Stress : Analysis

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Contents

1 Introduction

Stress is a natural and necessary response of our body to an event that can arise from either internal or external factors known as stressors. Examples of external stressors are sudden road incidents during driving or coping with deadlines at work, while internal stressors may include, for example, a sudden onset of an allergic reaction, or come from personal expectations, goals, perceptions and desires.

By evolutionary design, stress episodes are supposed to be temporary responses to jolt the human body to escape dangerous situations. However in modern times, a massive and prolonged exposure to daily stressful situations is found to have a detrimental consequence on our health and can play a part on body disorder. Accumulation of stress could be responsible of short or long-term health issues, depending on the length of exposure of the subject and his adaptability. Health problems may include: anxiety, burnout, depression, high blood pressure and cardiovascular diseases such as heart attack and aneurysm expansion. Diabetes and skin conditions can also be related to the effect of stress on the body.

The aim of Soladis is to prevent health problems caused or worsened by stress (sleep, digestive and weight problems, heart diseases, depression, skin conditions...). This study in particular will focus on burnout, a condition that can be associated with many of the aforementioned diseases.

Burnout is described as a general sensation of feeling down, exhaustion and reduced job performance with a decrease of self-esteem which may lead to depression. The prevention of burnout is a major challenge in our society as it represents approximately 1 billion Euro of lost productivity in France and 50 to 60% of lost workdays in Europe. Worse, a 20% increase in the number of suicides has been observed over the last two years, of which a significant portion is attributed to burnout.

Even though the negative effects of burnout have been well documented, the current lack of referenced methods for diagnosis represents a challenge. Although various tools exist to assess the stress level of a subject, such tools are often designed as self-assessment questionnaires which under-perform in giving an objective measure of the stress condition of the subject. Moreover, there is a lack of referenced data allowing the classification of physical and psychological symptoms of stress and the distinction between acute and chronic forms of stress.

The main objective of this study is to build a "stress indicator" to evaluate the accumulated level of stress in order to prevent burnout. This global stress indicator encapsulates numerous stress indicators measured, and is associated to clusters profile assigned to each subject according to its ability to accumulate and evacuate stress.

Secondary objectives are :

1. The validation of the connected watch ZENSORIUM, produced by Nitto, compared to two other validated tools for stress measurement: the self-assessment PSM25 (Psychological stress measure with 25 items) questionnaire and the PHYSIONER device, produced by Codesna.
2. The definition of a guideline for measuring stress level according to the situation the subject is exposed to (working stress, external influences, general anxiety, etc. . .).

This report presents the final results of the study, with 52 subjects involved in the study. We emphasize that the models and the conclusions will evolve with time once the database increases.

Data sources, data acquisition protocol and indicators are described in Section 2. Statistical methodology for comparing and classifying stress profiles is described in Section 3. Results are presented in Section 4 and discussed in Section 5. The conclusions of the study are presented in the last section.

2 Data

2.1 Data sources

Stress measurements are collected through three different channels:

- Survey forms, assessing the **level of stress felt by the subject** (subjective measurement, associated with individual perception): two forms PSM25 and Sumer (from the French Department of Work, including the Karasek diagram).

  PSM25 is a self-assessment questionnaire measuring the stress experienced by the subject trough 25 eight-scale items assessing four features related to a specific type of stress: affective, cognitive, behavioural and somatic areas. The sum of the scores of all the areas gives the global PSM25 stress score.

  Sumer is a self-assessment questionnaire measuring the stress at work. It contains the Karasek questionnaire, which is a 26 four-scale items assessing four features related to a specific type of occupational-stress: Decision Latitude, Psychological Demand, Social Support and Work Acknowledgement.

- **Chronic stress** measured with the innovative device, *Physioner* by *Codesna*, consisting of a short two minutes respiratory protocol with heart rate monitoring, giving a precise measure of the stress accumulated over the days/weeks (i.e. chronic stress). It measures the imbalance between sympathetic and parasympathetic division of the autonomic nervous system.

- Connected watch, *Zensorium by Nitto*, monitoring Heart Rate and pulse pressure: assessing a **daily acute stress ratio**.

To enable an exploratory analysis linked to the environmental factors affecting the stress of a person, the collected data from the three sources is augmented with exogenous data from weather, traffic and air pollution.

2.2 Acquisition protocol

Stress of the participants is assessed by following the protocol below:

- Five visits are realized over a period of two months. An interval of two weeks is observed between each visit.

- For each visit, three different measurements are made:

  Felt stress is assessed using survey forms (PSM25 and Sumer) at the beginning of the day;

  Chronic stress is assessed using the PHYSIONER device, produced by Codesna (two minutes protocol) at the beginning of the day;

  Daily stress is assessed using the connected watch ZENSORIUM, produced by Nitto, worn by subjects throughout the day.

- At the end of the day, data collected by the watch is gathered and the next visit is scheduled.

This study provides indicators to detect the drift of one's stress from a "daily" stress to a chronic status potentially leading to a burnout phase.

2.3 Indicators

Psychological indicators are :

- Karasek questionnaire : 4 independent scores

  Decision Latitude

  Psychological Demand

  Social Support

  Work Acknowledgement

- PSM25 questionnaire : 1 global score and 4 subcategories
  - Affective
  - Cognitive
  - Behavioural
  - Somatic
- Work stress felts by the subject : 1 score

Physiological indicators are :

- Codesna : 2 measured indicators
  - Autonomic Nervous System Imbalance (ANSI)
  - Heart Rate Variability
- As the two indicators from Codesna are highly correlated we built the Adjusted ANSI indicator through a combination of the these two indicators: $Ratio = \frac{ANSI}{\frac{HRV}{IdealHRV}}$, the ideal HRV being the expected HRV according to the age of the subject.
- Zensorium : 2 indicators
  - Median of SDPP where SDPP is Standard Deviation Pulse Pressure
  - Daily acute stress

Exogenous indicators are:

- Weather information: 3 indicators
  - Daily sunshine percentage
  - Daily precipitation
  - Maximum and minimum temperatures
- Traffic information: 1 indicator
  - Traffic-waste-time calculated as

$$\frac{EstimatedTimeInDailyTraffic - EstimatedNormalTime}{EstimatedNormalTime}$$

- Air pollution: 4 indicators
  - Fine particle matter 2.5μm (PM2.5) concentration
  - Fine particle matter 10μm (PM10) concentration
  - Nitrogen dioxide (NO2) concentration
  - Ozone (O3) concentration

3 Data Analysis

All subjects are analyzed together, in a single population sample, regardless of the study site.

3.1 Principal component analysis (PCA)

This statistical procedure aims at converting a set of potentially correlated variables into a set of linearly uncorrelated ones: the principal components (PC). This procedure is often used to explore datasets beforehand.

In order to explore the database and decrease the number of uncorrelated variables, a first PCA is applied to the whole dataset on standardized data. A second PCA is then applied to select the minimum number of variables which maximize the explained variance.

3.2 Indicators steadiness

In order to assess the steadiness of all the indicators, a first graphic representation was done to represent their evolution across time for each subject. Furthermore, a linear mixed model was created to have an analytic assessment of the evolution of each selected indicator across time, from visit 1 to visit 5. *Subject* was the statistical unit for the assessment of random effect during the repeated measures with first-order auto-regressive structure AR(1) which means that correlation between two consecutive visits is maintained.

For each estimator two models were built: one that studies the steadiness of the average in each site and a second that studies the evolution of the measures for each individual.

3.3 Clustering

To categorize the observations of visits, numerous clustering techniques have been experimented and it was observed that a simple k-means technique did not yield promising results due to an inherently indistinguishable dataset.

An objective method has been chosen, by letting an algorithm pick the highest scoring indicators involved and henceforth perform a classification. The algorithm in question is a modified version of the sparse clustering algorithm.

The concept is based on creating dissimilarity indexes between each visit. A feature ranking index was a Gaussian mixture model. The concept behind feature selection is to choose the parameters deemed to be important as unnecessary indicators tend to add noise to the distinguishing factor.

Normally feature selection is an integral part of supervised machine learning, however in this work, it has been applied to achieve improved cluster classification. The concept is also in line with the creation of a global stress indicator which provides a collective stress score for the person involved. The objective is to capture similar hidden groups, which might be only defined by a few indicators, leading to the possibility of improved cluster classification and even improved comprehension of the differences of the identified groups.

All visits were taken independently and scaled using the difference between the minimum and the maximum.

The algorithm in question is an iterative algorithm which attempts to find the top features which maximize the inter cluster distance.

3.4 Global Stress measurement

According to the correlation between the features calculated from each tools, they are merged together in order to obtain a global stress indicator.

Figure 1 describes the decision rules for the construction of the Stress Global Score. According to the combination of stress's level measured from the three independent indicators, felt stress from PSM25, ANSI from Codesna and daily acute stress from Zensorium watch, 4 stress categories were identified :

1. Low
2. Moderate
3. Intermediate
4. High

Score 1	Score 2	Score 3	Global Stress
R	R	R	High
R	R	O	
R	R	V	
R	O	O	Intermediate
O	O	O	
R	O	V	Moderate
O	O	V	
R	V	V	
O	V	V	Low
V	V	V	

Figure 1: Construction of the Stress Global Score

For example :

1. if two of the three indicators (let's say Felt and Acute stress) result as 'Orange' level in their own scales, and the third one (ANSI) results in a 'Green' level in its scale, then the stress global score is 'Moderate'.
2. if at least two indicators (let's say Felt stress and ANSI or Acute stress and ANSI) result as 'Red' level in their own scales, then the global score stress is defined as 'High'.

4 Results

4.1 Principal component analysis (PCA)

The PCA tests are first ran on the whole dataset (i.e. all visits taken together, $\sim$200 observations) with all indicators built or collected from sensors (physiological data and exogenous data), which corresponds to 22 variables. Data is standardized. The number of components to select is determined at the point beyond which the corresponding eigenvalues are all small and with low variations. This corresponds to selecting principal components with Eigenvalues >1 which leads to seven principal components explaining (in cumulative) almost 80% of the data. Focusing on the first 3 components (that explain 50% of the data), the following conclusions are derived:

- PC1 is mainly dominated by sub-classes of PSM score, indicating that those sub-categories explain the same variation of the data.
- PC2 is dominated by exogenous data. This shows that most of the exogenous data collected affects the analysis in the same way, i.e. they vary accordingly. Indeed the weather indicators are in the same area of the PC2 versus PC1 plot (daily sunshine percentage, maximum temperature, sunshine ratio, etc.). Time wasted in traffic is correlated to daily precipitation, as featured on the same plot.
- PC3 is dominated by data monitored by Codesna: ANSI, Heart Rate Variability and the synchronization between breathing and heart rate.
- In both PC2/PC1 and PC3/PC1 plots, a good agreement is observed in the Heart Rate monitored by the Zensorium watch and the Heart Rate monitored by Codesna.

The first PCA allows to decrease the number of input variables in the procedure by removing already spotted correlated variables. For example, instead of including all the different subcategories of the PSM survey, only one of them (or the total score) is used in the second PCA, knowing that the others will correlate with this one. Same argument for the exogenous data. The second PCA is realized with only 10 variables listed in Table 1:

- Four variables from survey forms
- Three physiological variables (Codesna and Zensorium)
- Three variables from exogenous data

This corresponds to selecting principal components with Eigenvalues >1 which leads to four principal components, as shown by the scree plot on the left panel of Fig.2. The analysis would thus be done on four components, that explain 59% of the data, as shown on the right panel of Fig. 2.

The first PC is strongly correlated (i.e. eigenvalues of the PC >0.5, see bold face in Table 1) with three of the input variables. PC1 increases with increasing PSM score and Psychological demand, and decreasing social support. This means that those three indicators vary together. For instance, if the PSM score increases (i.e. level of felt stress), the psychological demand will tend to increase as well while the social support will decrease: those results are coherent with each other since the social support measures something with a positive repercussion on someone's life while the other two variables measure a level of stress.

The second PC increases with two variables: Heart Rate and ANSI and decreases with time wasted in traffic (see bold face in Table 1).

PCA3 increases with increasing decision latitude and daily sunshine percentage.

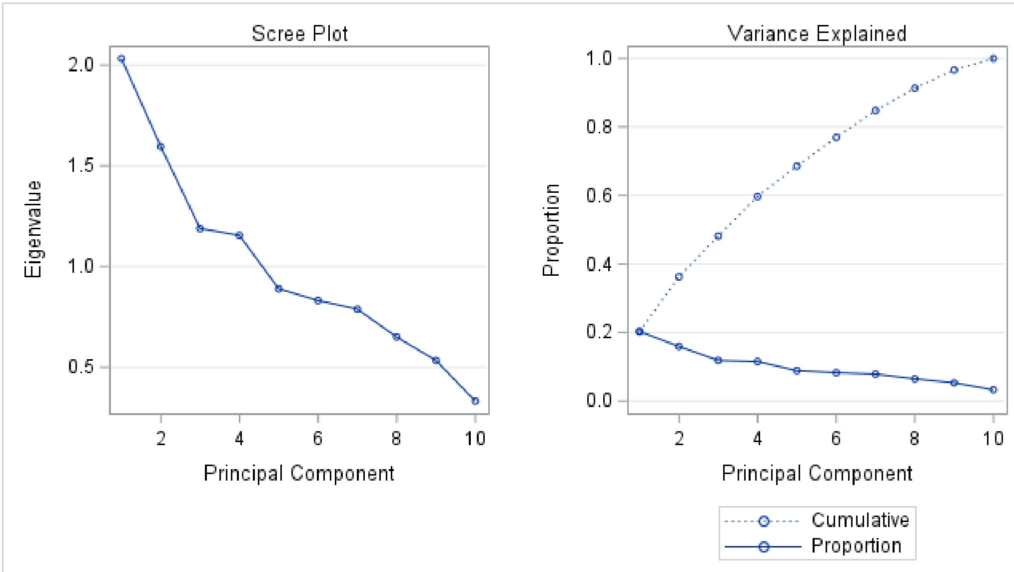

Figure 2: Scree plot for the variables on the left and proportion of the variance explained by principal component.

Principal Components Eigenvalues				
Variables	PC1	PC2	PC3	PC4
Decision Latitude	-0.295	- 0.089	**0.500**	**0.432**
Psychological Demand	**0.512**	-0.219	0.190	-0.136
Social Support	**-0.528**	0.115	0.015	0.007
PSM25 global score	**0.565**	-0.007	0.248	0.265
SDPP median	0.191	0.307	-0.279	**0.458**
HR	0.006	**0.487**	0.213	0.364
ANSI (adjusted)	0.045	**0.455**	0.255	-0.378
Daily sunshine percentage	-0.032	-0.047	**0.499**	-0.390
Time waster (traffic)	-0.054	-0.489	-0.256	0.092
Pollution concentration (PM2.5)	0.103	0.388	-0.388	-0.280

Table 1: Interpretation of the Principal Components

4.2 Steadiness of indicators

Figure 3 represents the evolution of the average by visits and by site of all the indicators. The blue line represents the average on subjects in Lyon, the red one the average on subjects in Paris and the green one represents the average on subjects in Sophia Antipolis.

The main observations from top left to bottom right are :

- First graphic on the left represents evolution of the Adjusted ANS Imbalance, Paris' results are significantly higher than Lyon or Sophia and increasing through visits from around 19.5% reaching peak around 31%. The results of subjects from Lyon are more stable between 12% and 16% and Sophia between 9% and 16%.
- Stress perceived at work or global score have the same behaviour : Paris has the lowest scores; in Lyon there is a slight decrease and in Sophia there is a slight increase.
- For the Latitude Decision, there is a large difference between three cities : Lyon has the lowest scores whilst Sophia has the highest ones.
- A similitude is noticed for The Psychological Demand between the three cities.
- Social Support is constant for Lyon, increasing in Sophia and has a parabolic relationship for Paris.
- Work appreciation is the lowest in Paris and similar in the others two cities.

The greater variability of Paris' results could be due to the low number of subjects for this site.

Steadiness was calculated for the main physiological indicators :

- Adjusted ANSI
- PSM25 Global Score
- Stress felt at work
- Karasek Decision Latitude (KDL)
- Karasek Psychological Demand (KPD)
- Karasek Social Support (KSS)
- Karasek Work Acknowledgement (KWA)
- Daily Acute Stress

Between them only the PSM25 Global Score shows a statistical difference between the measures collected over time (P-value = 0.0426 < 0.05). This implies that, except for this indicator, there is no significant linear trend over time, but the values remain broadly stable. See Table 2 below for all the results.

Parameter	Effect	Num DF	Den DF	F Value	P-value
Adjusted ANSI	Visit	4	210	0.73	0.5723
PSM25 Global Score	Visit	4	212	2.51	0.0426
Felt Work Stress	Visit	4	212	2.22	0.0677
KAR_DL	Visit	4	211	1.35	0.2537
KAR_PD	Visit	4	213	0.08	0.9873
KAR_SS	Visit	4	212	0.34	0.8475
KAR_WA	Visit	4	214	0.04	0.9967
Daily Acute Stress	Visit	4	207	0.37	0.8299

Table 2: Type 3 tests of fixed effects

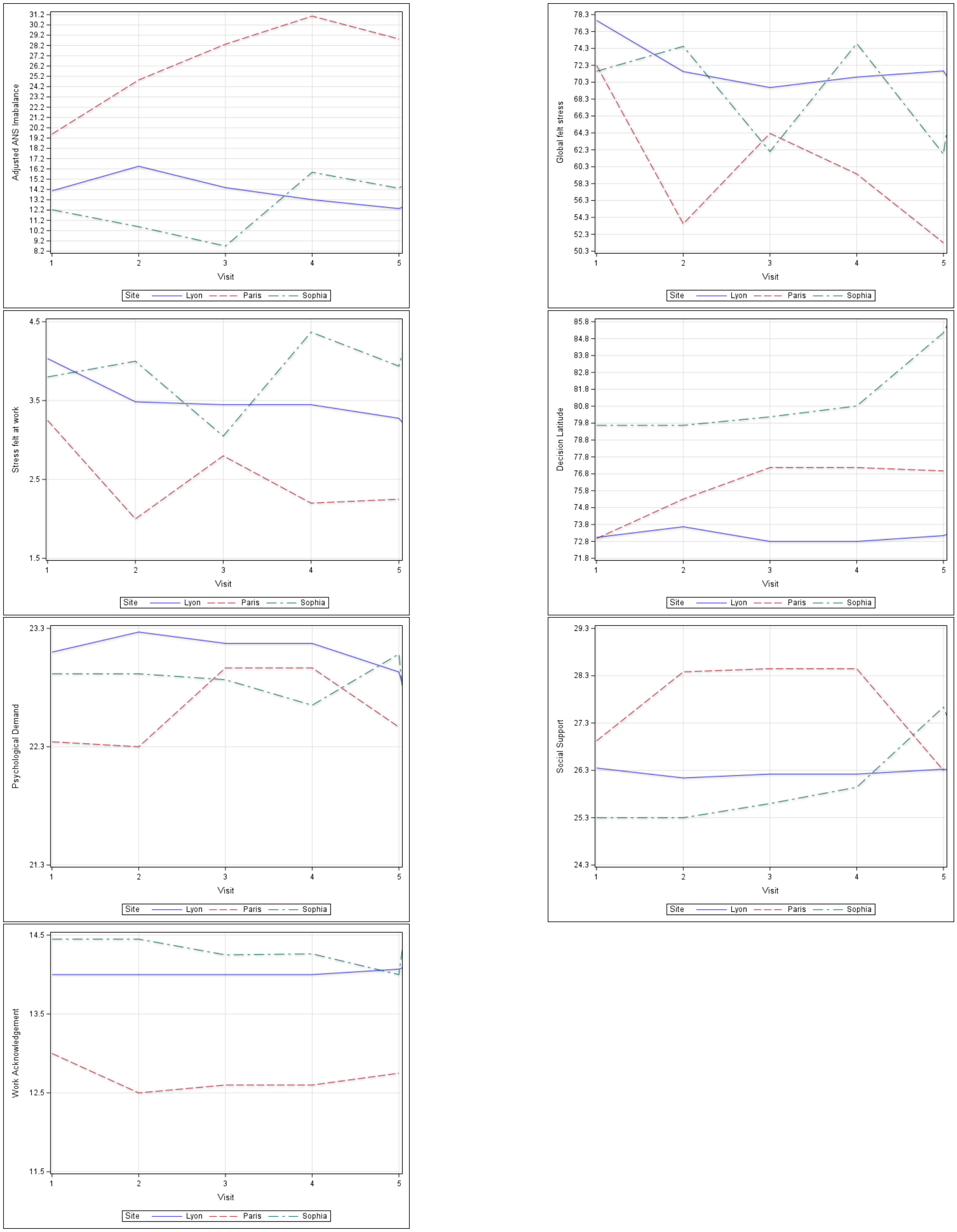

Figure 3: Evolution of indicators' (average on visits)

A detailed comparison between each pairwise visit for PSM25 Global score indicator is presented in Table 3. The only significant difference is observed between visits 1 and 3 (P-value = 0.0170 < 0.05).

Parameter	Visit	vs Visit	Estimate	Standard Error	DF	P-value	Alpha	Lower	Upper
PSM25 Global Score	1	2	3.3361	2.3717	210	0.1610	0.05	−1.3394	8.0116
PSM25 Global Score	1	3	7.7578	3.2276	242	0.0170	0.05	1.4000	14.1156
PSM25 Global Score	1	4	3.5956	3.7827	263	0.3427	0.05	−3.8528	11.0439
PSM25 Global Score	1	5	7.1588	4.2091	268	0.0901	0.05	−1.1283	15.4459
PSM25 Global Score	2	3	4.4217	2.4331	211	0.0706	0.05	−0.3747	9.2181
PSM25 Global Score	2	4	0.2595	3.2745	243	0.9369	0.05	−6.1905	6.7095
PSM25 Global Score	2	5	3.8227	3.8554	263	0.3223	0.05	−3.7686	11.4140
PSM25 Global Score	3	4	−4.1622	2.4575	210	0.0918	0.05	−9.0068	0.6823
PSM25 Global Score	3	5	−0.5990	3.3435	242	0.8580	0.05	−7.1850	5.9870
PSM25 Global Score	4	5	3.5632	2.5280	210	0.1602	0.05	−1.4202	8.5467

Table 3: PSM25 global score - pairwise comparisons

4.3 Clustering

In total, 8 clusters have been developed from the clustering algorithm described previously. This output is combined with the global stress indicator to give a picture of what can be expected from each cluster group. For example from the Figure 4 it can be observed that cluster group 1 and 4 show indicators which are opposite of each other.

	cluster								
	null	0	1	2	3	4	5	6	7
GlobalScore	Count	Count	Count	Count	Count	Count	Count	Count	Count
High			1			2		1	
Low	5	5	1	16	27	35	2	14	
Medium		3	11	2			2	2	3
Moderate	8	19	17	9	15	24	21	28	3

Figure 4: Global Stress by cluster groups

		CLUSTERS *Significance at 95%*	0 27p *(10,2%)*	1 30p *(11,4%)*	2 27p *(10,2%)*	3 42p *(15,9%)*	4 62p *(23,5%)*	5 25p *(9,5%)*	6 45p *(17,0%)*	7 6p *(2,3%)*	Total 264p
Physiological measured stress	Watch	Daily acute stress	0,22	0,22	0,15	0,15	0,17	0,25	0,20	0,19	0,19
		SDPP (mmHg)	4,01	3,87	2,93	3,23	3,36	4,27	3,73	3,61	3,58
	Codesna	Heart Rate Variability	1,69	1,33	1,11	1,18	1,39	1,72	1,27	1,18	1,35
		Adjusted ANSI (Ratio)	17,73	12,44	15,36	15,07	13,62	7,15	18,73	19,10	14,70
		ANSI	21,97	14,37	18,25	17,86	15,67	6,95	20,12	16,09	16,72
Felt stress	PSM25	SCORE_COGNITIVE	12,48	17,47	14,11	6,48	8,40	20,48	10,38	25,50	12,00
		SCORE_SOMATIC	15,44	20,97	17,19	9,40	11,13	26,28	12,93	34,50	15,31
		SCORE_BEHAVIOURAL	18,96	27,93	18,78	13,21	14,65	27,04	17,64	41,50	19,09
		SCORE_AFFECTIVE	23,74	33,93	26,48	15,86	17,18	37,68	20,76	45,33	23,69
		TOTAL PSM25	70,63	100,30	76,56	44,95	51,35	111,48	61,71	146,83	70,08
Felt stress at work	Karasek	Decision Latitude	73,41	72,07	78,15	77,86	76,13	79,20	76,62	72,67	76,17
		Psychological load	22,96	25,17	30,74	17,26	20,63	25,76	23,49	31,17	23,09
		Social support	12,67	11,67	14,74	13,21	13,27	9,96	12,73	10,50	12,70
		Work acknowledgement	13,89	13,00	14,52	14,05	13,65	12,68	14,33	12,00	13,74

Figure 5: Explanation of the clusters groups

An analysis based on the significance of each variable listed in Fig. 5 to the 8 clusters has been led to explain and label the different clusters. Variables listed in red have a negative impact on one's stress level while variables listed in green have a positive impact. Each group has been studied versus its complement in the whole sample.The table displayed in Fig. 5 shows the comparison of the mean of each group compared to its complements. When the difference to the mean of the whole sample is reaching a 95% significance, the value is highlighted and used to explain the cluster's meaning with respect to the variables the most representative for this cluster. For instance, the cluster C0 is characterized by high values (higher than the mean of the sample's population) of SDPP and Codesna's indicators, indicating a high level of daily acute stress and chronic stress. On the contrary, cluster C3 is characterized by low values (lower than the mean of the rest of the population) of daily acute stress, felt stress and psychological load, indicating a profile of a zen person.

Applying hierarchical clustering to the 8 groups already obtained allows us to find out similarities between these groups.

The hierarchical clustering analysis (or HCA) is a method to build a hierarchy of clusters. There are two main strategies :

1. Agglomerative : where each group starts in its own cluster and then pairs of the nearest clusters are merged in a new bigger cluster (moved up to a superior hierarchical level). The procedure is repeated recursively until only one cluster exists.

2. Divisive : where all groups start in one big cluster and the two furthest groups are split in two clusters (moved down to an inferior level). The method is repeated recursively until each group ends in its own cluster.

The results of a HCA are usually presented in a dendogram (as in Fig. 6). We applied the agglomerative HCA which led to two fusions of two groups as shown on Fig. 6: C4-C3 and C6-C0.

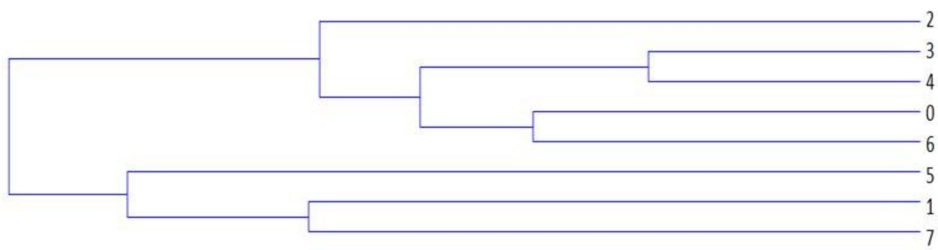

Figure 6: Hierarchical clustering

The HCA indicates as well similarities for the groups C1 and C7 as shown on the bottom part of Fig. 6. Even though the hierarchy is observed at a lower level than for the other groups (C4-C3 and C6-C0), complementary analysis from Fig. 5 led us to the conclusion to merge those two groups C1-C7. Consequently, our study is proposing 5 final clusters (C1-C7, C5, C0-C6, C3-C4 and C3) as five family types of stress person which are detailed in Fig. 7 of section 5.1.

4.4 Environmental impact on stress level : weather/air quality/traffic

Filters on weather	Filter on traffic (%)	PSM25 Global score	Chronic stress (%)	Daily stress (%)	Felt stress (at work)	Social support (Karasek)	Number of subjects
None	None	74.8	16.2	15.1	3.9	26.1	52
Sun	None	72.4	15.2	16.4	3.8	26.2	21
Partly cloudy	None	80.4	17.3	13.2	4.1	26.9	11
Cloudy	None	63.1	15.7	11.5	3.6	27.6	7
Rainy	None	82.4	15.9	16.6	4.1	23.6	12
None	30-102	73.4	11.9	15	3.2	25.4	11
None	0-30	75.2	17.4	15.1	4.1	26.2	41
Sun	0-30	75.5	16.7	16.8	4.2	26.6	18
Rainy	0-30	74	16.1	15.4	3.9	23.5	8

Table 4: Effects of the weather and the time spent in traffic on the different stress indicators.

Table 4 shows a summary of the environmental impact on someone's level of stress. The first two columns are a combination of filters on weather and amount of time lost in traffic, while the other columns give the mean values for the different main stress indicators for the corresponding number of subjects. The main general conclusions are summarized below:

- The stress indicators are linked to the weather. People are sensitive to the weather in terms of felt stress especially: the level of felt stress decreases with sun and increases with lower quality weather. The same tendency tends to be seen with chronic stress. The level of daily stress tends to react on the opposite way: a lower level of daily stress is observed with clouds than with sunny weather. Those results should be taken with cautious knowing that the watch used during those tests was notoriously known to be affected by the sun light due to their technology with optic sensors.
- No significant change has been observed with traffic indicator. This is probably due to the low statistics of our sample combined with the estimation made about the wasted time in traffic. It is not calculated specifically for the subjects, but the traffic indicator correspond to a general state of traffic on a day and specific area.

5 Discussion and general conclusions

5.1 Stress' profiles

From the data analysis carried out in this study and detailed in the previous section, five stress profiles have been identified, as listed in Fig. 7:

- Silent/ to be monitored
- Tensed
- Daily Stressed
- Job strain
- Zen

Fig. 7 is describing the characteristics of each family.

A stress intensity scale is rising from those groups, illustrated through the color gradient in Fig. 7), with reddish colors symbolizing a high level of stress, orange/yellow an intermediate level and green a low/zero level of stress.

C0	High level of stress during the day (higher than the mean) Anxious subjects with rather high level of chronic stress Moderate level of felt stress	The "SILENT/ TO BE MONITORED"	10,2%	27,2%
C6	Subjects without felt stress, with known work acknowledgement. However they tend towards a chronic stress. Subjects to be monitored		17,0%	
C1	Felt stress rather high / high pshychological load at work and a lack of social support and acknowledgement at work High percentage of time stressed during the day (higher than the mean)	The "TENSED"	11,4%	13,7%
C7	Subjects with a high level of felt stress in general and in their work with a high psychological demand and low work acknowledgement Potentially emotional persons		2,3%	
C5	Subjects with relatively high level of stress in general and at work With a high level of daily stress, but without chronic stress	The "DAILY STRESSED"	9,5%	
C2	Low level of daily stress (lower than the mean) However, high levels of cognitive and affective felt stress with a high psychological load at work	The "JOB STRAIN"	10,2%	
C3	"Zen" subjects without daily stress nor felt stress. Good management of work psychological load	The "ZEN"	15,9%	39,4%
C4	"Zen" subjects with low felt stress, with high social support at work and a good management of work psychological load		23,5%	

Figure 7: Characteristics of the five profiles of stressed person

5.2 Gender and stress level

Table 5 summarizes the results of this study for the stress indicators by gender. At the bottom of the table, the intervals used to scale each indicator between three stress levels (Low, medium and high) are given as a reference. Female subjects tend to have a higher value for felt stress (both the general result from PSM25 survey and the felt stress at work) and a higher daily stress, but seems to evacuate the stress well enough to not convert it into chronic stress.

Population	PSM25 Global score	Chronic stress (%)	Daily stress (%)	Felt stress (at work)	Social support (Karasek) between 8-32	Number of subjects
Whole	74.8	16.2	15.1	3.9	26.1	52
Female	81.4	13.4	16.6	4.1	25.7	22
Male	70.0	18.3	14.0	3.8	26.3	30
Low stress	25-83	<15	0-10	1-3	–	–
Medium stress	83-150	15-30	10-15	3-6	–	–
High stress	150-200	>30	>15	6-9	–	–

Table 5: Values of the stress indicators per gender. The lower part of the table gives as a reference the intervals used to classify the stress level for each indicator.

5.3 Limits

The authors are well aware of the limits of this study: the low statistics of the sample and the lack of highly stressed subjects. However, the analysis (i.e., PCA, clustering) led in this study have been carried out with acceptable level of precision to allow us to draw robust conclusions.

		The "SILENT/ TO BE MONITORED"			The "TENSED"			The "DAILY STRESSED"	The "JOB STRAIN"	The "ZEN"			
		0+6	0	6	1+7	1	7	5	2	3+4	3	4	Total
Stress Global Score	1	24	9	15	4	3	1	3	13	56	26	30	100
	2	41	14	27	24	20	4	19	10	42	14	28	136
	3	5	3	2	8	7	1	3	4	4	2	2	24
	4	2	1	1						2		2	4
	Total	72	27	45	36	30	6	25	27	104	42	62	264

		0+6	0	6	1+7	1	7	5	2	3+4	3	4	Total
Stress Global Score	1	33,3%	33,3%	33,3%	11,1%	10,0%	16,7%	12,0%	48,1%	53,8%	61,9%	48,4%	37,9%
	2	56,9%	51,9%	60,0%	66,7%	66,7%	66,7%	76,0%	37,0%	40,4%	33,3%	45,2%	51,5%
	3	6,9%	11,1%	4,4%	22,2%	23,3%	16,7%	12,0%	14,8%	3,8%	4,8%	3,2%	9,1%
	4	2,8%	3,7%	2,2%	0,0%	0,0%	0,0%	0,0%	0,0%	1,9%	0,0%	3,2%	1,5%
	Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

Figure 8: Visit distribution in number (top) and in percentage (bottom) by stress profile and link with the stress global score.

The clustering analysis has been done on 52 subjects corresponding to 264 visits. As explained previously in this paper, five families of stress have been identified (columns of the tables in Fig. 8) and a global score of stress is assigned for each visit, from 1 to 4 with 1 corresponding to a low level of stress (lines of the tables in Fig. 8).
The five families are globally following a stress scale as discussed previously: more people with a global score of stress of 1 is observed in the Zen family on Fig. 8.

The limits are visible on Fig. 8: the study sample contains only 4 visits (∼1.5%) corresponding to a high level of stress (level 4) and only 24 visits (∼9.1%) corresponding to a level 3 of stress.

6 Conclusion

This paper summarizes the results obtained on a sample of 50+ subjects enrolled on a stress measurement study. This work combines three types of stress indicators: felt stress (survey forms), daily stress or instantaneous stress (watch with optical sensors), chronic stress (two minutes breathing exercise synchronized with ECG). The strength of this study is the unique combination of these indicators probing a different type of stress. The main results are summarized below:

- The Principal Component analysis is leading to the following conclusion. The three measures of stress: felt (survey forms), daily (Zensorium) and chronic (Codesna), are globally explaining the data in the same way. The most robust result obtained is the same tendency observed for both chronic and daily stress. This led to the conclusion that both variables explain the data similarly. However, the output values from the PCA are not high enough to conclude that the three variables are correlated. Therefore, the conclusion is that the three stress indicators are coherent with each other and complementary.

- A global stress score is assigned at each visit based on the combination of the three stress measurements. This global score is combined with a profile of stress type. Indeed, a clustering technique led on 264 visits spread among 52 subjects identified five families of stressed people: the silent/to be monitored, the tensed, the daily stressed, the job strain and the zen.

- Each subject enrolled in this study has access to a personal report with details on each stress indicator and their respected sub-categories. Explanations are also provided on their global stress indicator and the family of stress person they belong to. They can also analyze the impact of the exogenous data (air quality, traffic, weather) on their stress management, as well of the impact of their lifestyle (sport, music, relaxation).