Elevation of Acute Mental Stress by Doubt and Work Interruption in High-risk Professional Environment

.

ABSTRACT

|  |
| --- |
| **Aims:** The INTRA group is a robotic emergency response organization for nuclear accidents. The staff must therefore be prepared for this type of situation of high stress level. To ensure that, the applicants to join the group are tested at the time of recruitment. In 2021, the recruitment tests were reinforced by completing the stress resistance test. At the time, this test consisted only of a Stroop test without any other measure of stress, providing only access to performance under stress. It was therefore necessary to improve this stress test.  **Methodology:** The new stress-test (version 1) was broken down into several consecutive sequences including a Stroop test, a psychotechnical test under acute stress conditions, and again a Stroop test. The applicant was equipped with a chest strap with sensors to access to the heart rate variability (HRV) for each sequence and a performance score was calculated. The cross-comparison of the results allowed access to the subject's performance under acute stress as well as to the resilience to stress by comparing the subject's performance between the two Stroop tests. Between 2021 and 2024, 26 subjects were subjected to the stress test: average age 46.5 years old (SD=8.6), 15% female.  **Results:** The study of the stress-test was carried out in 2 periods, using respectively version 1 and 2 of the psychotechnical test. The analysis of the protocol based on version 1 made it possible to hypothesize that interruption and doubt or outcome uncertainty contributed to increasing the level of stress during the Stroop, but were absent of the psychotechnical test. It was therefore decided to systematically generate interruption and doubt during the psychotechnical test in period 2. The results were very satisfactory: the percentage of subjects with a higher level of stress on the psychotechnical test compared to the Stroop test increased from 33 to 73% (p=.05) and the average increase in HRV was up to 41% for the psychotechnical test compared to the Stroop test (p<.02) while not significant in period 1.  **Conclusion:** Doubt or outcome uncertainty related to decision-making combined with activity interruption is a significant factor in the generation of acute mental stress. In the context of the present study, doubt leads to questioning and comparing different options whereas uncertainty relates to the validity of the outcome resulting from decision-making. |

*Keywords: acute stress, doubt, interruption, performance, stress-test; resilience, Stroop test, uncertainty*

1. INTRODUCTION

Following the Chernobyl accident, the major players in the French nuclear industry decided to pool financial, technical and human resources. The aim was to develop, operate and maintain a fleet of remotely operated ground and air vehicles to intervene in a major nuclear accident that might occur on French territory. Today, the INTRA Group (*INtervention Robotique sur Accidents*, Robotics response on accidents) is available 24/7 in preparation for such an eventuality. In order to maintain the operational teams, agents of the INTRA group are trained periodically on large-scale exercises and the on-call teams are trained every week in the management of a nuclear accident during training sessions or exercises (see Fauquet-Alekhine, Buchet et al., 2023).

In order to guarantee the operationality of the agents of the INTRA group, an evaluation of the capacities of the agents to intervene in a major nuclear accident is carried out at the time of recruitment. In 2021, an analysis of the recruitment process undertaken by the new technical and scientific director of the INTRA group, specialist in performance under stress, showed that it was incomplete. This was especially the case in terms of the evaluation of performance under stress: the stress-test applied in the recruitment process only included a Stroop test (Stroop, 1935; Scarpina et al., 2017); this was adapted for performance evaluation under a low level of stress, and resilience to stress was not assessed. However, it was necessary to increase the level of stress to which the candidates were subjected with the Stroop test during the recruitment process. It was also necessary to assess their resilience to stress after an episode of acute stress because they might tackle such a situation in case of major nuclear accidents.

Therefore, a new stress-test was developed. It integrated a new version of a psychotechnical test under stress (FA Test) developed in 2012 (Fauquet-Alekhine et al., 2012) administered between two Stroop tests. The objective of the resulting stress-test was to assess performance under acute stress of the applicants for recruitment within the INTRA group, and to assess the subject's resilience to stress by comparing the measurements obtained in the first and second Stroop tests. For the psychotechnical test to be experienced as an episode of acute stress by the subjects, it was necessary to ensure that the level of stress induced by this test was significantly higher than that induced by the Stroop test.

The application of the new stress-test was carried out from 2021 to 2024 during recruitment periods occurring one to four times a year.

The theoretical objectives were to test the following hypotheses:

• H1-The physiological measurement of the stress level carried out during the Stroop test is consistent with the analogous measurements available in the scientific literature: this comparison contributes to validating the test protocol,

• H2-The psychotechnical test, known as the FA Test developed in 2012 (Fauquet-Alekhine et al., 2012) and adjusted in 2021 in a new version (version 1), makes it possible to create an episode of acute stress with a higher stress level than the Stroop test: this is necessary to ensure that the subject experiences an episode of acute stress between the Stroop test,

• H3-The stress-test creates an episode of acute stress that contributes to affecting some subjects’ resilience to stress: if all the subjects passing the stress-test show resilience to stress, there may be a doubt regarding the efficacy of the stress-test, and the stress-test must be adjusted.

The practical objective of this study was to improve recruitment tests in the INTRA group concerning the evaluation of performance under stress of future agents.

2. material and methods

**2.1 Development of the stress-test**

The core of the stress-test consists of 3 sequences: sequence 1 is a Stroop test, sequence 2 is the psychotechnical test of Fauquet-Alekhine (FA Test, Fauquet-Alekhine et al., 2012), and sequence 3 is a Stroop test identical to sequence 1. A diagram represents the succession of sequences on Fig. 1.

The Stroop test consists of reading visual information offered on A4 cards as quickly as possible in 45 seconds. The subjects read words designating colors or designate colors on the basis of colored squares presented on the card, in order to verify that they are able to read properly and correctly identify colors. On the last card, they must say the color of the ink used to write the name of a color that is not that of the ink. This last map allows the supervisor-researcher to calculate a coefficient of performance under interference. Interference is induced by the cognitive disturbance that the subject undergoes by having to say the color of the ink of a word that designates another color: if the ink is red and the written word is "blue", the subject will tend to say blue instead of red. The performance under interference score is calculated by taking into account the number of information produced by the subject in 45 seconds, corrected by the number of hesitations and errors.

The FA Test consists of 12 questions on geographical culture, logic, classification, Raven matrices (Raven, 2003) and logical sequences. In 2021, the version 1 used was adjusted from the original version 0 (Fauquet-Alekhine et al., 2012) in order to increase the subject's stress level by integrating additional visual and auditory stressors. Indeed, whilst passing the FA Test, the subjects are exposed to auditory and visual stimuli where the intensity and number increase with time (water flow, beeps and flashes whose frequency increases over time, permanent footstep noise, an auditory message). At the beginning of the test, subjects are informed that they must complete it in the minimum time and that it is not possible to return to a question already covered, or to ask clarifying questions to the supervisor.

Une image contenant texte, capture d’écran, Police, diagramme

Le contenu généré par l’IA peut être incorrect.

**Fig. 1. Diagram of the core sequences of the stress-test**

**2.2 Measurement equipment for HRV**

The measurement of stress levels can be done objectively and unquestionably by a physiological measurement. This is preferred to a self-assessment of the perceived stress as the questionnaire assessment is subjective and subject to various biases related to the subject (e.g. social desirability bias; see (Fauquet-Alekhine & Boucherand, 2023). One of the more simple and reliable physiological measurement methods is the measurement of cardiac variability (HRV): in their review, Fauquet-Alekhine & Granry (2023) showed that, among the wearable devices to measure the physiological level of stress, calculating HRV from heart rate measurements was the optimal solution combining simpleness and reliability.

Regarding the measurement of stress resilience, O'Donohue et al (2021) published a review of methods for assessing stress resilience. Unsurprisingly, they are identical to methods for measuring stress levels: in terms of psychological assessment, the methods are based on the use of interviews and questionnaires, or even a combination of the two or the combination of several questionnaires. In terms of physiological assessment, the review reports that the methods used are measurement of HR (heart rate), HRV (heart rate variability), salivary alpha-amylase, salivary or blood cortisol, and inflammatory markers. The review refers in particular to the article by An et al. (2016) which validated the use of HRV for the assessment of resilience to stress. It is this physiological parameter that is chosen in the present study to access the subjects’ level of mental stress and their capacity for resilience to stress.

During the stress-test, the subjects are equipped with a Polar H10 (chest strap with sensors) for the measurement of the heart rate (HR) connected via Bluetooth to a smartphone with EliteHRV application for acquisition; a subsequent computer analysis using the Kubios software allows access to the heart rate variability (HRV) by FFT (Fast Fourier Transform) of the signal. This device has already been tested and validated in other studies (e.g. Gilgen-Ammann 2019; Speer 2020). The physiological quantity HRV is particularly reliable and easy to measure in order to objectively access the stress level (Fauquet-Alekhine & Granry, 2023). HRV was calculated after FFT by making the ratio of low frequencies (LF) to high frequencies (HF) respectively on the following bands: 0.04-0.15Hz and 0.15-0.4 Hz.

**2.3 Test protocol and analysis protocol**

The stress-test is a test carried out individually in the sole presence of the supervisor-researcher in a closed and silent room. The material presented to the subject is physical (cardboard cards for the Stroop test and a bundle of sheets of paper with pencil for the FA Test). The stress-test is divided into 3 phases: briefing-tests-debriefing.

The purpose of the briefing is to explain to the subject what the test consists of. During this phase, the explanations remain superficial so that discovery of the tests remains a stressor for the subject. The risks incurred by the subject during the test as well as measures to minimize these risks are explained. The subject is informed that he or she is carrying out the test on a voluntary basis and that he or she can withdraw from the test at any time. The subject is also informed that the data collected will be anonymized in order to be integrated into the database of a stress study. At the end of the briefing, the subject signs an informed consent summarizing all this information and attesting to the informed and voluntary nature of his or her participation, then fills in a sociodemographic questionnaire, as well as a compliance questionnaire to record whether the subject consumes an energy drink (e.g. tea, coffee) or smokes a cigarette or other substance.

Prior to taking the stress test, the subject signs a self-health questionnaire drawn up by a behavioral psychologist and an occupational physician to ensure that he or she does not present any contraindication concerning the taking of a test under acute stress. For example, a subject suffering from epilepsy could declare a seizure during the visual stimuli associated with the flashes.

The subject is then equipped with the Polar H10 chest strap, seated in front of a table where the documents will be placed. Table and chair are in a cubicle equipped with all the devices that will generate the auditory and visual stimuli. The stress test does not involve any particular physical effort, which makes it possible to measure and calculate a HRV that is essentially influenced only by the effect of mental stress. The supervisor-researcher remains nearby to give instructions for each of the stress-test sequences. He also monitors that the HR measurement is effective.

At the end of the stress-test, the supervisor-researcher debriefs the subject in order to give details regarding the structure of the test, to collect feelings about the test, to give opportunity to ask questions, and above all, to make sure that there is no trauma due to the test, and finally to ask for confidentiality regarding the test.

Performance and stress level are calculated for each subject and for each of the three sequences.

**2.4 Study period**

The study was conducted from 2021 to 2024. It was made up of 2 periods. Period 1 has integrated version 1 of the FA Test. This period consisted of analyzing the first results to test H1 and identifying adjustments necessary to optimize the stressful nature of the FA Test so that they produce an effective acute stress episode (test of hypothesis H2). Period 2 integrated version 2 of the FA Test after the results and adjustments following period 1 to test H3.

**2.5 Participants – Ethics**

Between 2021 and 2024, 26 subjects were taking the stress-test: average age 46,5 years old (SD=8,6), 15% female.

The participants were candidates who applied to be recruited to the INTRA group for the most part, and were volunteers to take the test, and for the remainder, agents from the INTRA group who volunteered to participate in the study.

The design of the study was examined and approved by the Committee for Ethics, Standards and Protection of the INTRA group, approval number #CESP/PHFA/100.

3. results and discussion

**3.1 Validation of the physiological measure of stress by measuring HRV heart rate variability in the Stroop test: test of H1**

Bibliographic research was conducted to identify studies with HRV measurement results during Stroop testing available in the literature. Studies that included partial Stroop tests or for which the HRV measurement was performed after the test and not during the test were rejected (e.g. Subramanyaet al., 2015). Stroop tests performed in virtual modalities were rejected (e.g. Gradl, S. 2020) in order to have experimental conditions comparable to those of the present study. Finally, studies based on a number of subjects less than 10 were not retained (e.g. Uysal & Tokmakçı, 2017).

In total, 5 articles were selected. The reference list of the study, the experimental characteristics and the results obtained for HRV during the Stroop test are summarized in Table 1.

**Table 1. Characteristics of the selected scientific articles concerning the measurement of HRV during a Stroop test**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Reference** | **median or average age** | **Number of subjects** | **Device to mesure HRV** | **frequency domain (LF;HF) (Hz)** | **Stroop HRV** |
| Siska (2002) (p45) | 23 | 91 | telemetric system VariaPulse TF3 | NA\* | 2,08 |
| Petkar (2011) | 25,5 | 20 | Polar RS810 | 0.04-0.15;  0.15-0.4 | 2,25 |
| Vazan et al. (2017) | 23 | 55 | ECG | NA\* | 2,22 |
| Endukuru & Tripathi (2016) | 28 | 50 | ECG | 0.04-0.15;  0.15-0.45 | 2,21 |
| Huerta-Franco et al. (2015) | 29 | 39 | ECG | NA\* | 3,1 |

*\*ECG: electrocardiogram; NA: Not Available*

It should be noted that these studies carried out by university laboratories concerned a population of relatively young subjects: the average age is 27.5 years, whereas the present study concerned subjects whose average age was 46.5 years. It therefore seemed relevant to assess the consistency of the HRV measurement results obtained in this document with those of the literature. To do this, a correlation analysis was carried out between the mean age and the average HRV of the five studies selected in the literature and presented Table 1. The correlation coefficient is r=0.71 (p<.02). The graphical results are presented in Fig.2. On the same graph is represent the point obtained for all the subjects who participated in the present study in period 1, for whom the average value of HRV in the Stroop test obtained during sequence 1 of the stress-test was 4.24, to be compared with the theoretical value predicted by the linear trend line, 4.57, i.e. a deviation of about 7.7% from the theoretical value. The first finding is that the measurements made in the present study were consistent with the results of the studies available in literature. The second finding is that the HRV measured in a Stroop test increases with age.

Une image contenant texte, capture d’écran, Tracé, ligne

Le contenu généré par l’IA peut être incorrect.

**Fig. 2. Evolution of HRV with the subject's age during a Stroop test**

*round points: data from literature*

*square point: data from the present study*

**3.2 Stress-test in period 1**

As a reminder, the stress test in period 1 - sequence 2 has integrated version 1 of the Fauquet-Alekhine psychotechnical test (FA Test, see details in the section “Development of the stress-test”). During period 1, 11 subjects took the stress-test. Table 2 gives the values and standard deviations of the HRV of the first Stroop test (sequence 1) and the FA Test that were measured in period 1. The results showed that subjects had a higher HRV on the FA test than the Stroop tests for 33% of them only, leading to an average value lower on the FA test than the Stroop tests. The HRV obtained as an average value in the FA Test was 3.5% lower than the average value obtained in the first Stroop test, which was not satisfactory insofar as the FA Test is supposed to offer the subject an episode of acute stress whose stress level is higher than the Stroop test.

**Table 2. Measured values and standard deviation of the Stroop test and FA Test HRV in period 1**

|  |  |  |
| --- | --- | --- |
| **Period 1** | **HRV :**  **mean** | **HRV :**  **SD** |
| Stroop sequence 1 | 4,27 | 2,57 |
| FA Test (version 1)  sequence 2 | 4,12 | 3,25 |
| Stroop sequence 3 | 4,38 | 2,70 |

After analyzing these results and reflecting on the observations made during the stress-test in period 1, it was noticed that during the Stroop test, the subjects made some errors that implied an intervention by the test supervisor asking them for a correction. This generates a doubt that was combined with the interruption of the processing that the subjects are making when reading the cards. However, this was not the case for the FA test. It was therefore decided to introduce this doubt and this interruption of treatment during the FA Test by systematically making the following remark during questions 1 and 11, regardless of the answer that the subject would produce to these questions: "Are you sure of the answer you gave to this question?"

**3.3 Stress-test in period 2**

The stress-test in period 2 was therefore integrated into version 2 of the FA Test, for which the remark was made in questions 1 and 11 by the supervisor. This had the effect of introducing doubt combined with an interruption of treatment of the FA test twice, and this in a systematic way for all subjects. During period 2, 15 subjects took the stress-test.

The percentage of subjects with a higher level of stress on the FA test compared to the Stroop test increased to 73% (p=.05) in period 2. In period 2, the average value of the HRV obtained in the FA Test was 41.1% higher than the average value obtained in the first Stroop test (sequence 1), which was satisfactory in relation to the desired effect. Table 3 gives the values and standard deviations of the HRV of the first Stroop test (sequence 1) and the FA Test version 2 that were measured in period 2. Table 4 gives the variations in HRV between periods 1 and 2 as well as the variations in performance under interference between the Stroop tests (sequences 1 and 3).

**Table 3. Measured values and standard deviation of the Stroop test and FA Test HRV in period 2**

|  |  |  |
| --- | --- | --- |
| **Period 2** | **HRV :**  **mean** | **HRV :**  **SD** |
| Stroop sequence 1 | 4,22 | 2,63 |
| FA Test (version 1)  sequence 2 | 5,95 | 3,84 |
| Stroop sequence 3 | 6,55 | 3,61 |

**Table 4. Variations in HRV and performance under interference between periods 1 and 2**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Period 1**  **N=11**  **18% female subjects(\*)** | **Period 2**  **N=15**  **13% female subjects(\*)** | **Statistical test z (assessing the significance of a difference between 2 percentages)** |
| Variation in the average HRV between sequences 1 and 2 (Stroop / FA Test) | -3.5% | 41.1% | z=2.69, p=.01 |
| Variation in the average HRV between sequences 1 and 3 (Stroop / Stroop) | 2.5% | 55.4% | z=2.71, p=.01 |
| Variation in average performance by interference between sequences 1 and 3 (Stroop / Stroop) | 6.2% | -26.0% | z=2.46, p=.02 |

*\*For the two periods, the proportion of female subjects is similar (p=.72).*

In period 1, the HRV was almost constant over the 3 sequences (Student coefficient t=0.98, p=.99 for the mean HRVs of the two Stroop tests, sequences 1 and 3) with an insignificant increase in performance under interference (6.2%) between the two Stroop tests. This slight increase can be explained by the knowledge that subjects had concerning the Stroop test by having already done it a few minutes earlier in sequence 1. Since the subjects were not more stressed in sequence 2 than in sequence 1, and knew what to expect in sequence 3 because they had already taken the Stroop test in sequence 1, the stress level decreased slightly in sequence 3 and their performance improved slightly: only 18% of subjects performed worse in sequence 3 compared to sequence 1.

In period 2, HRV increased significantly between sequence 1 and sequence 2 (41.1%, compared with -3.5% in period 1 (p=.01)) as well as between sequences 1 and 3 (55.4% compared with 2.5% in period 1 (p<.01))), indicating that the FA Test was experienced as an episode of more acute stress than the Stroop test by subjects. This was confirmed by a decrease in performance under interference between sequences 1 and 3: while in period 1 there was a slight improvement in the average performance (6.2%), it deteriorated significantly in period 2 (-26%, p>.03), with 47% of subjects having a lower performance in sequence 3 compared to sequence 1, i.e. 2.5 times more than in period 1.

Therefore, the induced doubt effect combined with the interruption of the FA Test treatment is a significant stressor since they the only two parameters that have changed between period 1 and 2. (see the work of Zijlstra et al. (1999) addressing interruption). It may seem surprising that this stress adjustment is indeed more significant in terms of stress than all the auditory and visual stimuli implemented throughout the FA test. However, the analysis of the debriefings carried out with the subjects at the end of each of the stress-tests provided elements of understanding. For most subjects, they explain that they managed to ignore stimuli relatively quickly; some say "I put myself into my bubble to be more efficient and I don't hear or see anything anymore". This is not possible with the remark made by the supervisor at the time of questions Q1 and Q11 of the FA Test version 2. The subject is forced to pay attention to what the supervisor says, and s/he is led to deal with the doubt induced by the remark; contrary to what is done for auditory and visual stimuli, the subjects cannot "stay in their bubble". Xue et al. (2022) highlighted that the process of attention requires consciousness while the opposite is not true. In the present experiments, subjects were conscious of the auditive and visual stressors and forced themselves to reduce the attention to these stimuli, leading to reducing the consciousness of the stimuli ("I put myself into my bubble”). This contributed to lessening the effect of the stimuli as stressors. Conversely, regarding the question asked during the FA test at Q1 and Q11, lessening consciousness was impossible due to the supervisor ‘status (the leader of the stress-test) who forced the subjects to pay attention to this factor of interruption. The resulting forced consciousness of the question for the subjects forced them to engage in a process that led to doubt. The effectiveness of this stressor consequently increased HRV. Observations made during the stress-test showed that some subjects took several tens of seconds to process the remarks, re-examine their response and possibly make a correction.

The stress induced by doubt can be explained in the following way. When the experimenter asks the question, he interrupts the cognitive process of reflection in progress in the subject’s mind and induces another cognitive process focused on the object of the question. The dictionary of the American Psychology Association defines it as follows: doubt is a cognitive process related to the analysis of options as potential solution; this induces a lack of confidence about the possible answers. It results in the perception of a threat: the threat relates to not giving the right answer and thus failing the stress-test. According to Grupe & Nitschke (2013), when the perception of a threat is associated with uncertainty regarding avoiding or mitigating it, this leads to a state of anxiety. Anxiety in an emotion that may be the psychological manifestation of stress (Fauquet-Alekhine & Erskine, 2023:485). The conclusion is therefore that doubt induced by the question generates uncertainty which generates anxiety which increases the subject's level of stress.

**3.4 Stress Resilience Assessment**

According to Erskine & Georgio (2023:457), resilience is a capacity to recover quickly from difficulties, coming into its own when facing adversity or load.

By applying this definition to the stress-test of the present study, stress resilience should allow the subject, after the acute stress episode proposed in sequence 2 with the FA Test, to regain a level of stress and performance in sequence 3 close to what it was in sequence 1. During sequence 3 of the stress-test, it is therefore expected that the subject's HRV will return to a value close to that measured in sequence 1 and that performance during sequence 3 will not be significantly degraded compared to performance measured in sequence 1. Conversely, in case of lack of resilience, subjects must show a lower performance in sequence 3 compared with sequence 1 combined with an increase in HRV.

When the mean value of HRV for each of the subjects in period 1 is calculated between sequences 1 and 3, the result is -6%. This means that the stress level of subjects in period 1 decreases between sequences 1 and 3. When the average value of the variation of performance under interference for each of the subjects in period 1 is calculated between sequences 1 and 3, the result is +6% (p=.004). This means that the performance level of subjects in period 1 increases between sequences 1 and 3. In period 1, these average values indicate that the subjects show resilience to stress; even more: analysis of individual data shows that all subjects showed resilience to stress. As suggested above, these variations can be explained by the fact that, in period 1, the subjects were not disturbed by sequence 2 and, since they have just taken the Stroop test in sequence 1 that they repeat identically in sequence 3, their stress level decreased, and their performance increased.

In order to assess the resilience to stress of the subjects in period 2, the following proportions were calculated by taking as thresholds the variations produced by the subjects in period 1 considered as the control group:

* percentage of subjects whose variation in HRV between sequences 1 and 3 is greater than -6%,
* percentage of subjects with a variation of performance under interference less than 6% between sequences 1 and 3 (i.e. positive variation less than 6% relating to an insufficient improvement of the score, or negative variation relating to a degradation of the score of performance),
* percentage of subjects affected by the previous two points, i.e. both a greater variation in HRV than for the control group (period 1) and a variation in performance under interference lower than that of the control group.

The results indicate that:

* 73% of subjects in period 2 had a higher variation in HRV than the mean variation of the control group, the mean variation being 99% in period 2 compared with -6% in period 1 (p<.0001),
* 47% of subjects in period 2 had a lower variation in performance under interference than the average performance of the control group, the mean variation being -24% in period 2 compared with 6% in period 1 (p<.03),
* 27% of subjects combined a greater variation of HRV than in the control group and a lower variation in performance under interference than in the control group; as mentioned above, in period 1, no subject showed this combination.

The conclusion is that, in period 1, all subjects showed resilience to stress and in period 2, 27% of the subjects showed a lack of resilience to stress.

In order to verify whether this proportion of 27% of subjects not resilient to stress is admissible, a literature review was carried out in order to compare the results of the present study with the proportions of non-resilient subjects identified in other studies. Few articles report such a proportion following the experience of an episode of acute stress. Only 5 articles were identified. Table 5 indicates the type of acute stress episodes experienced by the subjects and the proportion of non-resilient subjects identified.

**Table 5. Studies indicating the proportion of non-resilient subjects identified according to a type of acute stress episodes experienced by the subjects, and associated references**

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of stress** | **Proportion of resilient subjects** | **Proportion of not resilient subjects** | **Bibliographic reference** |
| older adults residing in areas heavily impacted by Hurricane Ike | 79% | 21% | Pietrzak et al. (2013) |
| Hurricane Katrina | 66% among mothers 70% among young people | 30-34% | Self-Brown et al. (2013) |
| aftermath of the Wenchuan earthquake | 75% among young people | 25% | Liang et al. (2019) |
| Swedish tourists exposed to the 2004 Indian Ocean tsunami | 72% | 28% | Johannesson et al. (2015) |
| aftermath of the 9/11 terrorist attacks among police officers | 78% among police | 22% | Pietrzak et al. (2014) |

It should be noted that Table 3 reports episodes of acute stress of a different nature than the one proposed in this study. It is clear that the level of stress induced by the acute stress episodes in Table 3 must be much higher than that of the present study. It should also be noted that the evaluation of the subjects' resilience to stress is not done immediately after the event but weeks or months, or even in the years that follow.

However, it is interesting to note that the proportion of subjects identified as non-resilient varies from 21 to 34%, i.e. a median value of 27.5%. This leads to validating the proportion of subjects being non-resilient equal to 27% in the present study.

The implication in the world of work is that, when an interruption of an activity combines with doubt or outcome uncertainty related to decision-making, in about 27% of cases, the resulting stress state has a non-negligible probability to affect the workers’ resilience capacity and result in negatively affecting performance.

4. Limitations

The present study involved a low proportion of females. This does not allow for an impact study of gender. However, the impact of gender has been demonstrated by Satish et al. (2015).

5. Conclusion

The results of the study tested the following theoretical hypotheses H1, H2 et H3 which led to the following conclusions:

H1-The physiological measurement of the stress level carried out during this experiment is consistent with the analogous measurements available in the scientific literature.

The H1 hypothesis is validated, and the results show that the level of stress associated with an episode of acute stress increases with age.

H2-The psychotechnical test, known as the FA Test developed in 2012 and adjusted in 2021 in its version 1, did not create an episode of acute stress with a higher stress level than the Stroop test. On the other hand, once adjusted in its version 2, the FA Test was satisfactory.

The fact that the H2 hypothesis was validated with version 2 of the psychotechnical test known as FA Test compared to version 1 shows the importance of doubt combined with the interruption of activity as an important stressor. The study also shows that systematic auditory or visual stimuli can have a reduced effect on stress when the subject is able to ignore them. The results obtained in the present study suggest that almost all subjects are capable of performing this type of abstraction.

H3-The stress-test creates an acute stress episode that affects the stress resilience of some subjects only when the new version 2 of the FA Test is applied, i.e. when including the generation of doubt.

The H3 hypothesis is validated: the method for assessing the subjects' resilience to stress gives a proportion of subjects detected consistent with the results available in the literature. These results also show that the assessment of stress resilience can be done satisfactorily by combining the comparative measurement of stress level by HRV and the variation in performance before and after the experience of the acute stress episode.

Regarding the practical objective of this study consisting of improving recruitment to the INTRA group, it is achieved insofar as the new stress-test integrating version 2 of the FA Test is effectively discriminating in terms of resilience to stress. However, the predictive nature of this stress-test remains to be verified in the context of a longitudinal study currently underway at the group INTRA.

Regarding the scientific contribution of the present study, two major points should be retained. First is the objectification of the increase of heart rate variability (and therefore stress level) with age when taking the Stroop test. Second is the demonstration that doubt combined with activity interruption is a factor contributing to increasing stress level according to a process where doubt leads to stress: doubt generates uncertainty which produces a state of anxiety which then increases stress.

Regarding the process of doubt and stress, it should be noted that the relationship between uncertainty and stress as well as the relationship between anxiety and stress are well documented in scientific literature (see for example: Blanchard & Canteras, 2024; Greco & Roger, 2003; Grupe & Nitschke, 2013). However, the literature is devoid of studies concerning punctual doubt as a contributing stressor during an episode of acute stress. From a research perspective, it would be interesting to deepen these findings, by examining other contexts of acute stress episodes to better understand the process of doubt applied to stress.

Consent

All study participants were volunteers, have been informed that the data collected during the study will be used in an anonymized manner in the context of their exploitation and associated writings, were informed that they could withdraw from the experiment at any time, were informed of the risks involved and the measures implemented to reduce the risks, and signed an informed consent before engaging in the experiment.

Ethical approval

The design of the study was examined and approved by the Committee for Ethics, Standards and Protection of the INTRA group, approval number #CESP/PHFA/100, based on the Code of Human Research Ethics of the British Psychological Society. The study was therefore performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

**Disclaimer (Artificial intelligence):**

The author hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

An, E. (2016). Heart rate variability as an index of stress resilience. (Doctoral dissertation), Fuller Theological Seminary. Retrieved from ProQuest Dissertations and Theses database (Accession No. 10109465)

Blanchard, D. C., & Canteras, N. S. (2024). Uncertainty and anxiety; evolution and neurobiology. Neuroscience & Biobehavioral Reviews, 105732.

Endukuru, C. K., & Tripathi, S. (2016). Evaluation of cardiac responses to stress in healthy individuals-a non invasive evaluation by heart rate variability and stroop test. Int J Sci Res, 5, 286-289.

Erskine, J., & Georgiou, G. (2023). Stress and resilience in the workplace. pp.455-483. In Fauquet-Alekhine, Ph., & Erskine, J. (2023). The Palgrave Handbook of Occupational Stress. Palgrave Macmillan: London, UK.

Fauquet-Alekhine, Ph., Geeraerts, Th., & Rouillac, L. (2012). Improving simulation training: anesthetists vs nuclear reactor pilots. Socio-Organizational Factors for Safe Nuclear Operation, 1, 32-44.

Fauquet-Alekhine, Ph., & Boucherand, A. (2023). Psychological assessment of the state of mental stress at work. pp.97-115. In Fauquet-Alekhine, Ph., & Erskine, J. (2023). The Palgrave Handbook of Occupational Stress. Palgrave Macmillan: London, UK.

Fauquet-Alekhine, Ph., Buchet, M., Bleuze, J., & Lenoir, Ch. (2023). Occupational training, Competencies, and Stress. pp.269-298. In Fauquet-Alekhine, Ph., & Erskine, J. (2023). The Palgrave Handbook of Occupational Stress. Palgrave Macmillan: London, UK.

Fauquet-Alekhine, Ph., & Erskine, J. (2023). The Palgrave Handbook of Occupational Stress. Palgrave Macmillan: London, UK.

Fauquet-Alekhine, Ph., & Granry, JC. (2023). Physiological assessment of the state of mental stress at work. pp.65-95. In Fauquet-Alekhine, Ph., & Erskine, J. (2023). The Palgrave Handbook of Occupational Stress. Palgrave Macmillan: London, UK.

Gilgen-Ammann, R., Schweizer, T., & Wyss, T. (2019). RR interval signal quality of a heart rate monitor and an ECG Holter at rest and during exercise. European journal of applied physiology, 119(7), 1525-1532.

Gradl, S. (2020). The Stroop Room: A Wearable Virtual Reality Stress Laboratory Based on the Electrocardiogram. FAU University Press.

Greco, V., & Roger, D. (2003). Uncertainty, stress, and health. Personality and Individual differences, 34(6), 1057-1068.

Grupe, D. W., & Nitschke, J. B. (2013). Uncertainty and anticipation in anxiety: an integrated neurobiological and psychological perspective. Nature Reviews Neuroscience, 14(7), 488-501.

Huerta-Franco, M. R., Vargas-Luna, F. M., & Delgadillo-Holtfort, I. (2015). Effects of psychological stress test on the cardiac response of public safety workers: alternative parameters to autonomic balance. In Journal of Physics: IOP Publishing, Conference Series 582(1), article 012040, 1-7.

Johannesson, K. B., Arinell, H., Arnberg, F.K. (2015). Six years after the wave: trajectories of posttraumatic stress following a natural disaster. J. Anxiety Disord., 36, 15-24.

Liang, Y., Cheng, J., Zhou, Y., & Liu, Z. (2019). Trajectories of posttraumatic stress disorders among children after the Wenchuan earthquake: A four-year longitudinal study. European journal of psychotraumatology, 10(1), 1586266.

O’Donohue, J.S., Mesagno, C. & O’Brien, B. (2021). How can stress resilience be monitored? A systematic review of measurement in humans. Curr. Psychol., 40, 2853-2876.

Petkar, H. (2011). Effects of working memory demand on performance and mental stress during the Stroop task (Doctoral dissertation, Concordia University).

Pietrzak, R.H., Van Ness, P.H., Fried, T.R., Galea, S, & Norris, F.H. (2013). Trajectories of posttraumatic stress symptomatology in older persons affected by a large-magnitude disaster. J. Psychiatr. Res., 47, 4520-26.

Pietrzak, R.H., Feder, A., Singh, R., Schechter, C.B., Bromet, E.J., … (2014). Trajectories of PTSD risk and resilience in World Trade Center responders: an 8-year prospective cohort study. Psychol. Med., 44, 1205-19.

Raven, J. (2003). Raven progressive matrices. In Handbook of nonverbal assessment (pp. 223-237). Boston, MA: Springer US.

Satish, P., Muralikrishnan, K., & Balasubramanian, K. (2015). Heart rate variability changes during stroop color and word test among genders. Indian J Physiol Pharmacol, 59(1), 9-15.

Scarpina, F., & Tagini, S. (2017). The stroop color and word test. Frontiers in psychology, 8, article 557, 1-8.

Self-Brown S, Lai BS, Thompson JE, McGill T, Kelley ML. (2013). Posttraumatic stress disorder symptom trajectories in Hurricane Katrina affected youth. J. Affect. Disord., 147, 1198-204.

Šiška, E. (2002). The Stroop Colour-Word Test in Psychology and Biomedicine. Acta Universitatis Palackianae Olomucensis. Gymnica, 32(1), 45-51.

Speer, K. E., Semple, S., Naumovski, N., & McKune, A. J. (2020). Measuring heart rate variability using commercially available devices in healthy children: A validity and reliability study. European Journal of Investigation in Health, Psychology and Education, 10(1), 390-404.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. Journal of experimental psychology, 18(6), 643-662.

Subramanya, P., & Telles, S. (2015). Performance in the Stroop task and simultaneously recorded heart rate variability before and after meditation, supine rest and no-intervention. Int J Brain Cogn Sci, 4(1), 8-14.

Uysal, F., & Tokmakçı, M. (2017). Evaluation of stress parameters based on heart rate variability measurements. IU-Journal of Electrical & Electronics Engineering, 17(1), 3057-3063.

Vazan, R., Filcikova, D., & Mravec, B. (2017). Effect of the Stroop test performed in supine position on the heart rate variability in both genders. Autonomic Neuroscience, 208, 156-160.

Zijlstra, F. R., Roe, R. A., Leonora, A. B., & Krediet, I. (1999). Temporal factors in mental work: Effects of interrupted activities. Journal of Occupational and Organizational Psychology, 72(2), 163-185.