

Flattening the curve: COVID-19 induced a decrease in arousal for positive and an increase in arousal for negative words

Milica Popović Stijačić^{1,2,1}, ORCID: 0000-0002-5785-3974,

Ksenija Mišić^{3,4}, ORCID: 0000-0003-0613-0431

Dušica Filipović Đurđević^{2,3,4}, ORCID: 0000-0001-5044-5428

¹Department of Psychology, Faculty of Media and Communications, Singidunum University,
Karađorđeva 65, 11000 Belgrade, Serbia

²Laboratory for Experimental Psychology, Faculty of Philosophy, University of Novi Sad, Serbia, Dr
Zorana Đinđića 2, 21000 Novi Sad, Serbia

³Laboratory for Experimental Psychology, Faculty of Philosophy, University of Belgrade, Serbia, Čika
Ljubina 18-20, 11000 Belgrade, Serbia

⁴Department of Psychology, Faculty of Philosophy, University of Belgrade, Serbia, Čika Ljubina 18-20,
11000 Belgrade, Serbia

¹ Corresponding author's email: milica.popovic.stijacic@fmk.edu.rs; mobile phone:

+381642376294

Flattening the curve: COVID-19 induced a decrease in arousal for positive and an increase in arousal for negative words

In this study, we collected affective ratings of emotional valence and arousal for 882 Serbian words and compared their values at three points in time: before the onset of the COVID-19 pandemic (2018), during the COVID-19 lockdown (2020) and after the government measures were abandoned (2022). Although valence ratings were more stable than arousal ratings, we did not observe a significant change in either valence or arousal ratings across the time points. A more detailed look into the data revealed the change in arousal that was different across the valence values. Our analyses demonstrated that, upon the onset of the COVID-19 pandemic, emotionally negative words elicited higher arousal ratings, whereas emotionally positive words elicited lower arousal ratings. It revealed that our participants became more sensitive to the negative content and less sensitive to the positive content. We hypothesise that this pattern could be linked to reduced resilience and consequently could represent a mental health risk.

Keywords: emotional valence, arousal, words, COVID-19, lexical norms

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Previous Normative Studies of Emotional Valence and Arousal

Affective states are commonly defined by two dimensions – emotional valence and arousal. Emotional valence represents our evaluation of the degree to which a stimulus is positive or negative (pleasant or unpleasant). On the other hand, arousal represents the degree to which we experience a stimulus as exciting or relaxing (Kuperman et al., 2014). Theoretically, these two dimensions are orthogonal (Colibazzi et al., 2010; Posner et al., 2005). Within the space of these two dimensions, stimuli may have low (negative) valence and high arousal, e.g. 'war', but also may have high (positive) valence and high arousal, as in case of the word 'happiness'. Neutral stimuli lie in the middle of both dimensions, e.g. 'analysis'. Neuroimaging studies support that emotional valence and arousal are different dimensions with separate neural bases (e.g. Colibazzi et al., 2010; Kensinger & Schacter, 2006).

A few decades ago, researchers recognized the importance of conducting normative studies and collecting a wide variety of psycholinguistic variables for large word samples (i.e. the Big data approach; Keuleers & Balota, 2015). Having large norm databases is crucial for running different kinds of cognitive studies, not only within the area of psycholinguistics but also for research in domains like memory, decision-making, attention and similar. All research that utilizes words is in need of various psycholinguistic descriptions of words in order to control for different stimuli features.

One conclusion that could be drawn from most of the norming studies that focused on words' affective norms concerns the relation between emotional valence and

arousal ratings. Most of these norming studies reported that valence-arousal relationship could be described via the quadratic function or the U-shaped function, meaning that positively and negatively valenced words tend to be more arousing compared to neutral words (Bradley & Lang, 1999; Kanske & Kotz, 2010; Moors et al., 2013; Planchuelo et al., 2022; Redondo et al., 2007; Warriner et al., 2013).

Many normative studies addressed the reliability of ratings by comparing the ratings of emotional valence and arousal in terms of the correlation between the two points in time (Kyröläinen et al., 2021; Stadhagen-Gonzales et al., 2016; Delatorre et al., 2019; Lopez-Carra et al., 2020; Popović Stijačić & Filipović Đurđević, in prep.). Table 1 shows correlations between the data collected in two points in time within normative studies for valence and arousal of words and faces. The emotional valence showed higher correlations (ranging from .83 to .98) compared to the arousal (ranging from .53 to .76) and consequently more stability.

Table 1

List of Studies Comparing the Ratings of Emotional Valence and Arousal from Different Normative Studies

Language	Study	Comparison study	Emotional valence	Arousal
PRE-COVID PERIOD (norms collected before 2020)				
English	Warriner et al., 2013	Bradley & Lang, 1999	$N=1029, r=.95$	$N=1029, r=.76$
Spanish	Stadhagen-Gonzales et al., 2017	Hinojosa et al., 2015	$N=636, r=.97$	$N=636, r=.71$
	Delatorre et al., 2019	Redondo et al., 2007	$N=1031, r=.98$	$N=1031, r=.75$
		Redondo et al., 2007	$N=1034, r=.83$	$N=1034, r=.53$
Serbian	Popović Stijačić & Filipović Đurđević, in prep.	Popović Stijačić & Filipović Đurđević	$N=111, r=.90$	$N=111, r=.73$

(accepted for
publication)

French	Monnier & Syssau, 2014	Niedenthal et al., 2004	$N=33, r=.96$	$N=33, r=.71$
COVID PERIOD (norms collected between 2020 and 2022)				
Faces	López-Carral et al., 2020	Kurdi et al., 2017	$N=30, r=.88$	$N=30, r=.77$
English	Kyröläinen et al., 2021	Warriner et al., 2013	/	/
Spanish	Planchuelo et al., 2022	Stadhagen-Gonzales et al., 2017	$N=390$ (150 were COVID related)	$N=390$ (150 were COVID related)

Note: The list of normative studies is not exhaustive. N – The number of matching words; r – correlation between ratings from two norming studies

Correlations between different measurement points reported in table 1 indicate that emotional valence ratings are more stable than arousal ratings. However, correlations themselves reveal nothing about the factors that could be the source of arousal variation. Several studies posed this question (Hristova & Grinberg, 2015; Delatorre et al., 2019; Teismann et al., 2020).

Contextual Factors Influencing the Emotional Valence and Arousal Ratings

Hristova and Grinberg (2015) explored the difference in emotional valence ratings of negative, positive and neutral facial expressions after induction of a sad, happy, or neutral mood. Participants first watched different video clips, which served as mood inductors and then rated the mood of different facial expressions presented in photographs. The authors did not find a significant interaction between mood and emotion of a face. In other words, they did not record the mood congruency effect. The authors found that participants had a tendency to give higher emotional valence

regardless of the polarity of faces after the induction either of happy or sad moods.

Hristova and Grinberg (2015) concluded that valence ratings are influenced by arousal related to the induced mood since the neutral condition did not provoke differences in valence ratings of different types of faces. However, arousal was not a concern of their study, so it was not measured neither for the facial expressions nor the video clips.

One study examined how imagining a scene of suspense affected the evaluation of words' emotional valence and arousal (Delatorre et al., 2019), and then compared these estimates with the norming study from Redondo et al. (2007). The average new ratings of emotional valence and arousal were significantly lower than those from earlier research. The authors (Delatorre et al., 2019) found that when suspenseful context is introduced, the participants tend to rate positive words less favourable than in the usual context. Furthermore, under the same context, words evoked smaller arousal ratings in participants, regardless of their valence, i.e. words seemed more neutral than in 'normal' context ratings.

In another study, Tismann et al. (2020) investigated how mood affects assessing emotional valence and arousal of words. In this research, participants were tested on anxiety and depression and rated a multitude of words on arousal and valence scales. The authors did not find that more depressed respondents gave different estimates for these two dimensions than those with a lower level of depression. On the other hand, those with a higher level of anxiety tended to give higher arousal estimates for neutral words, suggesting a relationship between an anxiety and arousal.

A few papers published recently, focused more on the influence of the COVID-19 pandemic and worldwide lockdowns on emotional valence and arousal ratings of the words. López-Carral et al. (2020) collected emotional valence and arousal estimates of faces during the lockdown and compared them with the estimates from Kurdi et al.

(2017) norming study. Significantly higher valence estimates were observed for neutral and positively rated images compared to the previous study. However, although arousal estimates were numerically lower for neutral images, the differences were not statistically significant. In the language domain, Aki-Juhani Kyröläinen et al. (2021) investigated the effects of age and the pandemic on emotional valence ratings. Older participants tended to give higher valence estimates than younger participants, particularly during the pandemic. The authors interpreted these results as evidence that older participants are more resilient to the situational stressors caused by the pandemic.

Planchuelo et al. (2022) gathered emotional valence and arousal ratings for COVID-related (*hospital*) and COVID-unrelated words (*whale*) during the period of the lockdown in Spain (from March until May 2020). Compared to Stadhagen-Gonzales et al. (2017) arousal ratings collected during COVID were lower overall. However, the authors recorded arousal ratings for COVID-related terms were higher than for COVID-unrelated terms. On the contrary, although the emotional valence ratings were lower in the COVID period, the ratings, on average, were more positive for COVID-related positive words (*kiss, hug*) than for COVID-unrelated positive terms. There were no differences in ratings of emotional valence for COVID-related negative words (*medication, fear*).

The authors interpreted the increase in valence ratings for COVID-related positive words as a '*nostalgia boosting effect*' (Planchuelo et al., 2022, p. 6). This effect means that participants in the absence of usual social contact, which includes body interaction with other people, gave higher estimates for words related to social interaction (such as *kiss and hug*). On the other hand, lower arousal ratings for words were in accordance with '*pandemic fatigue*' (Rudroff et al., 2020). According to Rudroff et al. (2020), post-COVID fatigue is not caused only by the coronavirus disease, and it

could be a consequence of psychological factors, like stress, anxiety, depression and fear, that were common mental health issues during the pandemic. Authors (Planchuelo et al., 2022) concluded that the COVID-19 pandemic could be a relevant contextual factor influencing mental health and, therefore, emotional representations of words.

Our Goal

The motivation for this research came from the new situation caused by the COVID-19 pandemic and total closure as one of the measures to combat the pandemic. Research on mental health showed that restriction of movement and previous freedoms and the coronavirus was very stressful for the entire population (Damnjanović et al., 2020; Marchini et al., 2020; Morales-Rodríguez et al., 2021; Rudroff et al., 2020; Sadiković et al., 2020; Wang et al., 2021). A recent Serbian study (Sadiković et al., 2020), in which participants reported their emotional state of fear, anxiety, anger, and boredom, found that the fear and anxiety were at their peak at the beginning of the lockdown and that the level of slowly decreased after five weeks. Considering that previous studies showed that mental state (Tismann et al., 2020) or mood induction (Delatorre et al., 2019) influenced valence and arousal ratings, we assumed that changes in mental functioning during the pandemic could be caused by the change in valence and arousal ratings of words. One up-to-date study dealing with this issue (Planchuelo et al., 2022) found that the pandemic influenced both dimensions. COVID-related pleasant terms were estimated as more positive during the pandemic. Furthermore, although the arousal ratings were lower in general, during COVID-19, COVID-related words were rated as more arousing. Lower estimates of arousal during the pandemic are in line with Delatorre et al. study (2019). However, the changes in the valence estimates are

inconsistent across studies. Therefore, we still do not have full understanding of the effects of adverse context on affective dimension of word meaning.

In order to fill the knowledge gap, our study aimed to explore the sensibility of emotional valence and arousal of words on situational factors, like was COVID-19 pandemic. Thus, we set two goals. The first was to collect ratings of emotional valence and arousal of words during the lockdown and after the end of such restrictive anti-pandemic public-health measures. The second goal was to compare these ratings with the norms collected in the pre-pandemic period.

Method

Data were collected in three time points: before COVID-19 pandemic in 2018 (the first wave), during the onset of the pandemic and the lockdown in Serbia in 2020 (the second wave), and during 2022 (the third wave). Data from the first sample were taken from Popović Stijačić & Filipović Đurđević (in prep) while for other two data were collected specifically for the purposes of this paper.

Participants

Overall, 182 participants took part in the study. The first wave of the data collection was a selection from the Popović Stijačić & Filipović Đurđević (in prep) dataset, where 40 undergraduate psychology students rated presented words. For the second and the third wave, 42 and 100 participants, respectively, completed the questionnaire. The second wave sample consisted of undergraduate psychology students from the Department of Psychology, Faculty of Philosophy, University of Novi Sad, whereas the third wave consisted of volunteers that responded to an online ad distributed through Facebook ($M_{\text{age}} = 41.7$, $SD = 8$; 86% female). All participants read an informed consent form

before taking part in the study. The study was approved by the institutional review board of the Faculty of Philosophy, University of Belgrade.

Materials and design

Number of words presented to participants varied across three data collection waves: 2100 words were rated in the first wave, 802 in the second wave, and 882 in the third wave. The main sample for this study consisted of 802 words that were repeated across the three waves (Table 3). The word sample of 882 is described in Table 2 on a number of standard lexical variables.

In the selection process, we started from the initial database of 2100 Serbian nouns that we had at disposal (Popović Stijačić & Filipović Đurđević, in preparation) and continued by selecting words with lower concreteness ratings. In doing so, we relied on the finding that emotion plays a more significant role in case of abstract, as compared to concrete words (Kousta et al., 2009).

Table 2

The Descriptive Measures for the 882 Words that were presented in Total during the Second and the Third Waves.

Variable	<i>N</i>	<i>M</i>	<i>SD</i>	Min	Pct. 25	Pct. 75	Max
Word frequency	882	121.99	306.69	1	10	101	3676
Word length (in letters)	882	6.31	1.49	3	5	7	11
Imageability	882	3.60	1.19	1.72	2.71	4.26	6.82
Context Availability	882	4.78	0.95	1.5	4.14	5.47	6.75
Familiarity	882	4.73	1.12	1.38	3.97	5.61	6.88
Concreteness	882	3.31	1.08	1.18	2.59	3.77	6.81
Age of Acquisition	882	8.55	2.14	2.93	7.05	10.07	15.48

Note. All ratings from Authors (in prep), with the exception of word frequency which was sourced from Kostić (1999)

Procedure

Words were presented on the computer screen, and each participant had to provide ratings on an emotional valence scale and arousal scale. In the first two data collection waves, participants were rating words on both scales, whereas in the third wave, due to technical limitations of the used platform, each participant rated the words on just one of the two scales. In the first and the second wave, total of the presented words was split into smaller batches that were presented to participants. In the third one, lists were counterbalanced to ensure approximately equal number of ratings per word on both scales. Hence, each word rated by 17 to 27 participants in three time points. Number of ratings varied based on random assignment to the word list and the familiarity of the words to the participant rating them, since it was possible to select the option 'I am not familiar with this word'.

For both scales we used a 7-point Likert scale, however scales differed in the value interpretation. For emotional valence, extremes of the bipolar scale represented negative (1) and positive (7) words. The middle point (3) represented neutral words, not regarded as either positive or negative. On the other hand, arousal was rated on a unipolar scale, where low extreme represented words low in arousal, and high extreme highly arousing words.

At the beginning of the procedure, participants read the informed consent form and then were instructed on the rating procedure for emotional valence and arousal scales. Instructions contained examples of words that might be rated on the extreme of the scales. Participants then went on to rate each word on one or both scales. In the third data collection wave, this was followed by some additional questions that are not within the scope of this paper.

Results

The data were analyzed in R statistical software (R version 4.0.5; R Core Team, 2021) by using *dplyr* (Wickham, et al, 2022), *ggplot2* (Wickham, 2016), *gbm* (Ridgeway et al., 2017), *mgcv* (Wood, 2006; 2011), and *itsadug* (van Rij et al., 2016) packages.

In the first step, upon aggregating at by-item level, the main sample was created by selecting only the items that were repeated across the three data collection waves, and the descriptive measures were calculated for these words (Table 3).

Table 3

The Descriptive Measures for the 802 Words that were repeated across the three Data Collection Waves.

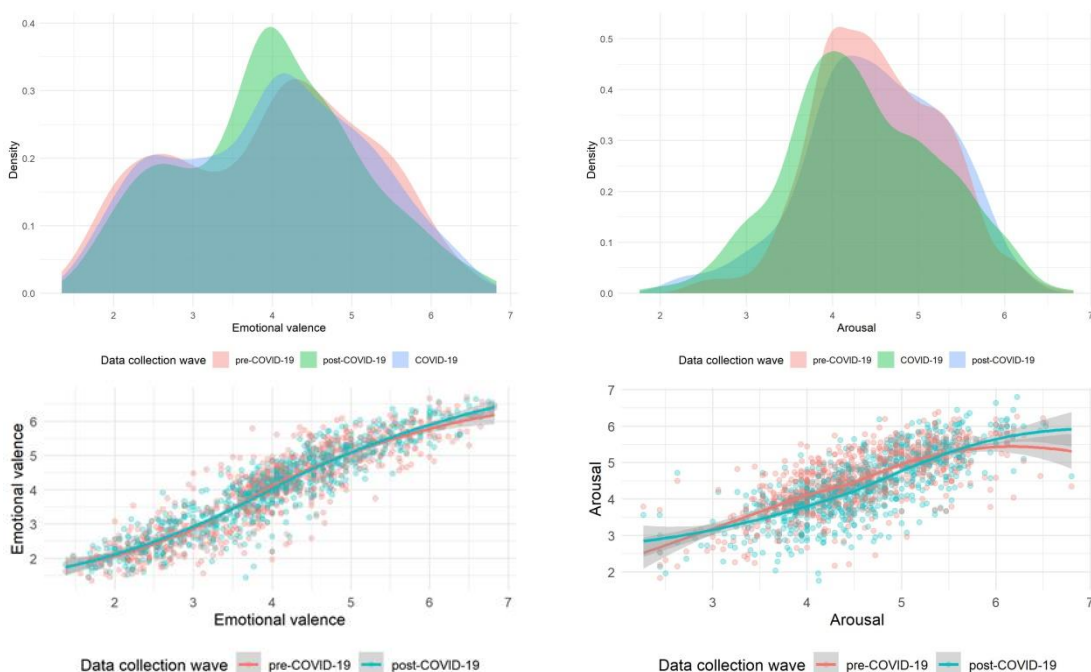
	Lexical variable	<i>N</i>	<i>M</i>	<i>SD</i>	Min	Pct. 25	Pct. 75	Max
<i>Valence</i>	The first wave	802	3.97	1.13	1.38	3.18	4.72	6.82
	The second wave	802	3.99	1.20	1.44	3.05	4.86	6.64
	The third wave	802	3.98	1.23	1.35	2.91	4.96	6.71
<i>Arousal</i>	The first wave	802	3.97	1.13	1.38	3.18	4.72	6.82
	The second wave	802	3.99	1.20	1.44	3.05	4.86	6.64
	The third wave	802	4.52	0.81	1.83	4	5.13	6.39

Our main interest was monitoring the change in valence and arousal ratings across the three testing phases. Therefore, we compared these variables across the three time conditions: pre-COVID-19, during COVID-19, and post-COVID-19. As can be observed in Table 3 and Figure 1, there were virtually no change in average valence ratings and only a slight numerical increase in arousal ratings in the post-COVID-19

testing. The observed pattern of valence data is confirmed by investigating bivariate correlation coefficients between pre-COVID-19 valence ratings and valence ratings collected during COVID-19 ($r=.928$, $t(800)=70.408$, $p<.001$), and also between pre-COVID-19 and post-COVID-19 valence ratings ($r=.898$, $t(800)=57.534$, $p<.001$). However, the same analysis revealed lower bivariate correlation coefficients in case of arousal. Although the observed correlations were again positive and high, their values were somewhat lower both in case of pre-COVID-19 arousal ratings and arousal ratings collected during COVID-19 ($r=.756$, $t(800)=32.673$, $p<.001$), and also between pre-COVID-19 and post-COVID-19 arousal ratings ($r=.704$, $t(800)=28.034$, $p<.001$). Therefore, we concluded that although valence remained stable across the three points in time in our dataset, the arousal ratings showed a tendency toward being less consistent.

Figure 1

The Emotional Valence and Arousal Distributions and Their Correlations Across the three Data Collection Waves

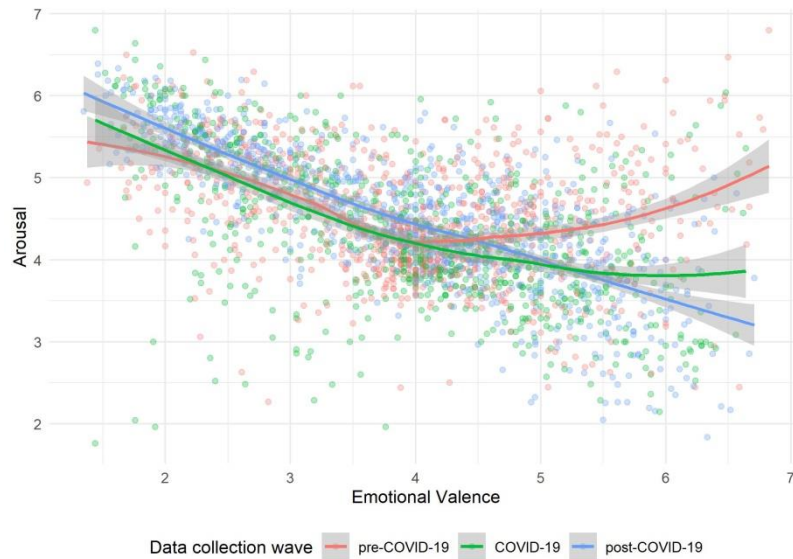


Note. **Top row:** the comparison of the Valence (left) and Arousal (right) rating distributions across the three data collection waves (pre-COVID-19, during COVID-19, and post-COVID-19). **Bottom row:** correlation between pre-COVID-19 and during-COVID-19, and between pre-COVID-19 and post-COVID-19 ratings of Valence (left) and Arousal (right).

In order to investigate the change in arousal ratings across time in more detail, we turned to the relation between valence and arousal. As illustrated in Figure 2, during our pre-COVID-19 testing we observed a typical U-shaped relation between the two variables (green line), as also reflected in low bivariate correlation coefficient between the two ($r=-.286$, $t(800)=-8.452$, $p<.001$). Behind this nonlinearity is the fact that typically words of negative valence are rated as the most arousing, followed by words of positive valence, whereas neutral words elicit the lowest arousal ratings. However, in our dataset, this pattern seemed to be changing across the three time conditions. During COVID-19 lockdown (blue line), the bivariate correlation coefficient between valence and arousal was higher compared to pre-COVID-19 ratings ($r=-.545$, $t(800)=-18.404$, $p<.001$), and the raising trend continued in the post-COVID-19 data collection wave (red line; $r=-.773$, $t(800)=-34.502$, $p<.001$). The increase in bivariate correlation coefficient values is caused by the disappearing of the nonlinearity in the monitored relation (see Figure 2).

Figure 2

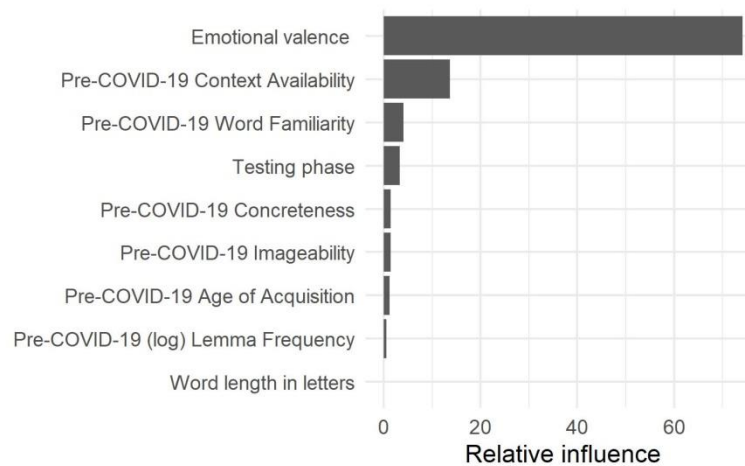
The Relation between Emotional Valence and Arousal across the three Data Collection Waves



We wanted to explore whether the observed change in the relation between valence and arousal across the three data collection waves was significant. Therefore, we turned to statistical modelling and built a regression model with arousal as the dependent variable. In order to select the relevant predictors, we applied General Boosting Machines, which suggested that the best predictors of arousal would be valence, context availability, familiarity and testing phase (Figure 3).

Figure 3

The Relative Importance of Variables in Predicting Arousal Ratings



In the next step, we built a General Additive Model to investigate whether the change in nonlinearity was significant across the three time conditions. Our analyses confirmed that the relation between valence and arousal differed across pre-COVID-19, during COVID-19, and post-COVID-19 conditions. As depicted in Figure 4, the nonlinear relation that was present in the pre-COVID-19 testing, was less expressed in the testing during COVID-19, and almost completely disappeared in the post-COVID-19 testing session, where the relation was linear. We found that the linearization was a consequence of selective change in arousal ratings across sessions. The arousal ratings tended to increase for words of lower valence, while decreasing for word of higher valence.

Table 4

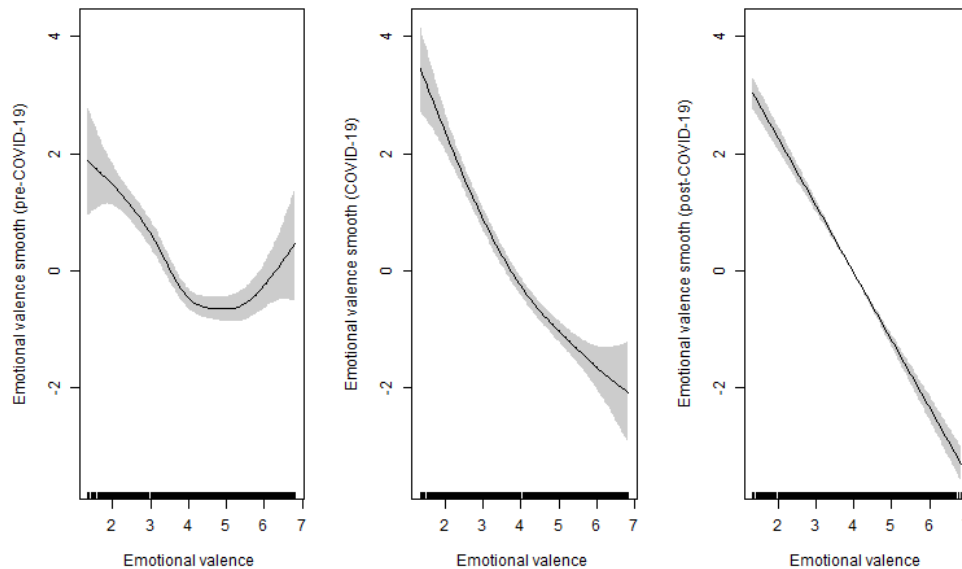
The Coefficients from the General Additive Model Fitting Arousal Ratings

Parametric coefficients				
	<i>Estimate</i>	<i>SE</i>	<i>t</i>	<i>p</i>
Intercept	3.143	.221	14.194	<.001
Testing phase: Prior-to COVID-19	.103	.087	1.192	.233
Testing phase: During COVID-19	-.344	.086	-3.988	<.001
Prior COVID-19 Context Availability	.459	.045	10.148	<.001
<i>Smooth terms</i>				
	<i>Edf</i>	<i>Ref.df</i>	<i>F</i>	<i>p</i>
s(Emotional Valence):Testing phase: Prior-to COVID-19	3.953	4.858	23.228	<.001
s(Emotional Valence):Testing phase: During COVID-19	2.757	3.420	95.022	<.001
s(Emotional Valence):Testing phase: Post COVID-19	1.000	1.000	463.029	<.001
s(Word)	196.187	800.000	.312	<.001

Note. s() – parametric smooth; edf – effective degrees of freedom, Ref.df – reference degrees of freedom

Figure 4

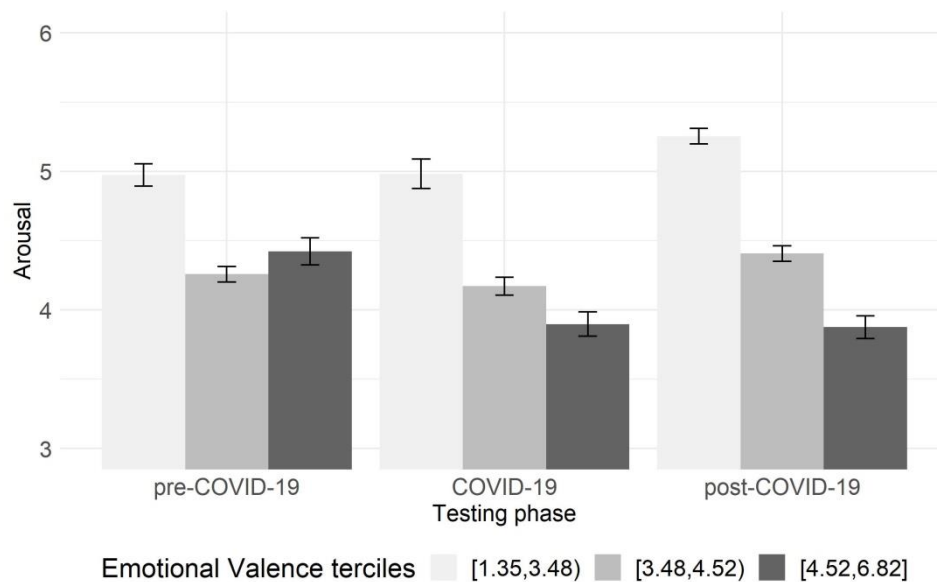
Partial Effects of Valence on Arousal across the three Time Conditions: Pre-COVID-19, During COVID-19, Post- COVID-19



To shed even more light onto the observed change in arousal ratings, we split our dataset into three equally-sized subsamples according to values of valence ratings. Low values represent words of negative valence, mid-range is related to neutral words, and high values represent words of positive valence. As illustrated in Figure 5, unlike arousal ratings of emotionally neutral words, which remained constant over time (except for the mild short-lived decrease during COVID-19), the ratings of emotionally charged words changed. However, this change was not the same for emotionally negative and emotionally positive words. The arousal by words of positive valence decreased during COVID-19 and remained on the same level in the post-COVID-19 period. On the other hand, the arousal by words of negative valence increased in the post-COVID-19 time.

Figure 5

Average Arousal Ratings across the three Data Collection Waves for three Groups of Words (Negative, Neutral, and Positive)

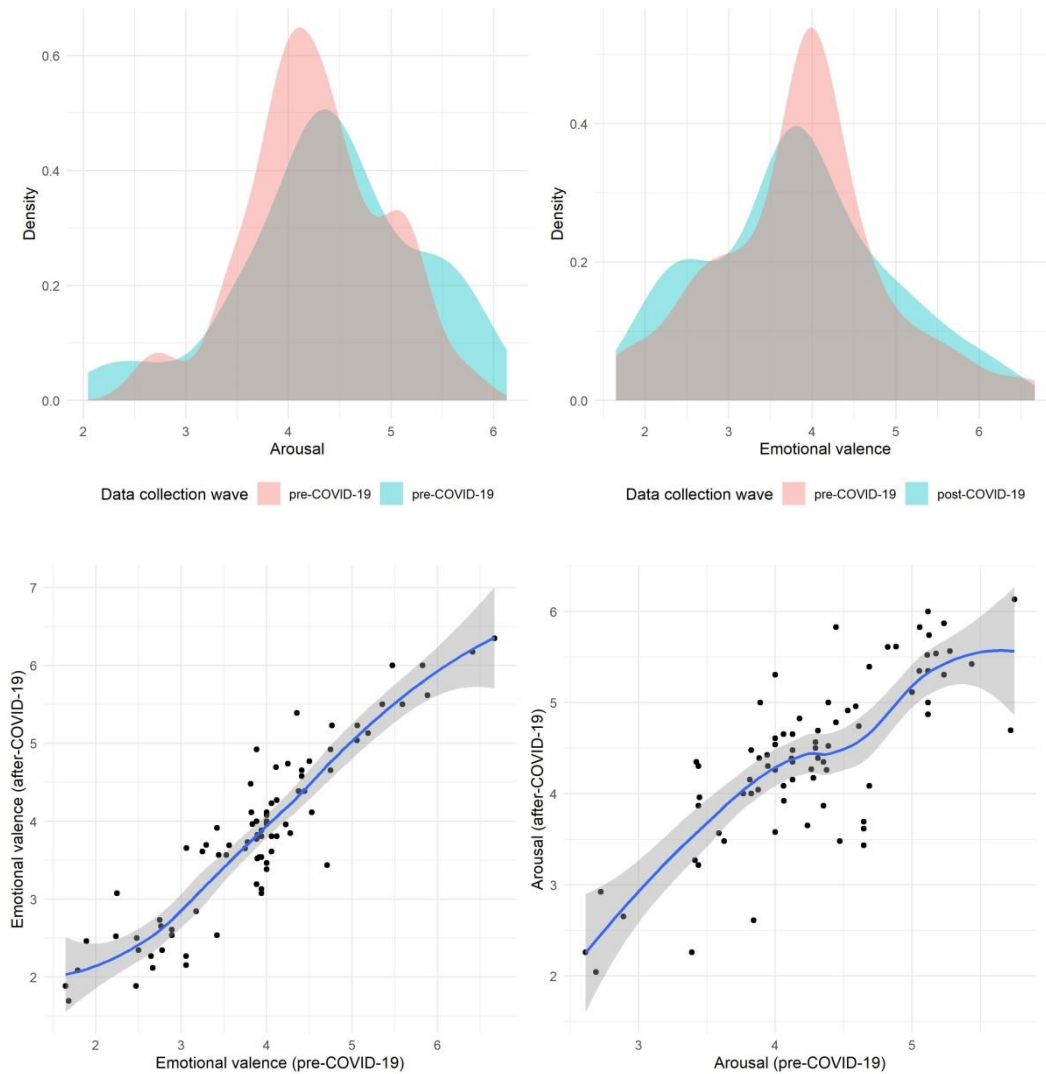


COVID-19 related words

In order to test whether our findings would differ for words which are related to COVID-19 in meaning, we conducted similar analyses on the subset of 80 words that we explicitly rated as covid19 related and presented to our participants in the second wave of data collection. Therefore, these are the words for which we have pre-COVID-19 ratings and post-COVID-19 ratings. As presented in Figure 6, neither the emotional valence, nor the arousal has changed in the post-COVID-19 data collection wave. Also, the pre-post correlation for both arousal ($r=.784$, $t(78)=11.17$, $p<.001$), and valence ($r=.915$, $t(78)=20.149$, $p<.001$) is fully comparable to the words from the main sample.

Figure 6

The Valence (left) and Arousal (right) Ratings Distributions and for Additional COVID-19 Related Words and their Correlations



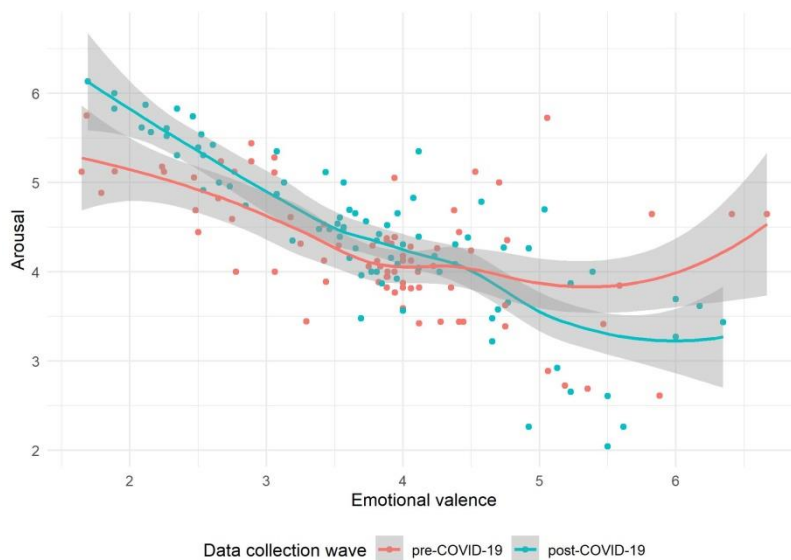
Note. Top row: The comparison of the valence (left) and arousal (right) rating distributions for additional 80 COVID-19 related words, across the two data collection waves (pre-COVID-19, and post-COVID-19). **Bottom row:** Correlation between pre-COVID-19 and post-COVID-19 ratings of valence (left) and arousal (right) for the same set of words.

Next, in order to test whether the increase in arousal for negative words and the decrease in arousal for positive words is different for COVID-related words we looked into the bivariate correlation between emotional valence and arousal in two points in

time. As presented in Figure 7, COVID-related words reveal the same pattern as the words in the main sample. We therefore conclude that our findings is revealing of the words in general.

Figure 7

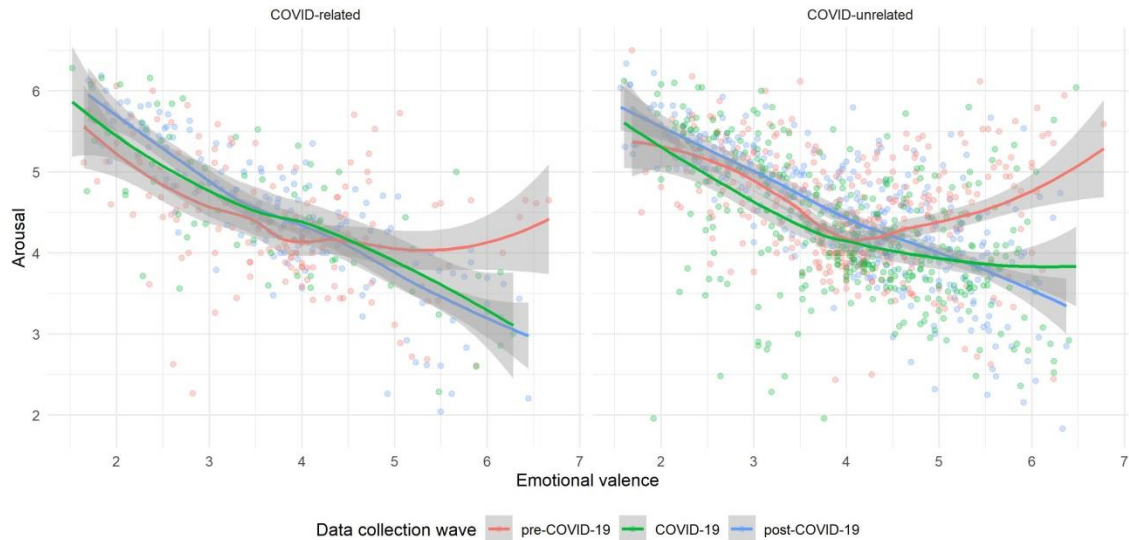
The Relation between Emotional Valence and Arousal of Additional Set of COVID-19 Related Words across the two Points in Time: Pre-COVID-19 (green), and Post-COVID-19 (red).



Finally, the three co-authors independently rated the full set of 882 words on COVID-19 relatedness, marking them either as related, or unrelated to COVID-19. We then selected only those words for which the coders were unanimous in categorization. By doing this, we obtained a subsample of 151 COVID-19 related words, and 359 words that were unrelated to COVID-19. As depicted in Figure 8, the pattern of results that we have described in this paper (Figure 2) is almost identical in two groups of items (COVID-19 related and COVID-19 unrelated words). Therefore, the selective change in arousal that we have observed across the three points in time is related to emotional valence, and seems to be independent of relatedness to COVID-19.

Figure 8

The Relation between Emotional Valence and Arousal of COVID-19 Related (left panel) and COVID-19 Unrelated Words (right panel) Across the three Data Collection Waves



Discussion

Since the beginning of 2020, the world has faced the COVID-19 pandemic. Worldwide there were long-lasting lockdowns, limiting everyday life, daily movement, and face-to-face social interaction. The severe consequences of illness caused by COVID-19 virus, many losses of loved ones, lack of information or too much misinformation represented risk factors that elicited mental health issues, such as stress, anxiety, and depression (Rudroff et al., 2020; Wang et al., 2021; Sadiković et al., 2020; Damnjanović et al., 2021). Several authors have questioned whether the COVID-19 pandemic could be a significant situational factor influencing mental health and our emotional representations of words (Planchuelo et al., 2021). Therefore, in our study, we set two objectives: to collect the emotional valence and arousal ratings of words during and

after the coronavirus pandemic and to compare them with the estimates collected before the pandemic.

We monitored valence and arousal ratings for a large set of Serbian words during the course of COVID-19 pandemic. Using the pre-COVID-19 database as the starting point, we collected ratings during the lockdown in Serbia and two years later, at the point in time when the pandemic was settling down (we refer to this condition as the post-COVID-19). We found that valence did not change across the three conditions, whereas there were some important findings related to the arousal ratings. Although at the global sample there were no dramatic changes, we observed important differences in the relation between valence and arousal across the three points in time. Our most important finding showed that while the arousal elicited by words of negative valence tended to increase over difficult times, the arousal elicited by words of positive valence tended to decrease. This pattern was the same for COVID-19 related and COVID-19 unrelated words.

Our novel finding is in accordance with the results reported in a recent paper by Dellatorre and colleagues (2019). In their study, the authors investigated the effect of context on affective ratings and found the tendency of arousal ratings to decrease in times of suspense. However, unlike in their study, which used artificially induced context, our study was conducted in a real-life context. A similar study conducted during the COVID-19 lockdown in Spain recorded lower arousal estimates (Planchuelo et al., 2022). However, to the best of our knowledge, no other study observed differential change in arousal depending on the valence of words (the overall arousal level in our study remained constant during the lockdown and two years later).

Rudroff et al. (2020) proposed the '*pandemic fatigue*' hypothesis to account for the decrease in arousal levels. They hypothesised that the stress induced by the

pandemic was at the root of this finding. Our results related to the decrease in arousal ratings of positive words fit with the post-COVID fatigue hypothesis (Planchuelo et al., 2022). However, unlike the studies of Rudroff et al. (2020) and Planchuelo et al., (2022) that were conducted only during the lockdown, our study also spanned the time when none of the anti-COVID regulations were in place. Moreover, the third-wave data were collected during the summer vacations - a typical time of relaxation. In spite of that, the COVID-19 induced change in arousal persevered, suggesting prolonged post-COVID fatigue. Alternatively, the sustained drop in arousal estimates for positively valenced words may be due to the newly emerged crises in 2022. Continuous exposure of people to catastrophic news might have led to even more significant bias towards negative stimuli. This scenario is justified as Karademas et al. (2007) found that lower optimism is associated with a greater bias toward negative stimuli. Similar results were recorded in Segerstrom's (2001) study. She found that participants with higher optimism (more positive outcome expectations) had attentional bias (measured by emotional Stroop task and skin conductance response) toward negatively and positively valenced words. On the contrary, those with higher pessimism had an attentional bias only towards negatively valenced words. She concluded that attentional bias towards negative or threatening stimuli is adaptive because we need to avoid or face a dangerous situation. On the other hand, individuals with negative outcome expectancies are more focused on such stimuli, which may lead to poor coping strategies (using avoidance as the primary coping mechanism).

Although we did not measure the optimism levels, finding that positive words aroused our participants less leads to some concern since it could indicate that people experience stress as when they were under the lockdown. Such orientation toward negative stimuli could lead to less adaptive coping mechanisms, thus weakening overall

resilience to stress. According to Levine (2003) natural disasters and war are in the top ten social factors that promote vulnerability, i.e. negative environmental factors for resilience. Our and many others studies conducted during COVID-19 pandemic suggest that people behaved differently, had stronger emotional reactions, and felt more distressed, compared to period before or after the pandemic (Damnjanović et al., 2021; Marchini et al., 2020; Morales-Rodríguez et al., 2021; Rudroff et al., 2020; Sadiković et al., 2020; Wang et al., 2021) .

In the light of affective models, our data support the affective circumplex model (Colibazzi et al., 2010; Posner et al., 2005), according to which words can be mapped onto two orthogonal dimensions. Our data fits into all previous studies which supported the idea that valence and arousal could change independently.

From the technical point of view, our data suggest caution when using or collecting norming data. Unlike valence that can be used without restrictions, the norming data on arousal should be used with caution. A potential diagnostic tool for the validity of arousal data can be the signature U-shaped relation with valence.

From the mental-health perspective, our findings revealed a very vulnerable position of individuals during the times of crisis. Our data suggests that such times increase our potential to react to negatively charged words, while at the same time decreasing our potential to react to positively charged words. In other words, not only are we more sensitive to negative content, we also lose the potential to be revived by the positive content.

Finally, our findings open the door for potential investigations of the effect of contextual factors on other lexical-semantic variables that are typically used in psycholinguistic research.

Declarations

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Conflict of interests

The authors have no conflict of interests to declare that are relevant to the content of this article.

Ethics approval

The study was approved by Institutional Review Board of the Department of Psychology, Faculty of Philosophy, University of Belgrade and certify that the study was performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Consent to participate

Consent to participate was obtained from all individual participants included in the study.

Consent for publication

All participants signed informed consent which included consent for publication.

Availability of Data and Materials

All the data and study materials are fully available on the OSF platform [<https://osf.io/cfq8n/>].

Code availability

R codes will be fully available on the OSF platform [<https://osf.io/cfq8n/>].

Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Ksenija Mišić, Milica Popović Stijačić and Dušica Filipović Đurđević. The first draft of the manuscript was written by Milica Popović Stijačić (introduction and discussion), Ksenija Mišić (method and results) and Dušica Filipović Đurđević (results and discussion). Graphical abstract was made by Ksenija Mišić. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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References

- Bradley, M. M. & Lang, P. (1999). Affective norms for English words (ANEW): Instruction manual and affective ratings. Technical Report C-1, The Center for Research in Psychophysiology, University of Florida.
- <https://pdodds.w3.uvm.edu/teaching/courses/2009-08UVM-300/docs/others/everything/bradley1999a.pdf>
- Colibazzi, T., Posner, J., Wang, Z., Gorman, D., Gerber, A., Yu, S., Zhu, H., Kangarlu, A., Duan, Y., Russell, J. A., & Peterson, B. S. (2010). Neural systems subserving valence and arousal during the experience of induced emotions. *Emotion*, *10*(3), 377–389. <https://doi.org/10.1037/a0018484>
- Damjanović, K., Ilić, S., Teovanović, P., & Lep, Ž. (2020). Psihološki profil pandemije u Srbiji [Psychological profile of the pandemic in Serbia]. Psychosocial Innovation Network. <https://psychosocialinnovation.net/wp-content/uploads/2020/11/Psiholo%C5%A1ki-profil-pandemije-u-Srbiji.pdf>
- Delatorre, P., Salguero, A., León, C., & Tapscott, A. (2019) The Impact of Context on Affective Norms: A Case of Study With Suspense. *Frontiers in Psychology*, *10*:1988. <https://doi.org/10.3389/fpsyg.2019.01988>
- Hinojosa, J. A., Martínez-García, N., Villalba-García, C., Fernández-Folgueiras, U., Sánchez-Carmona, A., Pozo, M. A., & Montoro, P. R. (2015). Affective norms of 875 Spanish words for five discrete emotional categories and two emotional dimensions. *Behavior Research Methods*. <https://doi.org/10.3758/s13428-015-0572-5>
- Hristova, E. & Grinberg, M. (2015). Influence of Induced Mood on the Rating of Emotional Valence and Intensity of Facial Expressions. In: Bassis, S., Esposito, A., Morabito, F. (eds) *Advances in Neural Networks: Computational and Theoretical Issues. Smart Innovation, Systems and Technologies*, *37*. https://doi.org/10.1007/978-3-319-18164-6_29

- Kanske, P., & Kotz, S.A. (2010). Leipzig Affective Norms for German: a reliability study. *Behavior Research Methods*, 42(4). 987-91.
<https://doi.org/10.3758/BRM.42.4.987>
- Karademas, E.C., Kafetsios, K. & Sideridis, G.D. (2007). Optimism, self-efficacy and information processing of threat- and well-being-related stimuli. *Stress and Health*, 23, 285–294. <https://doi.org/10.1002/smi.1147>
- Kensinger, E.A. & Schacter, D.L. (2006). Processing emotional pictures and words: Effects of valence and arousal. *Cognitive, Affective, & Behavioral Neuroscience*, 6(2), 110-126. <https://doi.org/10.3758/CABN.6.2.110>
- Keuleers, E. & Balota, D.A. (2015) Megastudies, crowdsourcing, and large datasets in psycholinguistics: An overview of recent developments, *The Quarterly Journal of Experimental Psychology*, 68(8), 1457-1468,
<https://doi.org/10.1080/17470218.2015.1051065>
- Kostić, Đ. (1999). Frekvencijski rečnik savremenog srpskog jezika [Frequency Dictionary of Contemporary Serbian Language]. Institut za eksperimentalnu fonetiku i patologiju govora i Laboratorija za eksperimentalnu psihologiju.
- Kousta, S.-T., Vigliocco, G., Vinson, D. P., Andrews, M., & Campo, E. D. (2011). The representation of abstract words: Why emotion matters. *Journal of Experimental Psychology: General*, 140(1), 14–34. <https://doi.org/10.1037/A0021446>
- Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: valence and arousal affect word recognition. *Journal of experimental psychology. General*, 143(3), 1065–1081. <https://doi.org/10.1037/a0035669>
- Kurdi, B., Lozano, S. & Banaji, M. R. (2017). Introducing the Open Affective Standardized Image Set (OASIS). *Behavior Research Methods*, 49(2):457–470.
<https://doi.org/10.3758/s13428-016-0715-3>

- Kyröläinen, A.J., Luke, J., Libben, G. & Kuperman, V. (2021). Valence norms for 3,600 English words collected during the COVID-19 pandemic: Effects of age and the pandemic. *Behavior Research Methods*. <https://doi.org/10.3758/s13428-021-01740-0>
- Levine S. (2003). Psychological and social aspects of resilience: a synthesis of risks and resources. *Dialogues in Clinical Neuroscience*, 5(3), 273–280. <https://doi.org/10.31887/DCNS.2003.5.3/slevine>
- López-Carral, H., Grechuta, K., & Verschure, M. J. (2020). Subjective ratings of emotive stimuli predict the impact of the COVID-19 quarantine on affective states. *PLOS ONE*, 15(8), e0237631. <https://doi.org/10.1371/journal.pone.0237631>
- Marchini, S., Zaurino, E., Bouziotis, J., Brondino, N., Delvenne, V. & Delhayé, M. (2021). Study of resilience and loneliness in youth (18–25 years old) during the COVID-19 pandemic lockdown measures. *Journal of Community Psychology*, 59, 468–480. <https://doi.org/10.1002/jcop.22473>
- Monnier, C. & Syssau, A. (2014). Affective norms for French words (FAN). *Behavior Research Methods*, 46, 1128–1137. <https://doi.org/10.3758/s13428-013-0431-1>
- Moors, A., De Houwer, J., Hermans, D., Wanmaker, S., van Schie, K., Van Harmelen, A.-L., De Schryver, M., De Winne, J. & Brysbaert, M. (2013). Norms of valence, arousal, dominance, and age of acquisition for 4,300 Dutch words. *Behavior Research Methods*, 45, 169–177. <https://doi.org/10.3758/s13428-012-0243-8>
- Morales-Rodríguez, F. M., Martínez-Ramón, J. P., Méndez, I. & Ruiz-Esteban, C. (2021). Stress, Coping, and Resilience Before and After COVID-19: A Predictive Model Based on Artificial Intelligence in the University Environment, *Frontiers in Psychology*, 12. <https://doi.org/10.3389/fpsyg.2021.647964>

- Niedenthal, P. M., Auxiette, C., Nugier, A., Dalle, N., Bonin, P., & Fayol, M. (2004). A prototype analysis of the French category “émotion”. *Cognition and Emotion*, 18, 289–312. <https://psycnet.apa.org/doi/10.1080/02699930341000086>
- Planchuelo, C., Baciero, A., Hinojosa, J. A., Perea, M. & Duñabeitia, J. A. (2022). Social context effects on emotional language: The influence of the COVID-19 pandemic on the emotional evaluation of words. *Acta Psychologica*, 229, 103686. <https://doi.org/10.1016/j.actpsy.2022.103686>
- Popović Stijačić & Filipović Đurđević (accepted for publication). Perceptual richness of words and its role in free and cued recall. *Primenjena psihologija*.
- Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: an integrative approach to affective neuroscience, cognitive development, and psychopathology. *Development and Psychopathology*, 17(3), 715–734. <https://doi.org/10.1017/S0954579405050340>
- Redondo, J., Fraga, I., Padrón, I., & Comesaña, M. (2007). The Spanish adaptation of ANEW (Affective Norms for English Words). *Behavior Research Methods*, 39, 600–605. <https://doi.org/10.3758/BF03193031>
- R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org/>.
- Ridgeway G. et al. (2017). *gbm: Generalized Boosted Regression Models*. R package version 2.1.3. <https://CRAN.R-project.org/package=gbm>
- Rudroff, T., Fietsam, A. C., Deters, J. R., Bryant, A. D. & Kamholz, J. (2020). Post-COVID-19 Fatigue: Potential Contributing Factors. *Brain Sciences*, 10(12), 1012. <https://doi.org/10.3390/brainsci10121012>
- Sadiković, S., Branovački, B., Oljača, M., Mitrović, D., Pajić, D. & Smederevac, S. (2020). Daily Monitoring of Emotional Responses to the Coronavirus Pandemic in

- Serbia: A Citizen Science Approach. *Frontiers in Psychology*, 11. <https://doi.org/10.3389/fpsyg.2020.02133>
- Segerstrom, S. C. (2001). Optimism and Attentional Bias for Negative and Positive Stimuli. *Personality and Social Psychology Bulletin*, 27(10), 1334–1343. <https://doi.org/10.1177/01461672012710009>
- Stadthagen-Gonzalez, H., Imbault, C., Pérez Sánchez, M.A. et al. (2017). Norms of valence and arousal for 14,031 Spanish words. *Behavior Research Methods*, 49, 111–123. <https://doi.org/10.3758/s13428-015-0700-2>
- Teismann, H., Kissler, J. & Berger, K. (2020). Investigating the roles of age, sex, depression, and anxiety for valence and arousal ratings of words: a population-based study. *BMC Psychology*, 8(118). <https://doi.org/10.1186/s40359-020-00485-3>
- van Rij, J., Wieling, M., Baayen, R. H., & van Rijn, D. (2015). itsadug: Interpreting Time Series and Autocorrelated Data Using GAMMs.
- Wang, Y., Di, Y., Ye, J. & Wei, W. (2021) Study on the public psychological states and its related factors during the outbreak of coronavirus disease 2019 (COVID-19) in some regions of China. *Psychology, Health & Medicine*, 26(1), 13-22. <https://doi.org/10.1080/13548506.2020.1746817>
- Warriner, A.B., Kuperman, V. & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavioral Research Methods*, 45, 1191–1207. <https://doi.org/10.3758/s13428-012-0314-x>
- Wickham H (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag New York. ISBN 978-3-319-24277-4, <https://ggplot2.tidyverse.org>.
- Wickham, H., François, R., Henry, L. & Müller, K. (2022). *dplyr: A Grammar of Data Manipulation*. <https://dplyr.tidyverse.org> , <https://github.com/tidyverse/dplyr>.

Wood, S.N. (2006). *Generalized Additive Models: An Introduction with R*. Chapman and Hall/CRC.

Wood, S.N. (2011). Fast stable restricted maximum likelihood and marginal likelihood estimation of semi parametric generalized linear models. *Journal of the Royal Statistical Society B* 73(1). p 3-36. <https://doi.org/10.1111/j.1467-9868.2010.00749.x>

