionnaire, which provides information about the effect of psychophysiological variables on memory variables, we found that variables best remembered are those related with sight in both groups SOG and NSOG such as elements and objects according to the Viberg [35] hierarchy of the senses where he established the sight in first order, postulated accorded too with San Roque et al. [36]. As in previous studies, soldiers remember those things related to their physical integrity since the elements were composed of blood, IED's, dead, and objects were composed of pistol, rifle, etc. [13] and in accordance with the attentional control theory (ACT), anxiety increases the allocation to threat-related stimuli [17]. In combat there are a lot of dangerous situations that cause increases of anxiety which involve the use of implicit memory [15, 17] and it is also known that the consolidation of the information in brain

storage is affected by high levels of cortisol causing a decrease in memory performance [37] and therefore, affects negatively the working memory of soldiers [13, 38]. But in this study the results reflects how the performance of working memory of SOG are not affected entirely by stress. SOG shows significantly higher percentage of correct answer and a significantly lower percentage of wrong answer than NSOG in all the variables in which the view is involved such as elements, text and objects which is the most important for humans since it is the sense by we receive more information. NSOG only shows a significantly higher performance than SOG in odours, but as we have seen in previous studies the sense of smell is through which we receive less information according to the order of the hierarchy of the sense: see, hear, touch, taste and smell [35]. Recalling the high values of anticipatory anxiety shown by SOG as opposed to NSOG and the results of the postmission questionnaire would be expected SOG's working memory performance would be lower. On the contrary we found SOG have a better significant performance in postmission questionnaire than NSOG. These results can be explained because SOG usually works with high levels of stress, so in the previous moment of a combat or a simulation they generate high levels of activation of the sympathetic nervous system and of stress due to, on the one hand, to the surprise factor of not knowing what they are going to find, and in the other hand, to a cognitive behavioral association by past experiences. The explanation may be that they active the fight-flight system of the organism to be at full capacity. Once the development of the combat simulation begins, SOG are able to better manage this stress without causing low performance in attention and working memory thanks to the acquired experience. These results shows that experience adquired with training can reduce the negative psychophysiological effects caused by stress in working memory. Therefore the hypothesis is partially confirmed since in both groups the psycophysiological response increases but SOG has a better memory.

Limitation of the study

Some limitation of this study should be mentioned. Firts, the relatively small sample size analyzed with only 35 participants, since when the data collection takes places, few soldiers were available to participate in the reaserch study. Second, the non-control of stress hormones such as cortisol to measured directly, the effect of stress and know the levels of cortisol that causes in each soldier during the combat simulation. Third, the non-use of direct measurements of cortical excitation. These limitation were unavoidable since we were subject to financial and tecnhnological constraints that prevented a better study. In future researches should try to address these problems to improve research.

Practical application

Data obtained helps us to understand how the stress of combat affects memory and performance of soldiers. This information help us to create betters training programs with the real needs that soldiers have in the main theaters of operations, trying that the psychophysiological response to the stress that occurs in maneuvers is not a blockade for the soldiers. In this way achieves that in terms of level of attention, memory and use of the information for decision making, soldiers are as well prepared as posible against stress and their performance is optimal.

Conclusion

Independently of experience, combat stress produce an increase in the psichophysiological response of soldiers, but experienced ones presented a lower negative effect on memory than non experienced.

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Compliance with Ethical Standards

Conflict of Interest The authors declares that they have no conflict of interest.

Research Involving Human Participants All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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