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Abstract. In European countries, namely in Portugal, it is common to hear some people mentioning that they are exposed to excessive and continuous psychosocial stressors at work. This is increasing in diverse activity sectors, such as, the Services sector. A representative sample was collected from a Portuguese Services' organization, by applying a survey (internationally validated), which variables were measured in five ordered categories in Likert-type scale. A multinomial logistic regression model is used to estimate the probability of each category of the dependent variable *general health perception* where, among other independent variables, *burnout* appear as statistically significant.

INTRODUCTION

According to the European Agency for Safety and Health at Work, psychosocial risks and work-related stress are among the most challenging issues in occupational safety and health, once they have a significant impact on the individuals' health. The proportion of workers exposed to psychosocial stressors at work is growing. This has negative consequences for workers, organizations, and national economies, which may explain the increasing number of studies in this research field ([1, 2, 3, 5], among others).

The Copenhagen Psychosocial Questionnaire (COPSOQ) is an internationally validated method for the assessment of psychosocial risks and their impact on workers' health and wellbeing. It includes relevant dimensions according to several important theories on psychosocial factors in the workplace [4, 5]. A short Portuguese version of COPSOQ (with 41 questions) was applied, in 2015, to a representative sample of workers of an important Portuguese organization of Services. We use 12 questions that belong to the 6 psychosocial dimensions (our independent variables) with epidemiological evidence for health, according to the medical community who are interested in identifying the possible causes and symptoms of some mental disturbs, such as burnout state, in order to assist the workers' treatment. We use multinomial logistic regression to estimate the probability of each of the 5 ordered categories (or levels) of the dependent variable *general health perception* (*GHP*), considering 4 quantitative independent variables (obtained as a mean of some of the 12 COPSOQ questions) and 2 qualitative variables as in Table 1. The dependent variable, with an approximately symmetric distribution, and the qualitative variables are coded in Table 2, which also includes the number of workers in each of the levels (3 have the highest numbers), marginal percentages and missing values.

In this study, Ordinal Regression is not considered because some assumptions are not verified, namely the test of parallel lines for the different link functions considered.

TABLE 1. Independent variables (quantitative and qualitative).

4 quantitative var.	COPSOQ questions	**2 qualitative var.**	COPSOQ questions
Family-work conflict	2 questions about: to feel that the job requires a lot of energy or time which ultimately affects negatively the private life.	*Sleeping troubles*	Woke up several times during the night and then could not fall asleep.
Stress	2 questions about: to be riled up or anxious.	*Depressive symptoms*	Sadness.
Burnout	2 questions about: emotionally and physically exhausted.		
Offensive behaviour	4 questions about: to have been the target of insults and verbal provocations, have been exposed to physical violence, unwanted sexual harassment.		

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TABLE 2. Case Processing Summary.

		N	Marginal Percentage
GHP: (dependent variable)	**1 - deficient**	235	4.7%
	2 - reasonable	1223	24.5%
	3 - good	1965	39.4%
	4 - very good	1207	24.2%
	5 - excellent	355	7.1%
Sleeping troubles: (independent variable)	**1 - nothing**	832	16.7%
	2 - little	1043	20.9%
	3 - moderately	1556	31.2%
	4 - very	1338	26.8%
	5 - extremely	216	4.3%
Depressive symptoms: (independent variable)	**1 - nothing**	800	16.0%
	2 - little	1333	26.7%
	3 - moderately	1783	35.8%
	4 - very	858	17.2%
	5 - extremely	211	4.2%
Valid		4985	100.0%
Missing		199	
Total		5184	
Subpopulation		2665[a]	

a. The dependent variable has only one value observed in 2017 (75.7%) subpopulations.

The multinomial logistic regression model

Multinomial logistic regression is a predictive model once it is used to predict the probabilities of the different possible outcomes of a categorically distributed dependent variable, given a set of independent variables (6 in our study). Let Y be the dependent variable *GHP*, with $K = 5$ categories, then the multinomial regression consists of a system of 5 logistic models which, after being standardized for the reference category of Y (in this case study we consider the first category "1-deficient"), allow us to compute the probability of Y taking the value of each one of the 5 categories. In matrix notation, where $\mathbf{X}$ is the matrix of the independent variables and $\boldsymbol{\beta}$ the vector of the coefficients [6, 7],

$$P(Y=1\,|\,\mathbf{X})=\frac{1}{1+\sum_{k=2}^{5}e^{\mathbf{X}\boldsymbol{\beta}_k}}\,,\quad P(Y=2\,|\,\mathbf{X})=\frac{e^{\mathbf{X}\boldsymbol{\beta}_2}}{1+\sum_{k=2}^{5}e^{\mathbf{X}\boldsymbol{\beta}_k}}\,,\ldots,\quad P(Y=5\,|\,\mathbf{X})=\frac{e^{\mathbf{X}\boldsymbol{\beta}_5}}{1+\sum_{k=2}^{5}e^{\mathbf{X}\boldsymbol{\beta}_k}}\,. \tag{1}$$

The $K-1=4$ odds of each category of Y, relatively to the reference category, are given by,

$$\frac{P(Y=2\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=e^{\mathbf{X}\boldsymbol{\beta}_2}\,,\quad \frac{P(Y=3\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=e^{\mathbf{X}\boldsymbol{\beta}_3}\,,\quad \frac{P(Y=4\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=e^{\mathbf{X}\boldsymbol{\beta}_4}\,,\quad \frac{P(Y=5\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=e^{\mathbf{X}\boldsymbol{\beta}_5}$$

and logarithmizing the two members of the equality we obtain 4 log odds, relatively to the reference category, of Y that constitute the multi-equation model,

$$\ln\frac{P(Y=2\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=\mathbf{X}\boldsymbol{\beta}_2\,,\quad \ln\frac{P(Y=3\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=\mathbf{X}\boldsymbol{\beta}_3\,,\quad \ln\frac{P(Y=4\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=\mathbf{X}\boldsymbol{\beta}_4\,,\quad \ln\frac{P(Y=5\,|\,\mathbf{X})}{P(Y=1\,|\,\mathbf{X})}=\mathbf{X}\boldsymbol{\beta}_5\,.$$

Thus, the logit for each non-reference category against the reference category (that it is the "standard" category to which the others will be naturally compared) depends on the values of the explanatory variables. The model is iteratively adjusted with the maximum likelihood method.

ANALYSIS AND RESULTS

After adjusting the multinomial logistic regression model, it is necessary to determine whether it reasonably approximates the behaviour of the available data. The likelihood ratio test of the final model (with all the independent variables) against the null model (only with a constant and where all the parameter coefficients are 0) and the chi-square statistic, as the difference between the -2 log-likelihoods (LL) of the null and final model, are presented in Table 3. Once the p-value = 0.000 (less than the usual significance levels, namely 0.01), we can conclude that the final model is outperforming the null, i.e. the adjusted model is statistically significant. Therefore, there is at least one independent variable of significant influence on the workers' *GHP*. Consistent with this are the smaller values of AIC (Akaike information criterion) and BIC (Bayesian information criterion) in the final model.

TABLE 3. Model Fitting Information (Model Fitting Criteria and Likelihood Ratio Tests).

Model	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC	BIC	-2 Log-Likelihood	Chi-Square	df	p-value
Intercept Only	10511.551	10537.608	10503.551			
Final	9182.425	9495.106	9086.425	1417.126	44	0.000

About the validity of the goodness-of-fit tests (Pearson and Deviance, available in the IBM SPSS, used in this study) we should note that there are 9745 cells (i.e., dependent variable levels by subpopulations) with zero frequencies. Thus, because there are many empty cells (73.1%), we cannot safely use the results of these tests.

To select the "best" predictors to include in the model we use the automatic stepwise method Forward Entry, which starts with a model that only includes the intercept and where the final model should only include important predictors. In Table 4 we have the likelihood ratio tests, which check the contribution of each effect to the model. For each one, the -2LL is computed for the reduced model (that is, a model without the effect) and the chi-square statistic is the difference between the -2LL of the reduced model from Table 4 and the final model reported in Table 3.

The results of the likelihood ratio tests for each of the independent variables indicate that the variables *family-work conflict*, *stress*, *depressive symptoms*, *sleeping troubles* and *burnout* have a statistically significant effect (all p-values are less than 0.01) under the logit of the probability of having a *GHP*, at least "2-reasonable", relatively to the reference category "1-deficient". The variable *offensive behaviour* does not appear as statistically significant. We should note that the intercept cannot be tested in this model because removing it simply causes one of the previously redundant factor levels to become non-redundant.

TABLE 4. The likelihood ratio tests (Model Fitting Criteria and Likelihood Ratio Tests).

Effect	Model Fitting Criteria			Likelihood Ratio Tests		
	AIC of Reduced Model	BIC of Reduced Model	-2 Log-Likelihood of Reduced Model	Chi-Square	df	p-value
Intercept	9182.425	9495.106	9086.425[a]	0.000	.	.
Family-work conflict	9188.928	9475.552	9100.928	14.503	4	0.006
Stress	9190.852	9477.476	9102.852	16.427	4	0.002
Depressive symptoms	9294.722	9503.176	9230.722	144.297	16	0.000
Sleeping troubles	9273.672	9482.126	9209.672	123.248	16	0.000
Burnout	9235.001	9521.625	9147.001	60.576	4	0.000

The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0.
a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom.

The probability of observing each dependent variable category is a function of the predictors given by the estimated parameters (denoted by B in Table A1, Appendix I), through equations in (1). The estimated parameters of the multinomial model summarize the effect of each predictor, where the ratio between each coefficient and its standard error, squared, equals the Wald statistic. The odd ratios (OR) for each category of the dependent variable, relative to the reference category ("1-deficient"), are available for each of the independent variables in the Exp(B) column of Table A1. Parameters with significant negative/positive coefficients decrease/increase the likelihood of that response category with respect to the reference category. When B is positive/negative then Exp(B) is higher/smaller than 1, which means that OR is Exp(B) to 1, thus the chance of having a certain level of *GHP* is $|1 - \text{Exp(B)}| \times 100\%$ higher/lower than the reference category (or, Exp(B) times higher/lower in that level than in level "1-deficient"). Note that, the parameters associated with the last level of each factor is redundant given the intercept term.

For "3-good" *GHP*, which is the category with the highest number of individuals, only *family-work conflict* and *stress* are not statistically significant, compared to the reference category. However, all levels of *depressive symptoms* and *sleeping troubles* as well as the *burnout* are statistically significant (the p-values of the Wald statistic are less than 0.05, then the null hypotheses of the parameters being equal to zero are rejected). Thus, we can say that almost all the independent variables allow to distinguish the probabilities of the category "3-good" compared to the category "1-deficient", but the same situation does not occur when we compare the coefficients of the category "2-reasonable" (where the majority of the independent variables are not statically significant) considering the reference category.

Passing from "1-deficient" to "5-excellent" *GHP* is significantly affected by *burnout* (B = - 0.826, p-value = 0.000, OR = 0.438), whenever we pass from one *burnout* level to the next/previous level, the chances of having excellent *GHP* decrease/increase $|1 - 0.438| \times 100 = 56.2\%$ (comparing with "1-deficient" *GHP*). Considering the independent qualitative variable *depressive symptoms*, workers with "1-nothing" present a higher probability of "5-excellent" *GHP* than those with "5-extremely". Having "1-nothing" in relation to having "5-extremely" *depressive symptoms* increases the chance of "5-excellent" relatively to "1-deficient" *GHP* in $|1 - 4.825| \times 100 = 382.5\%$ (Table A1, Appendix I).

Classification Results

We use multinomial logistic regression to classify individuals based on values of a set of predictor variables. The outputs of Table A1 (Appendix I) allow us to compute the probability of each individual belonging to each one of the dependent variable categories. For each individual, the predicted response category is chosen by selecting the one with the highest model-predicted probability. Table 5 shows the practical results of using this model, where cells on/off the diagonal are correct/incorrect predictions. Considering the dependent variable *GHP* with the five categories from "1-deficient" to "5-excellent" we can say, for example, that 1366 of the 1965 workers who chose "3-good" are classified correctly (approximately 69.5%). Overall, 45.2% of the individuals are classified correctly and the proportional percentage, based on Table 2, is $(0.047^2 + 0.245^2 + 0.394^2 + 0.242^2 + 0.071^2) \times 100\% \approx 28.1\%$. Thus, the model gives almost twice the correct classifications than would be obtained by mere chance. This compares favourably to the "null", or intercept-only model, which classifies all cases as the modal category.

TABLE 5. Classification (Observed versus Predicted).

Observed	**Predicted**					
	1 – deficient	2 – reasonable	3 – good	4 – very good	5 – excellent	**Percent Correct**
1 – deficient	**21**	119	75	20	0	8.9%
2 – reasonable	16	**420**	695	92	0	34.3%
3 – good	2	294	**1366**	303	0	69.5%
4 – very good	1	81	677	**448**	0	37.1%
5 – excellent	1	14	158	182	**0**	0.0%
Overall Percentage	0.8%	18.6%	59.6%	21.0%	0.0%	**45.2%**

CONCLUSIONS AND FINAL REMARKS

Using the multinomial logistic regression procedure, we have constructed a model for predicting workers' opinions about their *GHP*. According to the adjusted model, passing from the reference category ("1-deficient") to any of the other categories is not significantly affected by *stress*, but it is affected in a statistically significant way by the variables *burnout* and some levels of *depressive symptoms* and *sleeping troubles*. In general, the probability of having higher levels of *GHP* increases for the same decrease of level in these variables.

This case study also allows us to obtain the number of workers classified correctly in each category of the dependent variable.

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REFERENCES

1. A. Bakker, E. Demerouti and A. I. Sanz-Vergel, *Annual Review of Organizational Psychology and Organizational Behaviour*, **1**(1), 140114155134003 (2014).
2. C. Maslach and M. P. Leiter, *Journal of Applied Psychology* **93**: 498–512 (2008).
3. M. Stehlík, Ch. Helpersdorfer, P. Hermann, J. Šupina, L. M. Grilo, J. P. Maidana, F. Fuders and S. Stehlíková, *Information Sciences* 394-395, 246-272 (2017).
4. H. V. Neto, J. Areosa and P. Arezes, *Manual sobre Riscos Psicossociais no Trabalho* (Civeri Publishing, Col. RICOT, 2014).
5. T. S. Kristensen, M. Borritz, E. Villadsen and K. B. Christensen, *Work & Stress* **19**: 192–207 (2005).
6. D. W. Hosmer and S. Lemeshow, *Applied Logistic Regression* (2nd Edition, John Wiley & Sons, New York, 2000).
7. W. H. Greene, *Econometric Analysis*. (Seventh ed., Boston: Pearson Education. 803–806, 2012).

APPENDIX I

TABLE A1. The estimated parameters of the Multinomial Model.

	GHP:[a]	B	Std. Error	Wald	df	p-value	Exp(B)	95% Confidence Interval for Exp(B)	
								Lower Bound	Upper Bound
2 - reasonable	Intercept	0.452	0.768	0.346	1	0.557			
	Family-work conflict	- 0.085	0.091	0.871	1	0.351	0.919	0.769	1.098
	Stress	0.166	0.139	1.427	1	0.232	1.181	0.899	1.551
	[*Depressive symptoms* = 1]	0.781	0.421	3.440	1	0.064	2.184	0.957	4.984
	[*Depressive symptoms* = 2]	1.559	0.365	18.248	1	0.000	4.752	2.324	9.715
	[*Depressive symptoms* = 3]	1.565	0.271	33.262	1	0.000	4.784	2.810	8.143
	[*Depressive symptoms* = 4]	1.004	0.229	19.310	1	0.000	2.730	1.744	4.272
	[*Depressive symptoms* = 5]	0[b]	.	.	.	.	.	.	.
	[*Sleeping troubles* = 1]	0.704	0.405	3.028	1	0.082	2.023	0.915	4.472
	[*Sleeping troubles* = 2]	1.161	0.371	9.812	1	0.002	3.193	1.544	6.602
	[*Sleeping troubles* = 3]	0.663	0.270	6.011	1	0.014	1.941	1.142	3.297
	[*Sleeping troubles* = 4]	0.402	0.228	3.110	1	0.078	1.495	0.956	2.337
	[*Sleeping troubles* = 5]	0[b]	.	.	.	.	.	.	.
	Burnout	- 0.182	0.150	1.472	1	0.225	0.834	0.622	1.118
3 - good	Intercept	1.643	0.768	4.579	1	0.032			
	Family-work conflict	- 0.168	0.090	3.456	1	0.063	0.845	0.708	1.009
	Stress	0.203	0.138	2.157	1	0.142	1.225	0.934	1.605
	[*Depressive symptoms* = 1]	1.147	0.423	7.343	1	0.007	3.148	1.373	7.214
	[*Depressive symptoms* = 2]	2.288	0.371	37.920	1	0.000	9.852	4.757	20.404
	[*Depressive symptoms* = 3]	1.987	0.286	48.142	1	0.000	7.295	4.161	12.788
	[*Depressive symptoms* = 4]	1.064	0.251	17.991	1	0.000	2.899	1.773	4.740
	[*Depressive symptoms* = 5]	0[b]	.	.	.	.	.	.	.
	[*Sleeping troubles* = 1]	1.216	0.407	8.917	1	0.003	3.372	1.518	7.489
	[*Sleeping troubles* = 2]	1.642	0.378	18.872	1	0.000	5.163	2.462	10.829
	[*Sleeping troubles* = 3]	1.250	0.284	19.415	1	0.000	3.491	2.002	6.088
	[*Sleeping troubles* = 4]	0.537	0.248	4.684	1	0.030	1.710	1.052	2.781
	[*Sleeping troubles* = 5]	0[b]	.	.	.	.	.	.	.
	Burnout	- 0.579	0.148	15.281	1	0.000	0.561	0.419	0.749
4 – very good	Intercept	1.977	0.834	5.619	1	0.018			
	Family-work conflict	- 0.149	0.095	2.465	1	0.116	0.862	0.716	1.038
	Stress	- 0.059	0.144	0.166	1	0.683	0.943	0.711	1.250
	[*Depressive symptoms* = 1]	1.526	0.483	10.005	1	0.002	4.601	1.787	11.845
	[*Depressive symptoms* = 2]	2.489	0.436	32.524	1	0.000	12.044	5.121	28.326
	[*Depressive symptoms* = 3]	1.775	0.367	23.411	1	0.000	5.901	2.875	12.110
	[*Depressive symptoms* = 4]	0.819	0.347	5.576	1	0.018	2.268	1.149	4.475
	[*Depressive symptoms* = 5]	0[b]	.	.	.	.	.	.	.
	[*Sleeping troubles* = 1]	1.663	0.456	13.305	1	0.000	5.277	2.159	12.898
	[*Sleeping troubles* = 2]	1.968	0.431	20.877	1	0.000	7.159	3.077	16.654
	[*Sleeping troubles* = 3]	1.265	0.352	12.936	1	0.000	3.545	1.779	7.065
	[*Sleeping troubles* = 4]	0.383	0.327	1.376	1	0.241	1.467	0.773	2.784
	[*Sleeping troubles* = 5]	0[b]	.	.	.	.	.	.	.
	Burnout	- 0.691	0.153	20.326	1	0.000	0.501	0.371	0.677
5 - excellent	Intercept	2.382	1.024	5.413	1	0.020			
	Family-work conflict	- 0.354	0.111	10.145	1	0.001	0.702	0.565	0.873
	Stress	- 0.002	0.168	0.000	1	0.988	0.998	0.718	1.386
	[*Depressive symptoms* = 1]	1.574	0.682	5.327	1	0.021	4.825	1.268	18.365
	[*Depressive symptoms* = 2]	2.275	0.640	12.622	1	0.000	9.730	2.773	34.136
	[*Depressive symptoms* = 3]	1.586	0.591	7.201	1	0.007	4.886	1.534	15.568
	[*Depressive symptoms* = 4]	0.484	0.606	0.637	1	0.425	1.622	0.495	5.322
	[*Depressive symptoms* = 5]	0[b]	.	.	.	.	.	.	.
	[*Sleeping troubles* = 1]	1.190	0.550	4.690	1	0.030	3.288	1.120	9.656
	[*Sleeping troubles* = 2]	1.105	0.529	4.361	1	0.037	3.018	1.070	8.511
	[*Sleeping troubles* = 3]	0.242	0.466	0.269	1	0.604	1.274	0.511	3.177
	[*Sleeping troubles* = 4]	- 0.602	0.460	1.714	1	0.190	0.548	0.222	1.349
	[*Sleeping troubles* = 5]	0[b]	.	.	.	.	.	.	.
	Burnout	- 0.826	0.174	22.509	1	0.000	0.438	0.311	0.616

a. The reference category is: **1 - deficient**.
b. This parameter is set to zero because it is redundant.