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Effects of Socio-Emotional Stressors on Ventilation Rate and Subjective Workload during Simulated CPR by Lay Rescuers

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Abstract

Several studies have documented the occurrence of high ventilation rates during cardiopulmonary resuscitation, but to date, there have been no scientific investigation of the *causes* of hyperventilation. The objective of the current study was to test the effects of socio-emotional stressors on lay rescuers' ventilation rate in a simulated resuscitation setting using a manikin model. A within-subjects experiment with randomized order of conditions tested lay rescuers' ventilation rate on an intubated manikin during exposure to socio-emotional stressors and during a control condition where no external stressors were present. Ventilation rates and subjective workload were significantly higher during exposure to socio-emotional stressors than during the control condition. All but one of the nine participants ventilated at a higher ventilation rate in the experimental condition. All nine participants rated the subjective workload to be higher during exposure to socio-emotional stressors. Hence, exposure to socio-emotional stressors is associated with increased ventilation rates performed by lay rescuers during simulated cardiac arrest using a manikin model. These findings might have implications for the understanding of the type of situations which hyperventilation may occur. Awareness of these situations may have implications for training of lay rescues.

Introduction

Studies have documented situations where cardiac arrest patients receive cardiopulmonary resuscitation (CPR) that deviates substantially from established guidelines (Olasveengen et al, 2007; Abella et al, 2005; Aufderheide et al; 2004; Aufderheide & Lurie, 2004). The barriers for providing treatment in coherence with guidelines seem numerous and pervasive, but it has been suggested that performance decrements is associated with individual stress and social dynamics of the resuscitation situation (Abella et al., 2005; Pitts & Kellerman, 2004; Leary & Abella, 2008).

Hyperventilation, defined as delivery of excessive ventilation rates to intubated patients, is observed for both in-hospital (Abella et al, 2005; Losert et al, 2006) and out-of-hospital cardiac arrest (Wik et al, 2005; Kramer-Johansen, 2007), with experienced health personnel (Aufderheide et al, 2004; Aufderheide & Lurie, 2004), and immediately after CPR training (Verplancke et al 2008). No systematic investigation of the wide range of psychological stressors in CPR has been carried out. There is no uniform classification of what types of stressors that is present beyond the notion of CPR as being “stressful events” – nor is it a clear consensus concerning the contribution of specific stressors to performance decrements (Pitts & Kellerman, 2004; Cooper & Cooper, 2008).

Human mental resources for attention and information processing are limited (Norman & Bobrow, 1975; Simon & Chabris, 1999). Increased task workload often leads to performance decrements in one or more tasks when people have to perform several tasks at once (Norman & Bobrow, 1975). This means that there is a limit to how many tasks a person can do well at the same time. The maintenance of a steady ventilation rate (such as 10 breaths per minute which would require one breath every 6 seconds) would need some type of timing mechanism, either externally given (such as a metronome or clock) or endogenously produced (e.g. by counting, or by tapping the foot). Abella and coworkers (2005) pointed to the lack of a reliable internal timing to pace chest compressions – an argument that is also viable with respect to the maintenance of a steady ventilation rate. The unreliability of such a timing mechanism has been observed in other rhythmic tasks (Gilden et al., 1995; Ding et al., 2001; Chen et al., 1997). The maintenance of a steady ventilation rate would require mental or attentional resources that must be shared with other tasks. This implies reduced mental resources to maintain a steady ventilation rate in demanding situations. In this respect it can be hypothesized that increased workload would negatively affect ventilation rate.

The present study investigates the effects of socio-emotional stressors on ventilation rate in two simulated resuscitation scenarios with lay rescuers. Two experimental conditions were compared, one scenario where the subjects were exposed to socio-emotional stressors, and one control condition with optimal conditions with no stressors present. A within-subject design was used in order to control for individual differences (Maxwell & Delaney, 2004). Both ventilation rate and perceived workload were compared.

Methods

Participants

The sample included ten persons (6 male and 4 female) aged 19 to 27. Persons with extensive knowledge or recent experience with first aid were excluded. One male participant was excluded from data analysis due to failure to comply with experimental instructions. Data from nine participants were thus used in data analysis. Given the fact that no estimate of effect size was obtainable, a priori power analysis was not performed.

The number of participants was held to a minimum due to the emotional distress involved in the study, and the initial sampling of 10 persons was not extended.

Performance Variables

Ventilation rate was measured in terms of Inter-Response Intervals (IRI). IRI was measured in seconds, and denotes seconds between initiations of ventilations administered by the participant. IRI has previously been used to measure time intervals between rhythmic movements and allows for evaluation of temporal within-trial variations (Chen, Ding & Kelso, 1997).

Subjective workload was measured by NASA R-TLX (Hart & Staveland, 1988). This validated test consists of six sub-scores that measures different aspects of the workload a task may impose on a human worker (mental demands, physical demands, time pressure, effort, frustration, and evaluation of performance). These sub-scores are aggregated into a sum score that reflects the total level of subjectively experienced workload. The test was administered verbally by the research leader after both conditions.

Material and Data Analysis

A standard Skillreporter Resusci Anne (Laerdal Medical, Stavanger, Norway) connected to a laptop computer was used to record ventilations and chest compressions. Collected manikin data was transferred to QCPR Review (Laerdal Medical, Stavanger, Norway) for extraction of each time point for the onset of ventilations as the basis for estimating IRI values that were later analysed with SPSS 16 for Windows.

All data were analysed by paired samples *t*-tests unless noted in the text. The individual mean IRI for each condition presented in Table 1 reflects the arithmetic mean of the ventilation time series which consisted of consecutive IRI's. Effect sizes for ventilation performance and subjective ratings were calculated by dividing the mean difference between the conditions by the standard deviation of the participants' difference scores (thus reflecting the difference in between-group standard deviations). Minimum average IRI for each participant (corresponding to maximal average ventilation rate) was calculated by using an unweighted moving average window of a length of approximately 30 seconds on the ventilation time series.

Procedure

The participants were introduced to CPR as the overall theme of study before presented a consent form. The participants were informed of their option to withdraw from the study at any time for any reason, and that recorded data then would be deleted. A consent form was signed. The study was approved by the regional research ethics committee of western Norway.

Experimental instructions, scoring of subjective workload measures, screening and debriefing of the participants after the study was all performed in a room separate from where the experiment took place. The participants were explicitly instructed to the importance of maintaining a ventilation rate of 10 bpm (corresponding to the ERC 2005 guidelines[1]) before both scenarios. The participants were told to deliver ventilations to an intubated manikin using a self-inflatable bag.[2]. In addition, the participants were briefed on the importance of the dialogue with emergency medical services (EMS) dispatcher

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[1] In terms of CPR by team effort of lay persons, the 2005 ERC guideline suggests 100 chest compressions per minute and 10 ventilations per minute in patients with advanced airway in place. See Nolan (2005) for full details.

[2] This implies a combination of basic and advanced cardiopulmonary resuscitation since lay persons should not intubate a patient. Reasons for this choice were to better investigate ventilation rate under socio-emotional stressors and not to investigate CPR as such.

while awaiting professional assistance. The participants were asked to restate the information given during briefing in order to secure an explicit and positive understanding of correct ventilation and compression rate.

The participants were randomly assigned to one of two possible condition sequences. Relevant introduction was given before each experimental condition.

The control condition was described to the participants as a chance to test ventilation performance on a resuscitation manikin. The participant was taken into the laboratory where the already intubated manikin was placed on a table. The participant was asked to administer chest compressions for 30 seconds. Subsequently they were told to right away proceed to ventilate the resuscitation manikin for three minutes in accordance to the instruction given during the briefing. The participants did not have to perform other tasks or converse with anyone while ventilating the manikin. The participant returned to the briefing room after completing ventilation and chest compressions where the participants scored the sub-scores of NASA R-TLX.

The experimental condition was described as a simulated emergency situation where a patient had lost consciousness and some bystanders had gathered. No information was given on the medical status or situation. The participant was brought to the laboratory where a resuscitation manikin was lying on the floor surrounded by scattered furniture and co-student bystanders. The emergency situation involved a sudden cardiac arrest of a 28-year-old student during a study circle at the University Campus. Four accomplice assistants played the co-students, and the participant entered the situation immediately after the patient had lost consciousness. The participant was first ordered to administer chest compressions for approximately 30 seconds while an accomplice assistant intubated the patient. The participant then right away changed to the ventilation task as soon as the manikin was intubated. The accomplice assistant called up a mock-up EMS dispatcher on a cell phone, and asked the participant to communicate with the EMS dispatcher while ventilating the patient. The four accomplice assistants had relevant but different information concerning the patient and the situation (name, age, medical history, situation description, address, etc.), and the participant was forced to gather this information from bystanders and convey this in dialogue with the EMS dispatcher over the cell phone. The scenario lasted for approximately ten minutes, after which the participant was taken back to the briefing room for administration of NASA R-TLX.

The participant was debriefed on the purpose of the study after completing the last condition, and the research leader answered any questions that the participant might have concerning the study. A small token of appreciation for their participation was awarded.

Results

Ventilation IRI was substantially lower in the experimental condition than in the control condition, thus showing that the participants ventilated at a higher rate when exposed to socio-emotional stressors (table 1).

PLEASE INSERT TABLE 1 ABOUT HERE

A direct test of the hypothesis that socio-emotional stressors would increase ventilation frequency showed that a total of eight out of nine participants ventilated at a higher ventilation rate in the experimental condition than in the control condition (exact point probability p = .018, by binomial test). Even though the direction of the effect of socio-emotional stressors was almost uniform, the data reveals that there are large individual differences in the magnitude of the effect (see table 1 for data presentation).

Minimum IRI, indicating their maximum ventilation frequency, during 30 second intervals was also substantially lower during exposure to socio-emotional stressors than in the control condition. Four of the nine participants had minimum mean ventilation IRI that corresponded to ventilation rates over 20 bpm (table 1). The results clearly show that individual ventilation rates were higher in the experimental condition as opposed to the control condition.

Statistical analysis indicated that the participants experienced substantially higher workload in the experimental condition compared to the control condition (table 2).

PLEASE INSERT TABLE 2 ABOUT HERE

Changes in ventilation IRI and changes in subjective experience of workload between the two conditions correlated (Pearson's r = -.526, p = .146, R^2=.28)

Discussion

This study investigates possible human factor causes of hyperventilation. Ventilation rates were higher when participants were exposed to socio-emotional stressors than during the control condition. This effect was consistent for all but one participant. All participants experienced a higher workload when exposed to socio-emotional stressors, than they did in the control condition.

An increase in experienced workload was found to correlate with a shortening of the duration between successive ventilations. The observed correlation between ventilation and workload indicates that experienced workload and stress during the resuscitation situation might be a possible factor that increases the possibility for hyperventilation. This possibility of a relationship between stress and hyperventilation has been mentioned by others (Abella et al., 2005; Pitts & Kellermann, 2004; Leary & Abella, 2008).

Calculating the maximum ventilation rates over a time interval of 30 seconds led to results that are comparable to other studies where maximum ventilation rates in excess of 40 bpm have been reported (e.g. Aufderheide et al., 2004; Aufderheide & Lurie, 2004; O'Neill & Deakin, 2007). These ventilation rates have been associated with greatly reduced survival in animal studies (Aufderheide et al, 2004; Aufderheide & Lurie, 2004; Chiefetz et al., 1998; Karlsson et al., 1994; Pepe et al., 2003; Theses et al., 1999; Yannopoulos, et al., 2005) and can be assumed to be detrimental to the survivability of the human cardiac arrest patient (Aufderheide et al., 2004). However, the limit at which ventilation rates becomes detrimental to survival in humans is unknown. Nor is it known for how long these ventilation rates must be maintained to affect survival. Our findings of very high maximum ventilation frequencies at short time intervals not only show that continuous ventilation performance is variable but also that socio-emotional stressors may increase the incidence of high ventilation rates associated with detrimental effects on health of cardiopulmonary patients.

If the findings in this article are replicated and extended to cover professional advanced life support (ALS) providers we see a need to alter current training so that they are trained to resist the negative influences of socio-emotional stressors and to improve the adherence to CPR guidelines. The use of specific training programmes designed to improve team performance have had beneficial effects on performance in stressful situations in other work domains such as military operations and in the aviation industry (Salas et al., 2001; Alonso et al., 2006; Wiener et al., 1993; Helmreich & Merritt, 1998).

This study has several limitations. First, it tests the effects of socio-emotional stressors on lay rescuers using a simplified ventilation task with a ventilator bag on an intubated manikin. This is an artificial scenario since lay persons should not intubate a patient and they should not use a ventilator bag when performing CPR. We did not intend to test the quality of CPR but rather wanted to create an experimental situation that allowed testing for the presence of a phenomenon (e.g. “stress induces hyperventilation”) that other researchers have implied (Pitts & Kellermann, 2004; Leary & Abella, 2008).

Another limitation is that in general, lay persons have no or little formal training in CPR and that they did not know how to ventilate at a proper rate. However, all participants were explicitly instructed to ventilate at a rate of 10 bpm – corresponding to the current CPR guidelines (Nolan, 2005). Also, the use of a within-subject design that controls for individual differences allowed us to make a direct test of the hypothesis that socio-emotional stressors increase ventilation rates, a test where eight of nine participants ventilated faster during exposure to socio-emotional stressors. Even though the effect is present in lay rescuers, it remains to see to what extent the formal training and knowledge of professional ALS-providers can be a barrier that mitigates the possible negative consequences of socio-emotional stressors in CPR-situations. However since it has been shown that professional ALS-providers hyperventilate cardiac arrest patients during advanced life support it is reasonable to ask why this happens. Whether this is due to socio-emotional stressors or not is an empirical question.

Our study has implications for the design of training programmes for professional ALS-providers. If we understand the human factor causes of hyperventilation we can create training programmes that aim towards mitigating the negative effects of stressors that reduce CPR quality.

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Table 1

	Mean IRI for each condition		Minimum IRI over 30 second time interval	
	Control	Experiment	Control	Experiment
Participant				
1	8.80	6.55	7.30	4.56
2	7.35	7.05	6.81	2.56
3	8.51	5.79	7.69	4.26
4	10.15	6.73	8.39	4.85
5	6.68	4.21	5.26	3.16
6	6.63	5.23	6.02	1.49
7	10.81	11.17	8.77	7.19
8	6.79	2.65	5.92	1.58
10	4.86	2.64	4.55	1.97
Group Mean (SD)	7.84 (1.89)	5.78 (2.61)	6.75 (1.42)	3.51 (1.88)
Difference between groups [95 % CI of difference]	2.06 [0.967, 3.157] [a]		2.713 [2.428, 4.037] [b]	
Effect size*	1.447		3.089	

Table 1: Individual and group IRI for the two conditions. The table presents the mean and minimum IRI for each participant on both conditions. [a] Paired samples *t*-test $p = .002$; [b] Paired samples *t*-test $p < .001$, * See test for description of effect size calculations. Please note that a reduction in IRI between the conditions reflect an increase in ventilation rate. IRI can be transformed into bpm by calculating 60/IRI. Abbreviations: CI = Confidence Interval, IRI = Inter-Response Interval, SD = Standard Deviation, bpm = breaths per minute.

Table 2

	Experiment (Mean ± SD)	Control (Mean ± SD)	Difference between groups [95% CI of Difference]	Effect Size[α]
Mental demands **	72.78 ± 17.52	33.89 ± 20.88	38.89 [19.22, 58.56]	1.52
Physical demand	26.67 ± 10.61	18.33 ± 9.01	8.34 [-0.88, 17.55]	0.69
Time pressure **	67.78 ± 22.93	23.33 ± 28.28	44.45 [22.41, 66.48]	1.55
Effort **	68.89 ± 20.28	30.56 ± 23.24	38.22 [21.15, 55.52]	1.71
Frustration **	63.33 ± 26.93	18.33 ± 25.00	45.00[18.65, 71.35]	1.31
Performance	52.78 ± 19.22	62.78 ± 9.72	-10.00 [-25.25, 5.25]	-0.50
Mean **	58.70 ± 11.59	31.20 ± 15.59	27.50[16.86, 38.14]	1.99

Table 1: Subjective workload measured by NASA R-TLX in the experimental and control condition. ** $p < .005$, [α] See text for description of effect size calculation.