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Characterization of Anesthetists' Behavior during Simulation Training: Performance Versus Stress Achieving Medical Tasks with or without Physical Effort

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Abstract - Decades of research about stress have shown that it could be source of performance but also of cognitive deficit. The studies have led to highlight occupational stress variables that researchers have characterized by physiological measurements, data treatments and protocols becoming more and more complex with time. If these devices are gaining in precision, they are now too complex to allow non-specialist users to produce a quick interpretation of results. Yet for vocational training, specifically on simulators, trainers need to know in real time whether or not what they implement allows the trainees to learn in good conditions, i.e. by favoring the behavior produced by the positive effect of stress on performance. The present paper addresses the performance versus occupational stress during training sessions of anesthetists on simulator. We studied the performance and stress with or without physical effort using a simple protocol based on the use of basic heart parameters in order to obtain a quasi-instantaneous interpretation of the data. We identified cognitive deficit zone during training according to the Yerkes & Dodson (1908) relationship between performance and stress. We showed that performance versus stress during simulation training with or without physical efforts could be successfully analyzed for immediate assessment of stress influencing performance. Suggestions have been made for improving training sessions and avoid trainees' behavior induced by cognitive deficit. Limits of the protocol are exposed.
Keywords - Performance, Stress, Simulation

1. Introduction

For many years, stress has been shown by researchers to be both a source of performance and a source of cognitive deficits, therefore reducing performance. Getting information about the kind of influence of stress in a work activity has appeared very useful to be able to work mainly under the positive influence of stress. For this aim, qualitative considerations help, but the best is to maintain quantitative approach because of the objectivity. Many works have been done in order to make the link between stress and physiological parameters in a quantitative approach and studies have shown how to measure some of those parameters identified to be closely associated with the stressed state of subjects. Nowadays, with technical progresses and after conclusions of several decades of studies, medical facilities are available to do such investigations, which require specific devices, metrologies, and then demand specific software for analysis. At each step, specialists are necessary. Different relationships between the occupational stress and the performance have already been obtained by others (for example see Broadhurst, 1957; Drach-Zahary & Erez, 2002; Hancock *et al.*, 2002; and the review of Staal, 2004, Pearsall et al., 2009).

But for some industrial contexts concerned by the impact of stress on performance, such a complex organization cannot be applied, for a matter of time, money, and competencies, while it would be of great interest to have better knowledge in particular cases: classic training session, training on simulator, evaluation, crisis management… To address this need, we tested the use of a simple protocol, requiring basic metrology and simple straight data analysis on training simulators with trainers who are not necessarily experts in medical researches. This does not mean that we aim at demonstrating that protocols involving the stress description through a full set of physiological parameters (such as breathing rate, heart rate variability, hormone excretion, inter-beat interval consistency, blood pressure modulation, etc.) must be put away. We just suggest something else: a performance vs stress approach using a simple protocol and device for straightforward analysis.

1.1. Stress types

The stress which we were interested in this study is a short term stress, compared to long term stress linked with chronic stress exposure (refer for example to the studies of Maslova et al. (2002) who studied the effect of chronic stress on arterial blood pressure, or studies of Schubert *et al.* (2009) who compare both kinds of stress). All types of stress are concerned by psychological and physiological variable changes (McLean, 1974; Beehr & Newman, 1978; Karasek & Theorell, 1990; Palmer *et al*., 2003), some of them linked with genetics (Judge et al., 2012). In case of long term stress, physiological parameters vary differently than in case of short term stress. The time component is fundamental and specific. For the short term stress, time is mainly relevant in terms of length, while for long term stress, time is relevant in terms of frequency, which may lead to "chronic stress".

As we considered here stress at work, the stress was of occupational kind. We thus studied short term occupational stress, at which people at work are submitted when they are asked to perform a task bounded in a short time interval (about several seconds to several hours) rather than stress itself. We studied here the relationship between performance and stress, and mainly the influence of the conditions of stress on the performance. Yerkes & Dodson (1908) gave a theoretical description of this relationship, assuming that performance rises with the stress level until a given threshold beyond which performance decreases, suggesting that stress puts the subject in a cognitive deficit zone.

1.2. Heart parameters measurements

Measurement of the physiological parameters helps the characterization of the subject's state with regards to the stress. Here, a short recall of the physiological process is done. We shall not remind here the details of the physiological process taking place with occurrence of stress. We shall just focus on the main lines in order to justify the choice of the physiological parameters measured in our experiments.

To make it short, we shall consider a stressed subject in a given context. In case of an induced psychological pressure for the subject, two main systems will be called upon: the sympathetic nervous system and medulo-surenal gland, producing adrenaline / noradrenaline and corticotropin releasing hormone (CRH). The first one will have short term effects, mainly concerning a rise in blood glucose, heart and ventilation rate. The second one will have a long term effect (at least several hours), mainly related to the production of corticotropes and cortisol which have a moderating effect as opposed to adrenaline. The short term stress is thus mainly concerned by the sympathetic nervous system and its effects (see for example Davezies, 2008; Montano *et al*., 2009; Keitel *et al*., 2011).

Lots of studies are available concerning physiological measurements associated with state of stress of the subjects. Many publications are available about the spectral heart rate variability analysis, combined with respiration analysis and sudation. As said above, these techniques involve sophisticated metrologies and elaborated software which need, thereafter, a careful data examination to be sure of the conclusions (Fairclough *et al*., 2004; Montano *et al*., 2009; Müller *et al*., 2009; Rohleder *et al*., 2009; Schubert *et al*. 2009; Bailon *et al*., 2010). Using these techniques, Schubert *et al*. (2009) (as others before: Steptoe, 2000) have confirmed again how the mean heart rate increases with short term stress while it decreases with long term stress, showing that, for the kind of stress we were interested on, the mean heart rate is a pertinent parameter to characterize subjects' state of stress.

Aiming at elaborating a simple and straightforward protocol for performance vs stress analysis, we focused on heart rate measurements as physiological parameters to qualify stress.

1.3. Short term mental stress with or without physical effort

According to the bibliographic research, no publication is available concerning the analysis of stressful work situations involving subjects with a comparative study of the conditions thereafter said with or without physical effort.

Our contribution specifically focuses on this comparative point.

2. Materials and Methods

The method was based on the evaluation of the subjects' state of stress using perception questionnaire and heart rate measurements combined to the assessment of the performance. These quantitative data were supplemented by qualitative material obtained through interviews during debriefings of training sessions. The experiment was applied to anesthetist training sessions on full scale simulator.

2.1. The characterization of stress conditions by perception questionnaire

Several questionnaires for self-rating of stress have been established and scientifically tested. The Job Content Questionnaire of Karasek has not been retained here because, even if the macro-variables are watched through the items, a lot of questions not concerned by the training sessions are asked and some variables which are relevant to be asked are not investigated by the questionnaire. The Cohen's Perceived Stress Scale (PSS) (Cohen *et al*., 1983) as the more recent Work and Well-Being Questionnaire (Kilminster et al., 2007; Bridger *et al*., 2011), concern the long term stress and thus is not adapted to this study. The State-Trait Anxiety Inventory (especially the STAI form Y-A self-rating the subject's anxiety state) developed by Spielberger (1983) has not been used because it measures anxiety with too few reference to exogene parameters. The perception questionnaire of stress used for this experiment is the Peritraumatic Distress Inventory (PDI; 13 items). It has been elaborated in order to obtain a quantitative measure of the level of distress experienced during and immediately after a traumatic event.

This questionnaire has been scientifically tested by several (see for example Brunet *et al*., 2001), including in its French form (see Jehel *et al*., 2005 and 2006). It presents the advantage, compared to the STAI, to include items such as the frustration or guilt not to do more, the shame, the fear for one's safety or for others, which are important parameters concerning the job. It includes also the subject's feelings concerning physiological parameters (sweating, shaking, pounding heart). The problem for this questionnaire is that it is linked with the diagnosis of posttraumatic stress disorder (PTSD) which requires that a subject has high levels of distress during or after the traumatic event. We shall see thereafter that it can be a drawback when the subject is submitted to a too low level of stress.

2.2. Physiological measurements during training

On the contrary of sophisticated metrologies and elaborated software which need, thereafter, a careful data examination to be sure of the conclusions (Montano *et al*., 2009; Rohleder *et al*., 2009; Schubert *et al*. 2009; Bailon *et al*., 2010; De Jonckheere et al., 2010; Jo et al., 2013), we aimed at a simple solution based on heart rate.

Heart rate (HR) has been measured using a Polar FS2c composed of two parts. The first one is a detector with two electrodes to be put on the breath, touching the skin, close to the heart. The second one is a monitor which looks like a watch which can be worn on the wrist. The screen shows the mean value of the measured heart rate. The whole device is worn by the subject and at the end of the test, values of the mean heart rate and of the maximum are given. The technical specifications are:

- accuracy of time measurement: better than ± 2.0 s / 24 h
- accuracy of heart rate measurement: ± 1% or ± 1bpm, whichever larger
- measuring range : 15-240 bpm

It has been found (Fauquet-Alekhine et al, 2011 & 2012) that, to have pertinent heart parameters concerning stress, we could use a mean value and a maximum value of HR. We thus chose to use the basic parameters which are the mean heart rate (HR_{mean}) and maximum heart frequency (HR_{max}) to characterize the subjects' state of stress, keeping in mind that both parameters increase with stress intensity in the case of the short term occupational stress.

In addition, samples of salivary amylase were taken from each subject involved in the anesthetist's training just before and just after being involved in the simulated situation. The aim was to analyze the evolution rate (not discussed in this paper).

2.3. Subjects sample, training context and pedagogical goals

All the presented experiments have been conducted with and within a hospital university of Paris district. The subjects for this application were French students, all residents in Anesthesiology and Intensive Care in their third year of specialization, observed on full scale simulator.

Students were involved in a one day training session in operating theatre, and training was performed the whole week (5 days). It means one different group of about 6 students was received every day. At the end of the week, 27 French students were trained, playing different role depending on the scenario.

Four different scenarii were used per day (less than one hour each), and 3 students were training together per scenario, each scenario (about 30 min) followed by a debriefing session (30 to 45 minutes).

The participants of the simulated situation for a scenario were:

- 3 students playing the role of physician, nurse, and help,
- 1 physician trainer, playing the surgeon,
- 1 physician trainer piloting the simulator.

This implied that the number of cases available depended on the students who were involved in the situations and on the role they played. At the end of the week, the sample of subjects concerning the actor physicians was (*N*=18; 50% male), and the sample of subjects concerning the actor nurses was (*N*=18; 44.4% male).

Deontology has been presented during each introduction of the Stress-test or training sessions with the subjects. First of all, all subjects were volunteers. It was explained that all data would be used for research, anonymously, and that no access to personal data or to the links between data and identity would be given to anyone. A specific form was filled up and co-signed by the subject and the researcher each time.

Concerning physiological parameters, it was only measured for the student playing the physician's role: heart rate was recorded by the Polar monitor described above, and gave mean and max values at the end of the session.

During the simulated situation, the other students watched a video projection of the simulation in another room, together with the researcher and other physician trainers. In this room, a large size screen and an audio device allowed to watch and hear what was going on in the operating theatre.

The general pedagogical goal was to put students in a simulated situation pertinent to their future job where they need to make diagnosis, take decision and act to deal with the critical case.

The scenarii were clinical cases involving only one dysfunction (no cumulative cases).

The 4 scenarii were:

- Asphyxia related to post-operative cervical hematoma,
- Local Anesthetics intoxication,
- Peroperative third degree auriculoventricular block,
- Peroperative respiratory arrest related to injection of myorelaxant drug.

For further details about scenario contexts, see Geeraerts et al. (2013).

2.4. Performance evaluation and link with stress

Results presented in a previous work (Fauquet-Alekhine et al., 2011 and 2012) demonstrated that a Yerkes & Dodson curves could be fitted for performance concerned with short mental occupational stress. In this previous work, experiments were carried out with healthy subjects (*N*=18; 50% male), about 25-35 yo., same academic background and the same kind of job, taking a Stress-test made up of 12 simple questions. A 100% success could be expected for all of the subjects taking the test but we can see that it was not the case: a modal analysis of the performance coefficient K_p (Fig. 1) has shown that there was a range over which values spread. The range was yet narrow.

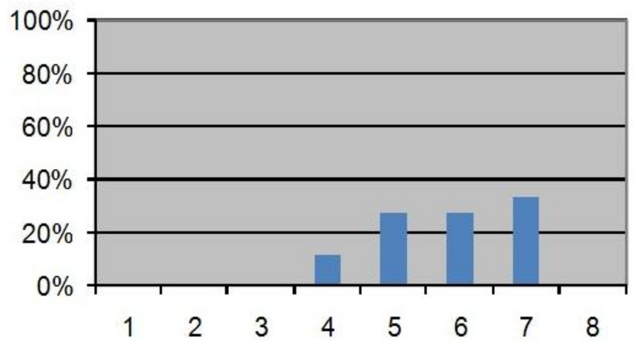

Fig. 1. The modal distribution of K_p for Stress-test.

Analysis of measurements of heart rate HR (discrimination of conditions, modal analysis) and correlation with results of the perception questionnaire of stress have allowed us to define a reduce coefficient of stress K_{sr} as :

$$K_{sr} = HR_{mean} \cdot HR_{max\ ampl}$$

where $HR_{max\ ampl} = HR_{max} - HR_{mean}$

Plotting the subjects' performance measured through the performance coefficient K_p vs the state of stress rated by the reduced stress coefficient K_{sr}, we obtained (Fauquet-Alekhine et al., 2011 and 2012) the bell curve (Fig. 2) where subjects working in stressful conditions were well discriminated on the right side of the graph (clear squares) from other subjects.

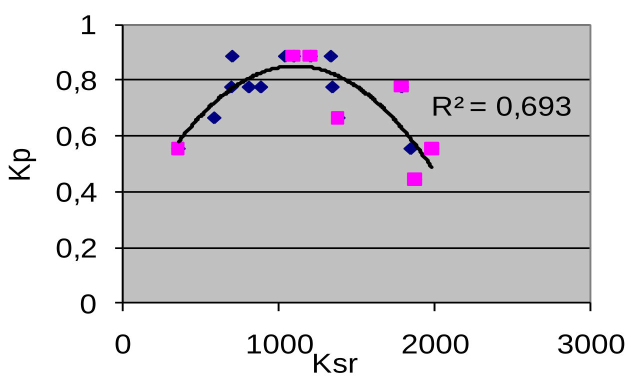

Fig. 2. Experimental data obtained during the Stress-test, plotted with performance coefficient K_p vs reduced stress coefficient K_{sr} and fitting a Yerkes & Dodson (1908) curves for a short mental occupational stress (Fauquet-Alekhine et al., 2011). The determination coefficient of polynomial fitted curve is $R^2 = 0.69$.

Using the concept of Human Functional States (HFS) suggested by Leonova (2009), we divided the bell curve into three main Human Functional States (Fauquet-Alekhine, 2012):

- the left part is linked to a HFS of positive state of stress or stable cognitive state, where performance rises with the stress,
- the central part reflects a HFS of transience (transient state) for the subject in terms of stress effects, where performance has raised with stress until a given threshold beyond which the variation is inverted,
- the right part concerns a HFS of negative state of stress or potential cognitive deficit state, where stress tends to put the subject in a cognitive deficit state, reducing the subject's capacity to fully use his/her cognitive resource and making performance decreasing.

These HFS are drawn on the graph presented in Fig. 3.

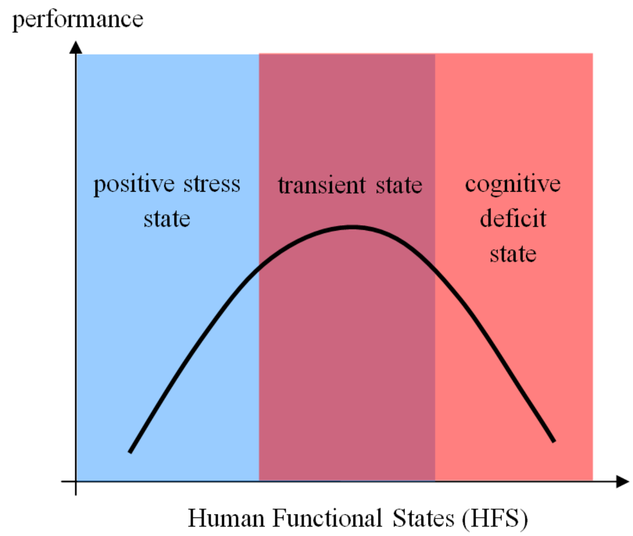

Fig. 3. Human Functional States (HFS) divided into three main parts: i) central part: transient state for the subject in terms of stress effects, ii) left part: positive state of stress, iii) right part: potential cognitive deficit state.

The coefficients of performance K_p vs stress K_{sr} gave a good representation of the subject's state of performance vs stress during a work activity in which mental stress is involved, which means without physical stress. This method has been applied in the present study, and extended to the case of short term occupation mental stress with significant physical effort.

In the present work, all training sessions were video recorded in the aim of performance rating. All records have been carefully watched by anesthetist-trainers afterwards in order to identify two specific times concerning the reach of expected results for each scenarii, that is the length of time taken by the anesthetist in the simulated situation to identify the symptoms, perform the etiologic diagnosis, take the symptomatic corrective measures, and take the etiologic corrective measures. The selected times for performance assessment were thus defined:

- Time to perform the symptomatic corrective measures: t_{sc}.
- Time to perform the etiologic corrective measures: t_{ec}.

The length of time taken to identify of the symptoms or perform the etiologic diagnosis were not selected because we observed that, in case of low performance, the delay between decision and action could be very long.

3. Results

3.1. Quantitative data from measurements

Two kinds of data were available for actor physicians only:

- Mean and maximum heart rates.
- Evolution rate of salivary amylase (not discussed in this paper).

A previous analysis (Geeraerst et al, 2013) showed that data had to be considered separately: on one hand, trainees involved in a significant physical effort and on the other hand for other trainees. If we considered in the whole set of data all cases of subjects, the resulting cluster could not be explained in terms of performance versus stress: the data did not show any specific shape, the bell curve did not appear and no other specific shape as well.

Two subjects did cardiac massage which induces a significant physical effort and a disturbance of HR. Others implicated in the first scenario were confronted with a difficult intubation case. This also involved significant physical efforts as we have observed in situation. The data related to these cases were treated separately from the others. The comparison of the HR values have shown that HR_{mean} covered the same range of values for both cases (with and without significant physical effort), and that $HR_{max\ ampl}$ covered a narrower range of values in the case of significant physical effort.

3.2. Perception through PDI questionnaire of stress

The questionnaire has been filled in by the subjects immediately after taking the test. To use the results, we affected to the answers a value from 0 to 4 according to the Likert scale suggesting: not at all, a few true, rather true, very true, extremely true. Then we calculated from the 13 answers for each subject a mean value, Q_{mean}.

If the Cronbach's alpha calculated was rather good (α = 0.8), the data related to the reduced stress coefficient K_{sr} versus Q_{mean} gave a correlation coefficient rather bad (Geeraerst et al., 2013). Yet the set of dots showed a cluster with a coherent global increase of both parameters. The low value of the correlation coefficient may be due to a poor differentiation of low stress cases and to an over self-estimation of stress in stressful cases.

3.3. Performance measurement

To evaluate performance of the students, we used time measurements concerning the reach of the final result:

- Time to perform the symptomatic corrective measures: t_{sc}.
- Time to perform the etiologic corrective measures: t_{ec}.

From these two parameters evaluated on the basis of analysis of video records of the sessions, we could build a performance coefficient K_p. It was based on the following remarks induced by the basic postulate that performance is linked with the right result (the problem is correctly solved) in the minimum of time.

From this postulate, we suggested that a relevant K_p decreases if time of observation or action increases: the students are less efficient if they take more time to deal with the problem.

The formulation is thus:

- K_p increase with inverse of time corrections t_{sc} and t_{ec}.

From this postulate, we built the coefficient as the sum of the inverse of t_{sc} and t_{ec}:

$$K_p = 1/t_{sc} + 1/t_{ec}$$

The K_p has been tested on simulated data with good agreement to expectation. The analysis of K_p with a limit approach confirmed the reliability of the K_p. The modal distribution of K_p for anesthetists' training sessions is presented on Fig. 4 according to the following modes:

[-inf; 0,001[, [0,001; 0,0075[, [0,0075; 0,01[, [0,01; 0,015[, [0,015; 0,02[, [0,02; 0,025[, [0,025; 0,03 [, [0,03; +inf[

We can see that the range over which values spread is larger than for the Stress-test (Fig. 2). This is due to the fact that for the Stress-test, subjects were expected to reach a 100% score as the questions of the test were easy, while for these training sessions, subjects discover the situation within an initial training and so are not expected to get a result tending to 100% success.

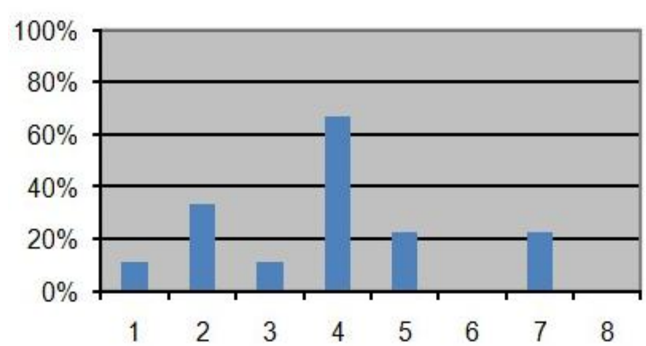

Fig. 4. The modal distribution of K_p for anesthetists training sessions.

3.4. The case of anesthetists' training without physical efforts

Considering only the cases of simulated situations with no disturbance due to physical effort, the performance coefficient K_p built as described in previous section vs the reduced stress coefficient K_{sr} gave a distribution of points of Yerkes & Dodson curve type (Fig.5) and led to the following conclusions: most of the students were actually in the cognitive deficit state according to the Human Functional States (HFS) defined above (Fig. 3).

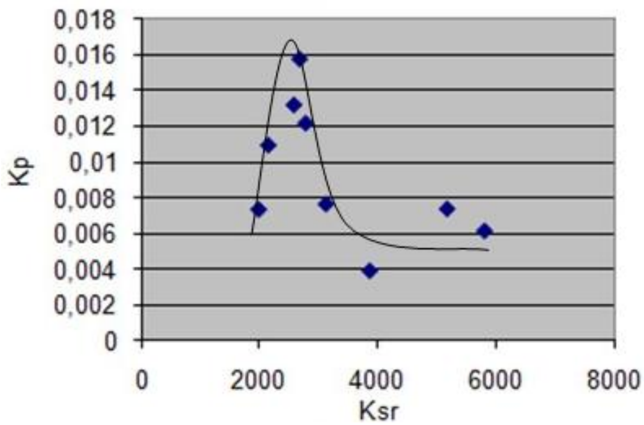

Fig. 5. Performance coefficient K_p versus reduced stress coefficient K_{sr} for anesthetist residents not submitted to strong physical efforts.

3.5. The case of anesthetists' training with physical efforts

Considering only the students concerned by occupational stress including a significant physical effort, we plotted the K_p versus K_{sr}. We obtained the following graph Fig. 6.

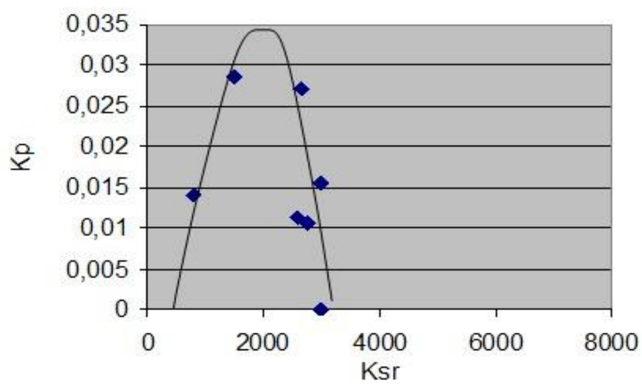

Fig. 6. Performance coefficient K_p versus reduced stress coefficient K_{sr} for anesthetist residents submitted to strong physical efforts.

In this case, we recognize again a Yerkes & Dodson curve type with most of the data located in the HFS of negative state of stress or potential cognitive deficit state.

The conclusions were that most of the students were actually in the HFS of negative state.

4. Discussion

4.1. The stressful aspect of the training and the factors of improvement

Application of the developed protocol studying performance vs stress has confirmed stressful conditions for anesthetists' training, showing that most of the subjects were in a cognitive deficit zone on a K_p vs K_{sr} graph of Yerkes & Dodson type curve (see Fig. 5 and 6), on the right side of the bell graph, both for work activities with or without significant physical efforts.

After analyzing the context of training on the basis of training sessions debriefing with trainees, the conclusions were that residents needed to be more familiar with the simulator and with the activity before being involved in this kind of working situations. Thus the main point of improvement would be to make them familiarized with the simulator before the training session itself, with a progressive approach of the simulator in several steps distributed on several days, including the familiarization with observers whilst working on simulator.

Another point of improvement according to the debriefing interviews was that trainees had to be able to perceive their knowledge and skills sufficient for the task in the perspective of increasing self-confidence: this implies to create or manage differently the previous steps of their training.

4.2. Influence of experienced simulation

Furthermore, another interesting point appeared. Checking the cases of students who had already been involved in at least one simulation training before taking the present experimental session, data showed for both cases (concerned or not by a significant physical effort) less stress for these students than for the students who discovered the simulator. This confirmed previous analysis (Geeraerst et al., 2013) which pointed out that this kind of experience influences stress but not performance of the trainees. Thus, it demonstrated that a progressive training would be benefic and that being used with this stress variable may reduce its influence as a stressful contributor.

4.3. The comparative state of stress with or without physical effort

As shown on the above graphs, the performance vs stress data could be fitted with bell curves, both in the case of residents who were involved in a significant physical effort during the work activity and for these who were not. Superimposing on the same graph these curves named NPE for "No Physical Effort" and WPE for "With Physical Effort" (Fig. 7), we pointed out several findings:

- The WPE curve was higher than the NPE curve in terms of K_p, which means that the residents' performance was higher when involved in a significant physical effort while dealing with the operation. Checking the experienced status of the subjects (already trained on simulator or not) showed no bias as experienced subjects were involved in both cases.
- The WPE curve was larger than the NPE curve in terms of K_{sr} by the left side of the X-axis, which means that stress of the residents involved in a significant physical effort covers lower values. We checked whether any physiological characteristics of

the subjects could produce these special shapes of curves but we could not find any bias.

- The WPE and NPE curves went along the same decreasing values in the HFS of potential cognitive deficit which means that in this zone, the relationship between performance and stress did not depend on the subject's involvement in a significant physical effort within this HFS.
- The extreme value of K_p of the curves were related to different values of K_{sr}; this corresponds to two different thresholds of optimized stress state. It appeared that for the WPE curve, this threshold occured sooner in terms of stress than for the NPE curve. It could be seen as a drawback, but at the same time the HFS were larger, offering thus a larger range of values of K_{sr} for which performance grew up.

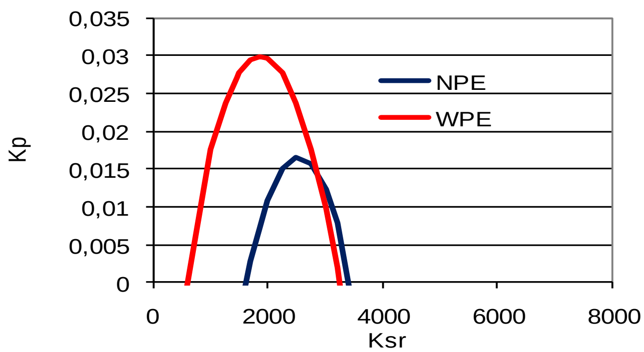

Fig. 7. Fitting curves for the two data cases named NPE for "No Physical Effort" and WPE for "With Physical Effort".

Explanations of these findings may be as following.

When subjects were submitted to a significant physical effort (physical stress), the difference between HR_{mean} and HR_{max} was less important than when the subjects were submitted only to a mental stress. The values of HR_{mean} and $HR_{max\ ampl}$ were compared with regards to the cases WPE and NPE. In particular, for $HR_{max\ ampl}$ the range for WPE was narrower than for NPE: in bpm, about [10; 30] for WPE and about [15; 50] for NPE. This was probably due to the physical effort making the mean HR more close to its extreme value. Thus, $HR_{max\ ampl}$ was less important with physical stress and consequently the coefficient of stress K_{sr} too. This produced an enlargement of the HFS and a shift to lower values of the extreme of the curve. This may be combined to another effect: when the subject was involved in an action requiring significant physical effort, the subject focused on this action which lessened the influence of other stressful factors and thus contributed to reduce their effect. We therefore might suggest the assumption that the subject was less stressed.

Concerning the higher values of K_p for the WPE cases, an explanation may be suggested in the light of Pearsall et al.'s work (2009). They found out that challenge stressors for teams positively affected the performance. If we consider the WPE cases as contexts with additional challenge stressors for teams on simulators, then it might contribute to explain the higher values of K_p for the WPE cases than for the NPE cases.

From the physiological standpoint, the relaxing effect of endorphins (released into blood while physical efforts) modifying HR values has been rejected because this effect occurs several tens of minutes after the beginning of the effort. In our cases, the simulated situations were too short.

Another explanation may be suggested regarding performance. As the possible bias due to subjects' training experience was eliminated, the higher performance for subjects submitted to a significant physical effort (physical stress) might be explained according to the following hypothesis: facing the emergency of an action that will save the patient (cardiac massage or strong intubation), the subject was forced to make a decision faster that in the other cases. The subject had less time to think about different questions, to doubt. The decision was therefore made earlier and increased thus the performance coefficient.

5. Conclusions

Demonstration was made for performance assessment versus short term mental occupational stress using a simple protocol and device. The results obtained in experimental and industrial conditions matched the Yerkes and Dodson theory (1908).

The simple protocol and device consist of:

- for each subject, the determination of a stress coefficient or a reduced stress coefficient on the basis of the mean and maximum heart rates measured by an individual portable heart rate meter during the work activity,
- for each subject, the determination of a standard performance coefficient according to the work activity.

The simple protocol and device qualified previously (Fauquet-Alekhine et al., 2011 & 2012) and used here can be successfully applied to:

- a group of subjects involved in the same work activity,
- a case of performance assessment vs short term mental stress which means that the time length of the activity must be short (several tens of minutes max) with or without significant physical efforts for the subjects if it is possible to consider these two cases separately.

The results and discussion presented in this paper showed that:

- The subjects (French healthy anesthetist residents trained on full scale simulator) could be divided in two groups, one concerned by mental occupational stress including a significant physical effort and one concerned by mental occupational stress only.
- Each group of students could be divided in three sub-groups according to the extreme of the bell curve associated to the Yerkes & Dodson curve and the

HFS defined consequently.

- The consecutive finding was that most of the students were not in good conditions of training because of a too high level of stress.
- It suggested another approach of the training session.

For this last point, we can develop suggestions as follows, taking into account both our knowledge in the field of simulation training and the debriefing interviews of our present experiments on simulators:

- Plan progressive simulation training.
- Each step of the progressive training is led by a specific pedagogical goal.
- The first step is a discovering period with no time pressure, no disturbance, and social support from the physician-trainers.
- The sessions include unconscious integrating period (nights).

It must be clear that, at this stage of the research, the protocol includes performance and stress, not only stress. This means that the protocol allows, for a sample of subjects, to rate the individual performance and stress with regards to the group. It does not permit to rate the performance and stress of one subject alone, or to evaluate only subjects' stress (without performance) inside the group.

The stress coefficient is fixed by the protocol while the performance coefficient determination depends on the work activity and must be carefully designed and calculated.

These research results have thus limits depending on the design of the study itself. These limits bound the application area of the protocol.

One of the limits of the protocol developed here is a basic postulate designing the study: it concerns the type of stress. For long term stress, or for another kind of stress than occupational stress, we cannot state whether our protocol may be applied or not. Theoretical considerations lead to the assumption that the protocol cannot be applied to long term stress.

At this stage of the research, the possibility to compare a given sample of subjects in a given context to another one is not studied. We just can claim that the protocol can describe with satisfactory accuracy the performance vs stress for a context of work. Nevertheless, it remains much less accurate than what could give the complex protocols including analysis of the whole set of physiological parameters (Fairclough *et al*., 2004; Montano *et al*., 2009; Müller *et al*., 2009; Rohleder *et al*., 2009; Schubert *et al*. 2009; Bailon *et al*., 2010; De Jonckheere et al., 2010; Jo et al., 2013). Yet it gives a instant assessment of performance versus stress with a satisfactory accurateness for training centers.

The simplifying hypothesis done to obtain the reduced stress coefficient compared to the stress coefficient gives another limit: results have been obtained with a sample of subjects inside a narrow age interval; in this case, the reference heart rate might have less influence in the calculation from one subject to another, which would perhaps not be the case within an interval including people of 25 and 60 yo.

Further experiments are planned to analyze these points and try to enlarge the application area of the protocol.

Declaration of conflict of interest

The authors declare no conflict of interest in relation to this article.

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