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Research Article

Establishing physical functioning, quality of life and well-being during the first wave of the COVID-19 pandemic in Croatia

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ABSTRACT

The sudden emergence of COVID-19 has led to the confinement of people in homes around the world. In Croatia as well, people were in self-isolation and stayed at home. Since confinement conditions may greatly affect physical and mental health, we investigated the scope of physical activity (PA), well-being and quality of life. A total of 580 adults were surveyed online about PA and health-related quality of life during the lockdown in Croatia. The results have shown that men are more involved in vigorous-intensity PA and have better physical and mental health in almost all domains. When comparing respondents regarding categories of PA, participants with high levels of PA function better physically, have fewer role limitations due to emotional problems and have higher levels of emotional well-being, vitality, and general health. Males, participants with lower BMI, fewer role limitations due to emotional problems, greater vitality and better social functioning have better physical health. Participants who consider that their PA is adequate and engage more in PA, who have fewer role limitations due to physical health, less physical pain, and better general health have better mental health. The results provide insights into the physical and mental components of health during the pandemic. This supports the premise that physical and mental health are highly dependent, and that there is a need to promote the importance of PA, especially for women and those who are less physically active in pandemic times.

Keywords: physical activity, quality of life, emotional functioning, well-being, COVID-19 pandemic

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Introduction

The phenomenon of coronavirus disease represents a threat to health, but it also has negative consequences on people's mental health. Croatia had the most stringent restrictions and measures to reduce infection with the new coronavirus. Measures of social distancing were introduced - public and religious gatherings and sports events were forbidden, restaurants, shops and border crossings were also closed. Such measures have led to people being able to move less and consequently less able to engage in physical activity. A new theoretical framework describes an unexpected situation of COVID-19 in the context of the lack of control and high level of risk that can seriously affect health and well-being, and can be increased by isolation (Amanzio et al., 2020). Confinement measures caused negative emotions and psychological distress that can lead to sleep disorders, muscle tension, pain, and digestive and circulatory disorders (Liu et al., 2020). The positive relation between physical activity and exercise with physical and mental health is well-recorded (Bird et al., 2021). Physical activity increases hormone levels that can make people less stressed, happier and improve their ability to overcome difficulties more easily (Anderson & Shivakuma, 2013).

Unlike the medical model that defines health as the absence of disease or difficulties, the World Health Organization determines health as "a state of complete physical, mental and social well-being" (World Health Organization, 2001). The concept of well-being encompasses assessments of social, health, material, and subjective domains of quality of life (Diener et al., 2018). The emotional component of well-being represents a dimension of subjective well-being, which is defined as the experience of positive and negative affect (Keyes, 2000). Due to the conceptual ambiguity, the wellness model defines health as an internal experience or emotion that people enjoy or lack (Larson, 1999). The wellness model emphasizes a permanent feeling and state of mental health that positively affects and improves physical health (Larson, 1997). According to the environmental model, which arose from systems theory, health is considered as people's continuous adjustment to their environment (Gochfeld & Goldstein,

1999). Health-related quality of life contains functioning and well-being in the physical, mental, and social aspects of people's lives (Larson, 1997).

Recent research confirmed the negative psychological impact of movement restrictions (Brooks et al., 2020; Lauri Korajlija & Jokić-Begić, 2020). It has been shown that greater subjective well-being benefits health (Lyubomirsky et al., 2005). Also, physical activity positively affects the quality of life (Kurklu et al., 2015). During confinement, people could not exercise or maintain supporting social relations. As a result, there was a decrease in emotional well-being (Stieger et al., 2021). Furthermore, people's vitality may be decreased when they are less active and productive (Arslan, 2021). Regarding gender, existing findings in other countries (Italy, Austria) show that women have worse mental health during pandemics (Pieh et al., 2020; Rossi et al., 2020).

In general, physical inactivity is one of the major public health problems (World Health Organization, 2018) and could be a risk for disease morbidity (Hallal et al., 2012). Such a negative lifestyle can automatically increase sedentary behaviour (Ammar et al., 2020). Regular physical activity (PA) contributes to physical health indicators, positive mental health, and well-being (Chekroud et al., 2018). Follow-up data shows that females are generally less involved in physical activities than males (Telama, 2009). The reasons can be attributed to major life transitions and changes that have a greater impact on women's physical activity. Restriction measures on physical distancing, outdoor activities and confinement have led to major changes in physical activity (Đogaš et al., 2020). Consequently, there was an increase in sedentary behaviour, which poses a risk for gaining weight, cardiovascular problems, and high blood pressure (Balanzá–Martínez et al., 2020).

Well-being refers to optimal psychological functioning (Ryan & Deci, 2001), which requires the realization of basic psychological needs - personal growth, competence, and relatedness (Deci & Ryan, 2000; Ryan & Deci, 2017). Movement restrictions can aggravate satisfying basic psychological needs due to disabling socializing. Failure to satisfy basic psychological needs is related to impaired physical and mental health (Reis et al., 2000). In addition, restrictions

during a pandemic have led to a lack of social interaction, and consequently to a decrease in well-being (Son et al., 2020).

The purpose of this empirical research was to investigate the relation of physical and mental health with the physical activity habits of Croatian adults during COVID-19. Previous studies established a tight relation between physical and mental health and show that they are also distinguishable constructs (Farivar et al., 2007; Hays et al., 1994). According to the study aim, we hypothesized that men would engage more in physical activity and have better physical and mental health than women. Further, it is assumed that those who exercise more will have better physical and mental health, due to the general fact about the benefits of physical activity. Also, dimensions of physical health will predict mental health, and vice versa (Lins & Carvalho, 2016).

Method

Sample and procedure

Study included 580 working-age adults residing in Croatia between 18 and 69 years (*M* = 34.56, *SD* = 11.39). There were 171 male and 409 female participants in the sample, and two-thirds of them were employed (63.30%). Table 1 summarized participants' characteristics by gender since men and women generally differ in physical appearance. Male participants had a higher body mass index (BMI) than females. Although BMI is under criticism because it does not give accurate information regarding body composition it is still widely used to indicate the level of risk for morbidity and mortality.

Table 1

Participants' characteristics regarding gender

	Males (*n* = 171)				Females (*n* = 409)			
	Min	*Max*	*M*	*SD*	*Min*	*Max*	*M*	*SD*
Age	18	64	35.34	10.57	18	69	34.24	11.71
BMI (kg/m^2)	18.31	43.39	27.39	4.71	15.78	44.62	23.86	4.23

Note: BMI - Body mass index.

A cross-sectional study using an online self-administered questionnaire was performed. The participants were invited to participate between 14th and 21st May 2020, during the first wave of the COVID-19 pandemic in Croatia using a virtual snowball sampling method over social networks. Authors shared information regarding the research using Facebook and asked their contacts to participate and to further share the survey over social networks. This was the most convenient way of collecting data due to the partial lockdown in Croatia and the closure of most facilities. Our inclusion criteria were having residence in Croatia during specified period and understanding of Croatian language. Our exclusion criterion was being minor. Participation was voluntary and anonymous, and each participant had given consent to take part in the survey.

Instruments

The web-based survey questionnaire included demographic data and self-reported PA levels, health-related quality of life, and level of agreement with the statement „*My level of physical activity is adequate*".

Demographic data

Demographic data included age, gender, self-reported body height and body mass, level of education and employment status. Body mass index was calculated using a standard equation. The level of agreement with the statement "My level of physical activity is adequate" was assessed on a Likert-type scale of 1-5. Value 1 represented the answer *"strongly disagree*", while value 5 represented the answer *"strongly agree*".

International Physical Activity Questionnaire – Short Form (IPAQ-SF)

Physical activity was assessed with the Croatian version of *the International Physical Activity Questionnaire – Short Form (IPAQ-SF)* (Craig et al., 2003). The questionnaire is publicly available, used worldwide, and free to use. It aims to identify the frequency and duration of several domains of physical activity: walking, physical activity of moderate-intensity, physical activity of vigorous-intensity, as well as sedentary behaviour. Data were processed using official guidelines (IPAQ Group, 2005). Physical activity was quantified and

presented as MET-minutes per week, where 1 MET represents the rate of energy expenditure while sitting at rest. For most people, this approximates an oxygen uptake of 3.5 millilitres per kilogram per minute (Physical Activity Guidelines Advisory Committee, 2018). MET-minutes per week of specific activity are calculated by multiplying the MET value of specific activity with the duration of that activity in minutes. The following values of the intensity of physical activity were recommended by the official guidelines for data processing and used in the analysis: 3.3 METs for walking, 4.0 METs for physical activity of moderate intensity, 8.0 METs of physical activity of vigorous-intensity (e.g., 8.0 * walking days * walking minutes). Average time spent in sedentary behaviour was also calculated and presented in hours.

Participants were classified into three categories of physical activity. They were classified in the category of high PA if they performed a PA of vigorous-intensity on at least three days of the week, while achieving at least 1500 MET-minutes per week of total PA, or had seven days a week of any combination of walking, moderate-, or vigorous-intensity PA, while achieving at least 3000 MET-minutes per week of total PA.

Respondents were classified in the category of moderate PA if they performed three or more days of PA of vigorous-intensity of at least 20 minutes per day, or PA of moderate-intensity or walking at least 30 minutes per day, or five or more days in the week of any combination of walking, moderate- and vigorous-intensity PA, achieving at least 600 MET-minutes per week. Participants not meeting the criteria for moderate and high PA categories were classified as being in the category of low PA.

Short-Form Health Survey (SF-36)

Participants' health-related quality of life was assessed using the Croatian version of *the 36-Item Short-Form Health Survey (SF-36)*. The survey consists of 36 items grouped into 8 main domains of health (Jureša et al., 2000; Maslić Seršić & Vuletić, 2006; Ware & Sherbourne, 1992; Ware et al., 1993). The questionnaire is free to use. Each category is scored on a scale of 0-100. Value 0 represents the worst overall health status, and value 100 represents the best overall health status. The physical health component consists of the domains

physical functioning, role functioning/physical, bodily pain, and general health. The domain of physical functioning refers to the levels and types of performing all physical activities. Role functioning is defined with health-related limitations in the amount or type of work. Bodily pain determines the discomfort with everyday activities caused by pain. Item example includes: "How much bodily pain have you had during the past 4 weeks?". Personal beliefs about the quality of health represent the general health domain. The mental health component consists of the domain's vitality, social functioning, role functioning/emotional, and emotional well-being. Vitality includes energy level and fatigue. The domain of social functioning refers to the impact of physical health or emotional problems on normal social activities. Role functioning/emotional measures the levels of problems with daily activities or work due to emotional problems. Emotional well-being represents a subjective evaluation of satisfaction and happiness, and dimensions of anxiety, depression, loss of emotional control and psychological well-being ("How much of the time during the past 4 weeks have you felt so down in the dumps nothing could cheer you up?"). The physical health component and the mental health component can be combined into physical component summary (PCS) and mental component summary (MCS) scores. Data processing and scoring of the survey were performed according to official guidelines (Ware et al., 1994; Ware et al., 1993). The survey was tested on a representative sample of the Croatian adult population and acceptable psychometric characteristics were recorded (Jureša et al., 2000). The reliability of domains in this research was estimated, and all Cronbach alphas are above .70 (Cronbach alphas were high for domains of physical functioning and emotional well-being, $\alpha \geq .90$).

Statistical analyses

Descriptive statistical parameters were calculated for physical activity and health subscales. Reliability was calculated using Cronbach's alpha test. Differences were estimated with t-tests and Cohen's d effect size, ANOVA's and Welch test, and Games-Howell post-hoc test for unequal groups and variances. A series of hierarchical multiple linear regression analyses were conducted to

determine the predictors of PA levels and health-related quality of life domains on PCS and MCS scores. Statistical analyses were performed using SPSS 25.0 (IBM Corp. Released 2017).

Results

Descriptive statistics were calculated for all elements of PA and health survey subscales (Table 2). All measured variables show satisfactory reliability, and indicators of skewness and kurtosis suggest that there are no major deviations of distributions (Kline, 2011). Participants' mean values of BMI in our sample are at the upper recommended limit according to the World Health Organization classification for the European population (M = 24.89, SD = 4.66). Respondents estimate that they are moderately physically active (M = 3.15, SD = 1.34).

Table 2

Descriptive statistics and reliability coefficients (N = 580)

	k	*Min*	*Max*	*M*	*SD*	*Sk*	*Ku*	α
Body mass index (BMI) (kg/m^2)	1	15.78	44.62	24.89	4.66	1.26	2.17	-
Attitude towards reaching appropriate levels of PA	1	1.00	5.00	3.15	1.34	-0.13	-1.29	-
IPAQ-SF								
Vigorous-intensity PA (MET-min/week)	1	0.00	10080.00	2091.46	2281.96	1.44	1.63	-
Moderate-intensity PA (MET-min/week)	1	0.00	5040.00	1203.07	1265.83	1.30	0.99	-
Walking (MET-min/week)	1	0.00	4158.00	1585.18	1283.09	0.77	-0.59	-
Total PA (MET-min/week)	1	0.00	19278.00	4879.75	3767.05	1.16	1.04	-
Sedentary behaviour (h/day)	1	0.00	16.00	5.64	2.91	0.36	-0.54	-
SF-36 Health Survey								
Physical functioning	10	0.00	100.00	86.72	20.95	-2.09	3.83	.92
Role limitations due to physical health	4	0.00	100.00	75.60	35.74	-1.18	-0.13	.85
Role limitations due to emotional problems	3	0.00	100.00	66.03	41.85	-0.66	-1.30	.86
Vitality/Energy	4	0.00	100.00	55.97	18.67	-0.39	-0.02	.85
Emotional well-being	5	0.00	100.00	64.39	18.42	-0.72	0.32	.90
Social functioning	2	0.00	100.00	71.38	24.71	-0.72	-0.13	.70
Bodily pain	2	10.00	100.00	79.25	21.08	-0.97	0.20	.85
General health	5	10.00	100.00	69.91	18.02	-0.73	0.49	.77
PCS	21	20.00	100.00	77.87	17.71	-1.05	0.43	.89
MCS	14	3.00	100.00	64.44	21.15	-0.61	-0.51	.91

Note: k – number of items; *Min/Max* – minimal and maximal score; *Sk* - skewness; *Ku* - kurtosis; *α* - Cronbach alpha reliability coefficient; PA - physical activity; MET - metabolic equivalent; PCS - physical component summary; MCS - mental component summary.

Regarding PA, our respondents are highly physically active (*M* = 2091.46 MET-min/week). They walk a little less (*M* = 1585.18 MET-min/week), and engage in moderate-intensity PA at least (*M* = 1203.07 MET-min/week). In average, they sit over five hours a day.

Participants estimate their physical functioning as the highest of all subscales related to the quality of life (*M* = 86.72, *SD* = 20.95), and energy level the lowest (*M* = 55.97, *SD* = 18.67). They have more role limitations due to emotional problems (*M* = 66.03, *SD* = 41.85) than physical health (*M* = 75.60, *SD* = 35.74; greater result means better health and functioning). In general, respondents rate their overall physical health and functioning on average better (*M* = 77.87, *SD* =17.71) than their overall mental health (*M* = 64.44, *SD* = 21.15) in our sample.

Physical activity, sedentary behaviour, health-related quality of life and gender

Participants' level of PA, sedentary behaviour, and health-related quality of life by gender are shown in Table 3.

Table 3

Gender differences in physical activity levels, sedentary behaviour, and health-related quality of life

	Males (*n* = 171)		Females (*n* = 409)		*t*	*Cohen's d*
	M	*SD*	*M*	*SD*		
Attitude towards reaching appropriate levels of PA	3.23	1.33	3.11	1.35	0.97	-
IPAQ-SF						
Vigorous-intensity PA (MET-min/week)	2497.59	2353.79	1921.66	2232.33	2.79**	0.25

Moderate-intensity PA (MET-min/week)	1303.63	1315.67	1161.03	1243.64	1.24	-
Walking (MET-min/week)	1503.53	1299.02	1619.32	1276.43	-0.99	-
Total PA (MET-min/week)	5304.79	3890.64	4702.05	3704.56	1.76	-
Sedentary behaviour (h/day)	5.98	3.11	5.49	2.81	1.81	-
SF-36 Health Survey						
Physical functioning	88.51	21.86	85.97	20.54	1.33	-
Role limitations due to physical health	82.02	30.11	72.92	37.56	2.81**	0.27
Role limitations due to emotional problems	75.05	37.59	62.27	42.99	3.38**	0.32
Vitality/Energy	60.73	18.43	53.97	18.44	4.03**	0.37
Emotional well-being	67.86	17.24	62.93	18.72	2.96**	0.27
Social functioning	77.41	20.58	68.86	25.86	3.85**	0.37
Bodily pain	83.46	19.23	77.48	21.58	3.14**	0.29
General health	73.36	15.58	68.47	18.78	3.00**	0.28
PCS	81.84	15.42	76.21	18.35	3.52**	0.33
MCS	70.26	19.17	62.01	21.48	4.35**	0.41

Note: ** $p < 0.01$; PA - physical activity; MET - metabolic equivalent; PCS - physical component summary; MCS - mental component summary.

Regarding PA, the only gender difference was found for vigorous-intensity PA ($t = 2.79$, $p < .01$, *Cohen's d* = 0.25), where male participants accumulated higher levels of vigorous-intensity PA in comparison to female participants. Significant differences were found in all eight-health domains in favour of males, except physical functioning where there are no gender differences. Males have fewer role limitations due to physical health ($t = 2.81$, $p < .01$, *Cohen's d* = 0.27) and emotional problems ($t = 3.38$, $p < .01$, *Cohen's d* = 0.32),

and less bodily pain (t = 3.14, p < .01, *Cohen's d* = 0.29) in comparison to females. They have more vitality/energy (t = 4.03, p < .01, *Cohen's d* = 0.37), emotional well-being (t = 2.96, p < .01, *Cohen's d* = 0.27) and better general health (t = 3.00, p < .01, *Cohen's d* = 0.28) than females. Also, males estimate that they function better socially (t = 3.85, p < .01, *Cohen's d* = 0.37).

Health-related quality of life and physical activity

Three groups of participants were compared in health-related quality of life using an analysis of variance (Table 4). Welch test and Games-Howell post-hoc test was used due to unequal sample sizes in groups regarding PA.

Table 4

Differences in health-related quality of life between participants with low, moderate and high physical activity

	Low PA (n = 42)		Moderate PA (n = 142)		High PA (n = 396)		*Welch's F*
	M	*SD*	*M*	*SD*	*M*	*SD*	
Attitude towards reaching appropriate levels of PA $_{(L, M, H)}$	1.71	0.92	2.45	1.19	3.55	1.22	95.24**
SF-36 Health Survey							
Physical functioning $_{(L, H)}$	79.05	21.56	84.79	20.04	88.22	21.02	4.29*
Role limitations due to physical health	65.48	39.79	71.83	37.41	78.03	34.45	3.02
Role limitations due to emotional problems $_{(M, H)}$	60.32	44.93	53.05	43.52	71.29	39.87	9.97**
Vitality/Energy $_{(L, M, H)}$	40.00	18.64	47.82	17.81	60.58	17.01	44.41**
Emotional well-being $_{(L-H, M-H)}$	55.33	22.69	59.27	18.16	67.18	17.32	13.89**
Social functioning $_{(M, H)}$	66.07	27.78	65.40	25.81	74.08	23.54	7.07**
Bodily pain	74.35	25.96	77.54	20.69	80.38	20.57	1.81
General health $_{(L-H, M-H)}$	60.36	18.85	64.29	18.45	72.94	16.95	18.05**
PCS $_{(L-H, M-H)}$	69.81	18.75	74.61	17.71	79.89	17.22	8.94**
MCS $_{(L-H, M-H)}$	55.43	22.84	56.39	20.83	68.29	20.00	20.99**

Note: * $p < 0.05$; ** $p < 0.01$; PCS - physical component summary; MCS - mental component summary; L – low physical activity group; M – moderate physical activity group; H – high physical activity group.

Welch test shows differences in attitudes about appropriate levels of PA in these three groups (W = 95.24, p < .01). Respondents with high PA estimate their level of PA more adequate than respondents with low and moderate PA. Also, participants with moderate PA estimate the level of PA more adequate than respondents with low PA.

It was found in the subsample that those with high PA physically function better, have higher emotional well-being, better general health and overall physical (PCS) and mental health (MCS) than those with low PA. Participants with high PA have significantly more vitality/energy than those with moderate and low PA. Adults with moderate PA have significantly more role limitations due to emotional problems, they function worse socially, have poorer health, and overall physical (PCS) and mental health (MCS) than those with high PA.

Predictors of physical and mental health

The Short-Form-36 Health Survey is a very well-known instrument, which has long been in use and measure two components: a physical dimension represents the physical component summary (PCS) and mental dimension represents the mental component summary (MCS). Recent finding shows that physical and mental health constructs are strongly interrelated, unlike earlier views (Ware et al., 1994). Hence, all domains contribute to both measures of PSC and MCS in different proportions (Lins & Carvalho, 2016).

To determine predictors of physical and mental health components, hierarchical regression analyses (HRA) were performed. In the first step of the HRA, age and gender were entered, BMI, attitudes about adequate levels of PA, and PA was added in the second step, and health-related quality of life domains in the third step. Prior to HRA intercorrelations were calculated (see Appendix). It is found that all predictors correlate with PCS and MCS, except between body mass index and MCS.

Table 5
Hierarchical linear regression for the physical and mental health component

	PCS (β)			MCS (β)		
Step	1.	2.	3.	1.	2.	3.
Predictors						
Age	-.12**	-.05	-.06	-.01	.02	.04
Gender	-.15**	-.18**	-.08*	-.18**	-.16**	-.07*
Body mass index (BMI)		-.13**	-.11**		-.01	.04
Attitude towards reaching appropriate levels of PA		.24**	.09*		.28**	.14**
Physical activity (PA)		.05	-.03		.11*	.08*
Role limitations due to emotional problems			.16**			-
Vitality/Energy			.33**			-
Emotional well-being			-.05			-
Social functioning			.22**			-
Physical functioning			-			-.05
Role limitations due to physical health			-			.27**
Bodily pain			-			.16**
General health			-			.26**
ΔR^2	.04*	.10**	.22**	.03**	.12**	.25**
R^2	.04*	.14**	.36**	.03**	.15**	.40**

Note: * p <0.05; ** p < 0.01; PCS - physical component summary; MCS - mental component summary; *Tol* < 1; *VIF* < 2.

Data in Table 5 shows that gender, body mass index, and domains: role limitations due to emotional problems, vitality/energy, and social functioning contributed to the explanation of 36% of the variance of PCS. Males, participants with smaller BMI, fewer role limitations due to emotional problems, more energy, and better social functioning have significantly greater PCS. The strongest predictor is vitality/energy ($\beta = .33$, $p < .01$). Significant predictors for MCS are attitudes toward adequate levels of PA, physical activity, and domains: role limitations due to physical health, bodily pain and general health, which explain 40% of the variance. Participants who are adequately and highly physically active, have fewer role limitations due to physical health, less physical pain, and better general health have significantly greater MCS. Attitudes toward PA and PA itself explained 12% of the variance of MCS.

Discussion

The worldwide spread of the COVID-19 caused by the SARS-CoV-2 virus led to unprecedented measures of social distancing and other anti-epidemic measures such as working from home, closing of schools and universities, entertaining and sporting facilities, public transport closures and restrictions of the free movement worldwide, including Croatia.

The main findings of the study showed that higher levels of PA are associated with better physical and emotional functioning, as well as well-being. This study extends our knowledge regarding the association between PA and quality of life and offers some new insights regarding the possible use of PA in minimizing the harmful effects of confinement during the pandemic, especially in the domain of emotional and mental health. To our knowledge, this is the first such study carried out on the Croatian adult population during the first wave of the COVID-19 pandemic.

Most of our respondents were classified in the category of high physical activity. Our sample was engaged in approximately 37 minutes of vigorous-intensity PA, 43 minutes of moderate-intensity PA and 69 minutes of walking daily which exceeds current recommendations regarding optimal levels of PA (World Health Organization, 2010). Confinement allowed more time for domestic

and recreational activities, which could have contributed to higher levels of PA (Hammami et al., 2020). Other studies reported lower levels of PA than our study (Ozdemir et al., 2020; Qi et al., 2020). In Croatia, anti-epidemic measures did not include major restrictions on sports and recreation outdoor activities, and limitations in the time spent outside which could at least partially explain rather high levels of PA recorded.

In our sample males accumulated higher levels of vigorous-intensity PA compared to females, 45 min/day vs. 34 min/day. The study conducted on the Chinese population also reported higher levels of PA among males (Qi et al., 2020), and pre-pandemic studies are also reporting higher levels of PA in the male population (Bauman et al., 2009; Jurakić et al., 2009). Findings about lifestyle during COVID-19 in Croatia show that women exercised less frequently and spent less time exercising during the pandemic than males and in comparison, prior to the COVID-19 (Đogaš et al., 2020).

Males reported higher health-related quality of life almost in all health domains. This was not the case in a similar Chinese study (Qi et al., 2020), where no gender differences were reported regarding PCS and MCS. Some pre-pandemic studies also reported lower scores in domains of health-related quality of life among female participants (Messina et al., 2016; Pekmezović et al., 2011). Emotional well-being was adversely affected by the epidemic outbreak (Yang & Ma, 2020). It is interesting to see that there has been a decrease only in social functioning and role limitation due to emotional problems during COVID-19 in comparison to domains of health-related quality of life in pre-pandemic (Maslić Seršić & Vuletić, 2006).

Participants classified as highly physically active had better emotional well-being, general health, PCS, and MCS in comparison to those with a low level of PA. Furthermore, those with a high level of PA had the most energy. Those in the subgroup of moderate PA had more role limitations due to emotional problems, lower level of social functioning, poorer health, and lower PCS and MCS scores in comparison to a subgroup of individuals with high PA.

This is in accordance with other studies carried out during the first wave of the COVID-19 pandemic which reported that higher moderate to vigorous PA

levels are associated with less depressive, and fewer anxiety symptoms, as well as with overall better mental health (Jacob et al., 2020; Meyer et al., 2020; Schuch et al., 2020). PA status positively affected the quality of life and mental health in the Turkish population during the COVID-19 outbreak (Ozdemir et al., 2020). Higher PA is protecting factor from mental health problems during COVID-19 as well in the Portuguese population (Silva Moreira et al., 2021). Reduction of total physical activity is related to worse status of psychological well-being (Maugeri et al., 2020).

Our results showed that age, gender, BMI, attitudes about adequate levels of PA, PA, health-related quality of life domains all correlate with PCS and MCS (except BMI which did not correlate with MCS). Minimally active and health-enhancing PA groups had better physical, psychological, social and environmental domains scores in comparison to the inactive group (Slimani et al., 2020). These positive correlations between PA and physical and mental domains of quality of life were also reported in the pre-pandemic period (Shibata et al., 2007; Stewart et al., 2003; Wendel-Vos et al., 2004).

Being male, having lower BMI, fewer role limitations due to emotional problems, having more energy and better social functioning led to significantly greater PCS in this research. Being adequately and highly physically active, having fewer role limitations due to physical health and less bodily pain, and having better general health led to significantly greater MCS. Associations between lower levels of moderate-to-vigorous PA and poor mental health and well-being were also found in the UK population (Jacob et al., 2020). It is important to note that PA was a significant predictor of the mental component summary score in our study; however, it did not play a significant role in predicting the physical component summary score.

Numerous studies showed beneficial effects of regular PA on mental health and reduction of the risk of depression and anxiety (Physical Activity Guidelines Advisory Committee, 2018). Recent studies performed in the period of COVID-19 pandemic also established significant relation between physical exercising and a reduced stress response (Popov et al., 2021). In their study, they reported that the level of physical exercise during the lockdown situation was a

predictor of better mental health, regardless of the level of physical activity of the respondents before the state of emergency was introduced (Popov et al., 2021). Another recent research reported that elite athletes and those with high level of physical activity experienced the lowest distress and that prolonged physical inactivity had negative effects of mental health (Sokić et al., 2021).

Furthermore, significant gender differences in mental health during COVID-19 pandemic were found in this study. Recent study found out that women experienced more depression symptoms and disorders while men had more anxiety symptoms and disorders (Vloo et al., 2021). Another research performed during lockdown in Italy reported that women had lower level of physical activity before the institution of lockdown and lower tendency to reduce physical activity levels during the lockdown than men (Orlandi et al., 2021). Care for family members, especially children in the environment of online education could have prevented many women from engaging in physical activities.

Regarding these facts on beneficial effects of regular PA and relation to the quality of life, it seems reasonable to advise to maintain healthy lifestyle routines including appropriate levels of PA even during the pandemic and to develop behavioural strategies for staying active in appropriate way, respecting social distancing and other anti-epidemic measures. This is even more important because the long-term impacts of the pandemic on physical and mental health are unknown, as well as it is unknown and impossible to predict when the pandemic will finally end. It seems that PA could have some protective effects on some of the harmful aspects of pandemic and confinement.

The strength of the study is the use of valid and reliable questionnaires used worldwide which allowed comparison of results with other studies. Furthermore, our study was conducted on a relatively large sample and it is the first to explore the association between PA and well-being, physical and mental functioning in the adult Croatian population. This study includes participants throughout the whole adulthood. Respecting empirical findings is necessary and can facilitate creating prevention measures in crises.

The main limitations of our study include cross-sectional design and sample, which consisted of more female participants. They were recruited by social media and the results might not be representative of the general adult Croatian population. A possible shortcoming may present an unknown balance of physical and mental dimensions because it is not recommended to express the overall score of these two dimensions on the SF-36. The information of frequency and duration of several domains of physical activity were collected with The International Physical Activity Questionnaire – Short Form (IPAQ-SF). This is a generally accepted and often used instrument but has some limitations. The vast majority of research findings show that the relationship between IPAQ-SF and objective measures of activity or fitness is lower than the acceptable standards. Moreover, as measured by objective criterion, IPAQ-SF typically overestimates physical activity in an average of 84 percent (Lee et al., 2011). Therefore, it can be assumed that the IPAQ-SF is a weak indicator of relative or absolute physical activity. Future research should be directed on preventive strategies using physical activity, especially for women, to counteract the negative effects of COVID-19 pandemic on mental health.

Conclusions

In conclusion, our research adds important information to the body of evidence regarding the association between PA and emotional well-being, quality of life, physical, and emotional functioning during the COVID-19 pandemic. The results showed that PA, besides other well-known beneficial effects on health, could offer an important contribution regarding the maintenance of mental health and well-being during the pandemic. Regarding all that, we recommend that regular PA should be encouraged and included in public health measures and guidelines during the pandemic to counteract the negative effects of confinement.

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Conflict of interest

We have no conflicts of interest to disclose.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Appendix

Intercorrelations among variables

	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.Age	-.04	.33**	-.09*	.03	.04	.01	.01	-.07	.14**	-.05	-.06	-.11*	-.11**	.01
2.Gender	-	-.35**	-.04	-.07	-.14**	-.17**	-.12**	-.16**	-.06	-.12**	-	-.12**	-.15**	-.18**
3. Body mass index (BMI)		-	- .14**	-.03	.05	-.04	.01	-.03	-.17**	-.03	.13** -.07	-.15**	-.13**	.01
4.Attitude towards reaching appropriate levels of PA			-	.46**	.23**	.40**	.29**	.25**	.16**	.23**	.20**	.31**	.30**	.34**
5.Physical activity (PA)				-	.16**	.37**	.23**	.15**	.12**	.11**	.09*	.25**	.18**	.25**
6.Role limitations due to emotional problems					-	.45**	.55**	.50**	.10*	.42**	.31**	.29**	.41**	.85**
7. Vitality/ Energy						-	.78**	.50**	.16**	.36**	.44**	.56**	.51**	.76**
8.Emotional well-being							-	.58**	.13**	.33**	.40**	.48**	.45**	.83**
9.Social functioning								-	.19**	.40**	.40**	.37**	.47**	.77**
10.Physical functioning									-	.32**	.26**	.25**	.60**	.17**
11.Role limitations due to physical health										-	.53**	.36**	.85**	.48**
12.Bodily pain											-	.49**	.77**	.45**
13.General health												-	.66**	.48**
14.PCS													-	.55**
15.MCS														-

Note: * $p < 0.05$; ** $p < 0.01$; PCS - physical component summary; MCS - mental component summary

Tjelesna aktivnost, kvaliteta života i dobrobit ljudi odrasle dobi tijekom prvog vala pandemije COVID-19 u Hrvatskoj

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SAŽETAK

Iznenadnim pojavljivanjem COVID-a-19 došlo je do zatvaranja ljudi u vlastite domove u cijelom svijetu. Jednako je bilo i u Hrvatskoj - ljudi su provodili vrijeme u samoizolaciji, zatvoreni u vlastitim domovima. S obzirom da takvi uvjeti života mogu značajno utjecati na tjelesno i mentalno zdravlje, ispitana je tjelesna aktivnost (TA), dobrobit i kvaliteta života. Ukupno 580 odraslih sudionika ispunilo je online upitnik o TA i zdravstveno orijentiranoj kvaliteti života tijekom uvjeta samoizolacije u Hrvatskoj. Rezultati su pokazali kako su muški sudionici bili više uključeni u TA visokog intenziteta, kao i da su procijenili svoje tjelesno i mentalno zdravlje boljim u svim domenama. Prilikom usporedbe ispitanika s obzirom na kategoriju TA, oni s višim razinama TA funkcionirali su bolje u tjelesnom smislu, imali manje ograničenja zbog emocionalnih poteškoća, više razine emocionalne dobrobiti, vitalnosti i općeg zdravlja. Muškarci, sudionici s nižim ITM-om te manjim ograničenjima zbog emocionalnih poteškoća, vitalniji i oni s boljim socijalnim funkcioniranjem imali su bolje tjelesno zdravlje. Sudionici koji smatraju kako je njihova razina TA adekvatna i više sudjeluju u TA, oni s manjim ograničenjima zbog tjelesnog zdravlja, manjom tjelesnom boli te boljim općim zdravljem imaju bolje mentalno zdravlje. Rezultati pružaju uvid u tjelesnu i mentalnu komponentu zdravlja tijekom pandemije. Dobiveni nalazi potvrđuju pretpostavku o visokoj povezanosti tjelesnog i mentalnog zdravlja te o važnosti promicanja TA, posebno kod žena i onih koji su manje tjelesno aktivni tijekom pandemije.

Ključne riječi: tjelesna aktivnost, kvaliteta života, emocionalno funkcioniranje, dobrobit, pandemija COVID-19

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Research Article

Does Changing the Font Type Affect the Processing of Words Written in Cyrillic and Latin Alphabet?

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ABSTRACT

To understand the reading process, it is necessary to explore the mechanisms of visual word recognition. The basic level of that recognition is the processing of letters, their size and visual identity. The specificity of the Serbian language is characterized by the parallel use of two alphabetic systems – Latin and Cyrillic, which contain a number of common, but also their own unique letters. Since some of the differences between the fonts are based on visual specific aditions at the end of letter's lines, there is also a significant contribution of fonts in letter recognition and reading. The main goal of this study is to examine the effect of font type on the processing of Latin and Cyrillic words. The aim was also to examine the effect of letter degradation on the word processing in these two alphabetic systems. The study included two experiments with Latin and Cyrillic words written in lowercase and uppercase. Participants were 221 students from the University of Banja Luka. Three factors were varied in both experiments: alphabet, "visual availability" (which refers to the visibility of words after degradation), and font type. Two analyses were performed ANOVA by subject (F1 analysis) and ANOVA by item (F2 analysis). Results show that there is a main effect of visual availability on processing speed of words. Visual degradation has slowed reaction time, but this effect is not the same in Latin and Cyrillic words. Significant interaction of font and alphabet is confirmed only in F2 analysis, so these results have limited validity. This study also revealed differences between lowercase and uppercase. Degradation of lowercase was more detrimental

that degradation of uppercase. The obtained results indicate that word processing in two alphabetic systems can be partly explained by the visual characteristics and grapheme structure of their letters.

Key words: Latin alphabet, Cyrillic alphabet, font, visual degradation, grapheme characteristics

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Introduction

Reading is a process that allows us to adopt a significant amount of information. But reading efficiency depends on a variety of factors. It is determined by the limitations of the human information processing system, but also by factors related to the characteristics of the text being read. Thus, it was found that the size and proportion of letters, the length of words in the text, as well as the background on which these words are written, significantly affect the readability (Tinker, 1963). A number of studies have also found a significant contribution of the font (Brumberger, 2003; Gasser et al., 2005; Halin, 2016).

The font refers to the letters represented in a particular shape and size. Line extensions and the shape of the letters represent the basic discriminant characteristics of different fonts that can be used to write and transmit information. Therefore, font characteristics should be optimal for reading and recognition. Font types should be different but should also retain the uniqueness of each letter that is particularly important. Font types can be divided into two categories: serif and sans-serif font, which differ in structural details at the ends of the letters. The serif font is characterized by having fine horizontal lines at the top and the bottom of most letters. One of the most representative groups of a serif font is Times New Roman (Hoffmeister, 2016). On the other hand, sans-serif fonts do not have those horizontal lines, as is the case with Arial fonts (Woods et al., 2005). The appearance of Times New Roman and Arial fonts also differs in width in certain parts of the grapheme, that is, in Times New Roman font certain parts of the letter are wider than the other parts of the letter, while in Arial font all parts of the letter are of the same width (Hoffmeister, 2016).

Some studies have shown that speed and accuracy in reading are better with the words written in sans-serif font than a serif font (Dogusoy et al., 2016; Moret-Tatay & Perea, 2011; Moriss et al., 2002; Woods et al., 2005). On the other hand, Banerjee et al. (2011) have shown the opposite results. A small number of studies have examined the effect of the font on the processing of Cyrillic words. A study conducted by Akhmadeeva and colleagues examined the difference in the legibility of Cyrillic words written in serif and sans serif fonts for Russian

Cyrillic readers (Akhmadeeva et al., 2012). They also wanted to explore whether general laws like ecological hypothesis, developed on the Latin typography material, are valid for the Cyrillic script. The results of their study showed no difference in the average numbers of the words read per minute between serif and sans serif variants. Certain differences were determined depending on gender, age, and academic success.

In a series of experiments (Alexeeva & Konina, 2016, Alexeeva et al., 2017, Alexeeva et al., 2019), the authors measured the legibility of Russian Cyrillic letters depending on the font (fixed-size serif Courier New/proportional serif Georgia) in parafoveal vision. Letters were briefly presented in parafovea, either in isolation or surrounded by the asterisks (imitating a letter being within a word), and the participants were asked to name them. The eye-tracking prevented participants from looking directly at the letters. The results showed that Courier New is a less legible font than Georgia, especially when a letter is a part of a sequence. The results support feature-based letter perception inside words. In addition, the first confusion matrices for the Russian alphabet were created based on experiment results. Their analysis revealed that independently of font, letters with ascenders/descenders and round envelopes were the fastest to be recognized whereas letters that contained other letters (т-г) decreased identification accuracy.

A review of previous research shows that a larger number of studies were done in the Latin alphabet compared to the Cyrillic alphabet. The specificity of the Serbian language is reflected in the specific phenomenon of synchronous digraphy, which represents the parallel use of two alphabetic systems - Latin and Cyrillic (Ivković, 2013; 2015). This means that the same word can be written in Cyrillic and Latin. Both alphabets are composed of thirty letters, where each letter is represented by one grapheme, except the letters “lj”, “dž” and “nj” in Latin. Several researchers have investigated the differences in the processing of these two alphabets. Some of these studies did not show the difference or dominance of the letters of one alphabet over the other (Ognjenović et al., 1995; Rot et al., 1986), while others did (Rohaček, 1973). Vejnović et al. (Vejnović & Jovanović, 2012; Vejnović et al., 2011) found that the words written in Latin were pronounced

faster than the words written in Cyrillic. On the other hand, Pašić (2004) has shown that the words in Cyrillic are read faster. Šokčević et al. (2013) also found that in the task of visual search of words, the search time is shorter for Cyrillic sets. The advantage of the Cyrillic alphabet was obtained in a study about word recognition conducted by Filipović-Đurđević et al. (2013). These studies clearly show that there are certain differences in the processing of two alphabets in the Serbian language. We wanted to examine whether the visual characteristics of the letters could explain these differences. Certain studies with the same goals have already been done which show that the effect of degradation is not the same in the Latin and Cyrillic alphabets (Borojević et al., 2018; Borojević & Stančić, 2019). In those studies that manipulated the amount of information available in such a way that the lower half, the upper half of the word, or the whole word was visible, it was found that the upper parts of the grapheme and the entire Latin grapheme contain the same amount of information needed for word processing, while lower parts have very low informative value. No such regularity was found for words written in Cyrillic. As an explanation of these results, it is stated that Latin graphemes have fewer line extensions in the upper part, as well as several specific extensions in the upper parts, while the lower parts of a larger number of graphemes have the same shape and are more difficult to distinguish. Since the font refers primarily to the visual aspect of the structural parts of the letter, the aim of this research is to check whether the manipulation of the font will lead to a change in the word processing speed in the two alphabetic systems. Since some of the differences between the fonts are reflected in the appearance of the line ends and the specific additions to them, we also tried to examine the effect of visual degradation in these, for fonts, important segments. This implies that the grapheme structure of the letters differs in these alphabetic systems and by including different fonts, knowledge about the effect of the visual characteristics on word processing will be expanded. Two typical representatives of serif and San-serif fonts were selected – Times New Roman and Arial. This study included two experiments. In one case, lowercase letters were used, while in the other experiment, uppercase letters were used. Numerous studies have shown that there is a difference in the processing of lowercase and uppercase letters, due to the specific appearance but also the

frequency of use (Arditi & Cho, 2007; Smith et al., 1969; Tinker, 1963), so that the relevant findings can be obtained by including both types of letters.

Experiment 1

The main goal of this experiment is to examine the effect of font type on the processing of Latin and Cyrillic words. Since Times New Roman, as a typical representative of serif fonts, has specific horizontal additions at the ends of the lines, it is assumed that they will lead to the facilitation of word processing in relation to the Arial font. As the differences between the fonts are determined partly by these additions at the ends of the lines, we also wanted to examine the effect of degradation in the upper and lower segments of the letters on the word processing in the two alphabetic systems. We assume that degradation will have different effects on the processing speed of Latin and Cyrillic words due to their specific grapheme structure. In this experiment, we used uppercase letters to create stimuli. Although they appear less frequently in written text, uppercase letters have specific visual characteristics that may differ, not only in relation to lowercase letters, but also in relation to which alphabetical system they belong to.

Method

Participants

One hundred and forty-one students from the University of Banja Luka participated in the experiment.[1] Participation in the research was conditioned by the fulfillment of three criteria. These criteria were: Cyrillic was the first learned alphabet, there is no preference for one alphabet in reading and writing (according to the participants' statements), and there are less than 30% errors in

[1] Part of the data collected on a number of respondents from this sample is published previously (Borojević et al., 2019).

the experimental task. All the participants had normal or corrected to normal vision.

Materials and design

Three factors were varied in this experiment: alphabet, visual availability of information, and font type. The alphabet was a between-subjects factor and had two levels - Cyrillic and Latin. Visual availability was also a between-subjects factor and had three levels - visible whole word, visible upper half of the word, and visible bottom half of the word. Although this could be a within-subject factor, we treated it as unrepeatable, in order to reduce the possibility of learning stimuli and getting used to them. Font type was also a between-subjects factor and had two levels – Times New Roman and Arial. The dependent variables were reaction time and a number of errors in the task. The stimuli were 60 words and 60 pseudowords, composed of six letters and written in Times New Roman 48 font. The words were nouns (masculine, nominative, singular).

All nouns had 6 letters, two syllables, and did not contain the letters "lj", "nj" and "dž", because they contain two characters in the Latin alphabet. Noun frequency ranged from 1 to 115 ipm. The average value was 34 (SD = 32.02). All nouns were selected from The Frequency Dictionary of Contemporary Serbian Language (Kostić, 1999). The same stimuli were presented in both alphabets and were written in uppercase letters. They were black, on a white background.

Procedure

The subjects were tested individually and were randomly divided into experimental situations that were created by a combination of three factors (2x3x2). The lexical decision task was used and 120 stimuli were presented in each experimental situation (60 were words and 60 were pseudowords generated in the Wuggy program; Keuleers & Brysbaert, 2010). At the beginning of the experiment, the subjects read the instruction, which said that a string of letters would appear on the screen, and their task was to answer whether the string shown represented a word or a pseudoword. The task started with the fixation point in the center of the screen for 50 milliseconds. After that, a stimulus was

presented at the same position. The participants responded by pressing the appropriate key („R" for word and „P" for pseudowords) on the keyboard. Each participant had 120 trials with an additional six trials for exercise. Response time was measured, as well as the number of errors in the experimental situation. The experiment was carried out using the software package SuperLab 4.5 for Windows (Cedrus Corporation, 2010). After the experiment, all participants completed a questionnaire examining the order of alphabet learning and the preferences for one alphabet in reading and writing. The whole procedure lasted about fifteen minutes.

Results and Discussion

We analyzed reaction times only for correct answers. Approximately 15% of the data was removed. Descriptive statistics are shown in Table 1. Reaction times were log-transformed before ANOVA was applied. We performed ANOVA by subject (F1 analysis) and ANOVA by item (F2 analysis) to examine the effect of three factors on words processing: alphabet, „visual availability" and font. In addition to the main effects, we also tested two-way interactions between all the varied factors.

Table 1

Descriptive statistics of experimental conditions

Alphabet	Visual availability	Font	*M*	*SD*
Cyrillic	VW	TNR	806.72	311.36
		Arial	931.72	376.44
	VB	TNR	1591.74	599.26
		Arial	1625.56	691.16
	VU	TNR	1423.48	608.75
		Arial	1622.90	730.75
	VW	TNR	870.32	357.74
		Arial	789.82	326.78

Latin	VB	TNR	1326.52	580.30
		Arial	1376.01	642.29
	VU	TNR	1437.78	677.70
		Arial	1391.38	638.84

Note. VW-visible whole word, VU-visible upper part of words, VB-visible bottom part of words

F1 ANOVA shows that there is a main effect of „visual availability" on reaction time ($F1$(2,129) =1 04.098, p < .001, ηp^2 = .617). Post hoc analysis with a Bonferroni correction revealed that visual degradation significantly increases the processing speed. Reaction time is shorter for visible whole word than for the visible bottom half of the word (p < .001) and for words where the upper half was visible (p < .001). On the other hand, there is no difference in reaction times between degraded words (p > .05). There is also a statistically significant effect of the alphabet on the processing speed of words ($F1$(1,129) = 8.881, p < .01, ηp^2 = .064). The response time for Latin words is shorter than the response time for Cyrillic words. Although the effects of these factors are highly statistically significant, the effect sizes are different. "Visual availability" has a large effect, and explained 61% of all variance in reaction time. Alphabet has a small effect size.

F2 ANOVA reveales also significant effect of „visual availability" on RT ($F2$(2,698) = 500.345, p < .001, ηp^2 = .589). The distribution of results is the same as in the F1 analysis. The same significant effect is found for alphabet ($F2$(1,698) = 44.540, p < .001, ηp^2 = .060), with shorter RT for Latin words. But, F2 ANOVA reveals a statistically significant interaction between alphabet and font ($F2$(1,698) = 15.603, p < .001, ηp^2 = .022). Cyrillic words written in Times New Roman are processed faster than the words written in Arial (p < .05), while there is no difference in RT between Latin words written in different fonts (p > .05) (Figure 1). The initial hypothesis about processing facilitation due to specific additions in the Times New Roman font was confirmed only for Cyrillic letters, although this outcome has a trivial effect size.

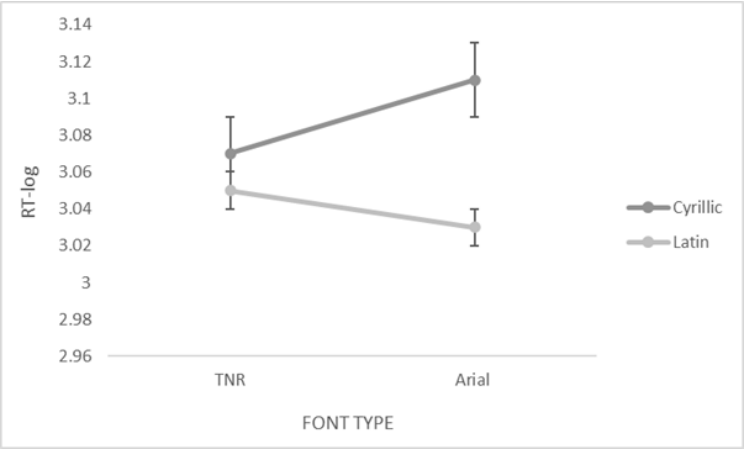

Figure 1. Reaction time depending on the font and alphabet.

Results also show that interaction between the alphabet and "visual availability" is also significant ($F2(2,698 = 6.820$, $p < .01$, $\eta p^2 = .019$). Visual degradation has slowed word processing (Figure 2), but visual availability of only the lower part of letters is more detrimental for Cyrillic than for Latin words. Non-degraded Cyrillic words are processed faster than words with the upper part visible ($p < .001$) and words with the lower part visible ($p < .001$). But there is also a difference with degraded Cyrillic words. Words with the upper part visible are processed slower than words with the lower part visible ($p < .05$). In Latin words, results show that reaction time is shorter for non-degraded words than for words visible in the upper part ($p < .001$) and words visible in the lower part ($p < .001$). But no differences in processing speed were found between the degraded Latin words ($p > .05$). Based on the obtained results, conclusions can be generalized about the effects of the alphabet and „visual availability" on words processing speed, because they are confirmed in F1 and in F2 analysis. But the effect of the font is significant only in F2 analysis, so the results can be limited only to the set of stimuli applied in this study.

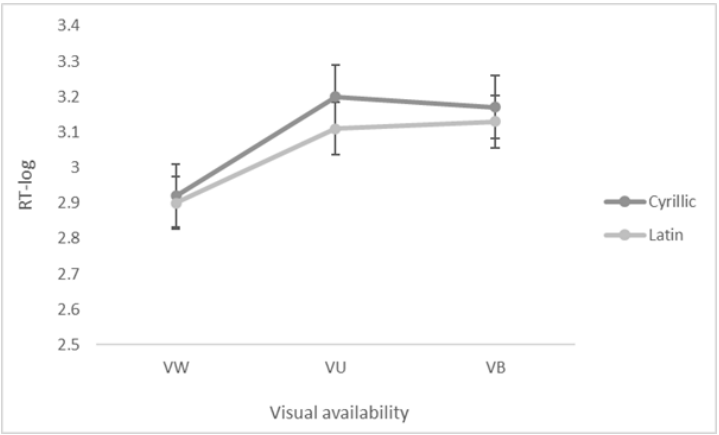

Figure 2. Reaction time depending on the alphabet and visual availability of words

Note. VW-visible whole word, VU-visible upper part of words, VB-visible bottom part of words.

Experiment 2

The aim of this experiment, the design and procedure were the same as in the previous experiment. A new group of subjects was randomly assigned to experimental situations. The final sample consisted of 80 subjects who met the same criteria as in the first experiment[2]. The only difference was in the type of stimuli. The lexical decision task was applied to the words and pseudowords written in the lowercase letters.

Results and Discussion

As in the first experiment, three factors were included in the analysis (alphabet, "visual availability" and font). But, for the Cyrillic alphabet, two levels of the "visual availability" factor had to be excluded from further statistical analysis due to a large number of errors (in this and in the previous study). A large number of errors in these experimental situations indicate that the informativeness of these

[2] Part of the data collected on a number of respondents from this sample is published previously (Borojević & Stančić, 2018).

parts of lowercase letters is higher compared to other parts, so their removal makes processing more difficult. For this reason, we did the analysis only for non-degraded words. Descriptive statistics are shown in Table 2.

Table 2
Descriptive statistics of expermental conditions

Alphabet	Font	M	SD
Cyrillic	TNR	882.49	352.68
	Arial	807.76	223.23
Latin	TNR	981.61	401.02
	aRIAL	922.67	398.51

We only included RT for correct answers in the analysis. Data were transformed by taking log-transformation and two separate analysis were run, ANOVA by subject (F1) and ANOVA by item (F2). F1 analysis did not reveal any significant effect of a varied factor on processing speed. But in F2 analysis results showed that there is the main effect of the alphabet on RT ($F2(1,235 = 20.309$, $p < .001$, $\eta p^2 = .080$). Latin words written in lowercase are processed slower than Cyrillic words (Figure 3). The main effect of font is also statistically significant ($F2(1,235 = 4.672$, $p < .001$, $\eta p^2 = .019$). The words written in Arial font are processed faster than Times New Roman, but the effect size is trivial (Figure 4).

Although certain differences were found in this experiment with respect to the font type, the results obtained are limited to the stimuli used in this study.

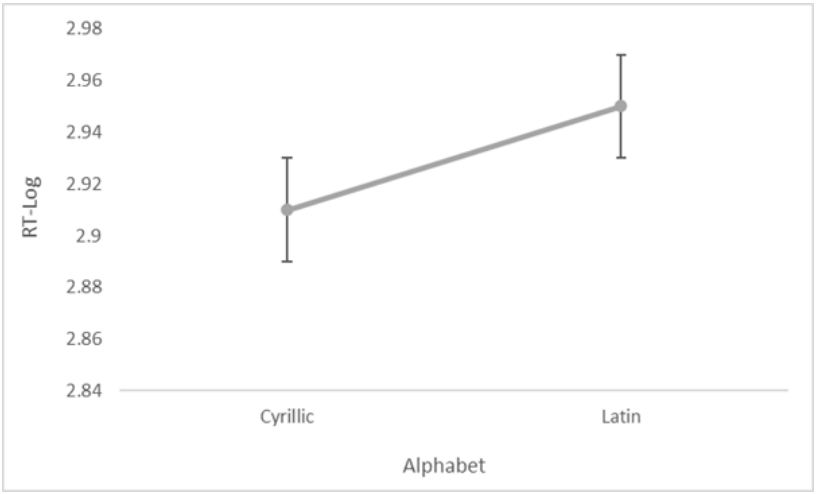

Figure 3 . Reaction time depending on the alphabet

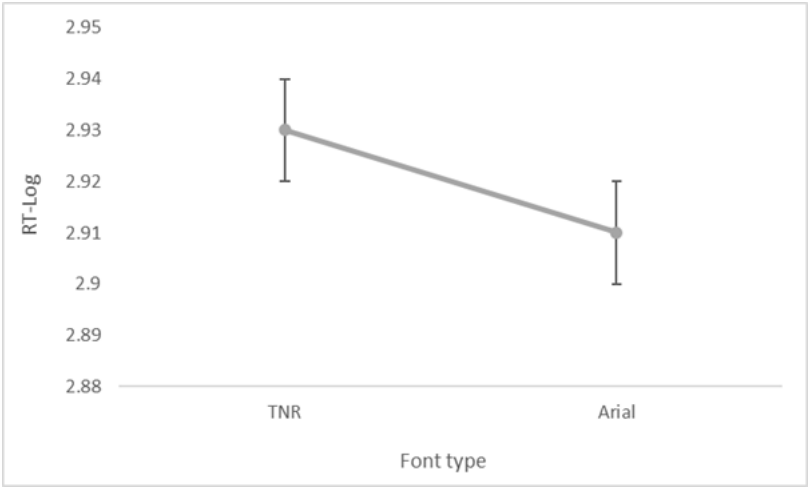

Figure 4. Reaction time depending on the font

General discussion

This research was conducted to examine whether the change in font affects the processing speed of Latin and Cyrillic words, given that fonts differ in visual properties. Previous two studies with degradation of graphemes

(Borojević et al., 2018; Borojević & Stančić, 2019) found a difference in the processing of Cyrillic and Latin words. It has been found that certain parts of the letter, viewed through a frame of horizontal asymmetry, are more informative than others. Arial font was used in those studies, but a few studies show that different fonts can improve or slow down the speed of letters and word processing (Dogusoy, et al., 2016; Moret-Tatay & Perea, 2011; Moriss et al., 2002; Pelli et al., 2006; Woods et al., 2005). We assumed that the words written in Times New Roman font would be processed faster because they contained specific additions in the form of small strokes at the end of the letters. This is partially confirmed only for the Cyrillic alphabet and for the words written in capital letters.

However, such conclusions are limited only to the stimuli selected for this study. With that limitation, it could be said that these results are in line with previous research, whose basic conclusion is that serif fonts contain letters that are more different from each other and allow faster reading with less fatigue (Bernard et al., 2003; Lannon, 2000; Mansfield et al., 1996). Serifs in Times New Roman also make it easy to point out the ends of letters and make identification easier. Those horizontal serifs that are positioned along the font baseline make it easier to track that line and read faster (Arditi & Cho, 2007). The results are also consistent with the findings of the research that was focused only on the Cyrillic alphabet (Alexeeva et al., 2019), which showed an advantage of serif fonts in recognizing letters and words. As this was not confirmed on the Latin stimuli, it could indicate that the visual representations of the letters in the two alphabets are unequal, and cause processing differences. But the differences found in processing speed depending on the font type are not so strong (according to the effect size). Serif as a small ornament at the end of the letter can be informative enough to lead to easier identification, but the amount of visible information seems to be more important. Removing the upper or lower parts of the letters significantly reduces the reaction time, regardless of whether they are written in TNR or Arial font.

In the experiment in which the stimuli were the words written in lowercase letters, the obtained results completely deviate from the initial

hypothesis. However, before the explanation of these results, it should be noted that due to a large number of errors, it was impossible to analyze certain experimental situations (those related to visual degradation). Visual degradation had such a pronounced negative effect that it was practically impossible to process the words accurately. Therefore, these experimental situations were excluded. It seems that in lowercase letters the individual segments of lines located in the upper or lower half contain a greater amount of information than in the case of uppercase letters. Obviously, the processing of lowercase and uppercase letters is not equally demanding, which has been confirmed by previous studies (Arditi & Cho, 2007; Smith et al., 1996; Tinker, 1969). Lowercase letters are commonly used, and this is why some authors consider them better stimuli (Sanocki & Dyson, 2012). Furthermore, lowercase letters differ in size and specific parts, the so-called ascenders, and descenders, which makes them more discriminable than uppercase letters that are the same size. The removal of these ascenders and descenders in this and in the previous study actually inhibited this letter discrimination. On the other hand, it was found that the words written in lowercase were processed faster in Arial font compared to Times New Roman. But, as in the first experiment, only one analysis conducted by items revealed these results, so we can not generalize it. Although the data are unexpected and have limited validity they could be explained by the interpretation offered by Woods et al. (2005). In a study they conducted in order to compare the legibility of lowercase letters in two different fonts, the advantage of the Arial font was also determined. The authors attributed this advantage to the font size. Arial's x-height (the distance between the baseline and the top of the main body of lowercase letters) is larger than Times New Roman's in the same point size, which makes Arial more legible. They also pointed out that Arial has a uniform stroke width, which increases its legibility.

Conclusion

This study has shown a particular effect of font type on word processing speed in the Serbian language. But this effect is weak and not the same in the Cyrillic and Latin alphabet. We selected Times New Roman and Arial as the two

representatives of serif and sans serif fonts. TNR is more frequent, and it is the most used font in written media. If we conducted research on another font that was designed for reading from the screen (such as Georgia) we might get a clearer perspective on the relationship between font and word processing in two alphabetic systems in the Serbian language. On the other hand, visual availability has shown a strong influence on processing speed. The degradation of letters had a very detrimental effect on word recognition. Therefore, further research should be taken in order to examine whether the difference in word processing can be explained by the visual characteristics of the letters. Instead of analyzing the upper and lower parts of the letters, research can also be shifted to a more specific, molecular level. It is necessary to determine whether certain structural parts of the letters (such as terminations, intersections, or curves) are more important for their processing and whether they differ in the Latin and Cyrillic alphabet.

Conflict of interest

We declare that we have no conflict of interest in submitting the manuscript "Does changing the font type affect the processing of words written in the Cyrillic and Latin alphabet?" in Primenjena psihologija.

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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Da li promjena tipa fonta utiče na obradu latiničnih i ćiriličnih riječi?

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SAŽETAK

Da bismo razumjeli proces čitanja, neophodno je istražiti mehanizme vizuelnog prepoznavanja riječi. Osnovni nivo tog prepoznavanja je obrada slova, njihove veličine i vizuelnog identiteta. Specifičnost srpskog jezika karakteriše paralelna upotreba dva alfabetska sistema – latinice i ćirilice, koja sadrže niz zajedničkih, ali i svojih jedinstvenih slova. Pošto su neke od razlika između fontova zasnovane na vizuelnim specifičnim dodacima na kraju linija slova, postoji i značajan doprinos fontova u prepoznavanju i čitanju slova. Osnovni cilj ove studije je da se ispita uticaj tipa fonta na obradu latiničnih i ćiriličkih riječi. Cilj je takođe bio da se ispita efekat degradacije slova na obradu teksta u ova dva alfabetska sistema. Studija je obuhvatila dva eksperimenta sa latiničnim i ćiriličnim riječima ispisanim malim i velikim slovima. Učestvovao je 221 student Univerziteta u Banjoj Luci. Varirana su tri faktora u oba eksperimenta: pismo, „vizuelna dostupnost" (koja se odnosi na vidljivost riječi nakon degradacije) i tip fonta. Urađene su dvije analize ANOVA po subjektu (F1 analiza) i ANOVA po predmetu (F2 analiza). Rezultati pokazuju da postoji glavni efekat vizuelne dostupnosti na brzinu obrade riječi. Vizuelna degradacija je usporila vrijeme reakcije, ali ovaj efekat nije isti u latinici i ćirilici. Značajna interakcija fonta i alfabeta potvrđena je samo u analizi F2, tako da ovi rezultati imaju ograničenu validnost. Ova studija je takođe otkrila razlike između malih i velikih slova. Degradacija malih slova je imala negativniji efekat od degradacije velikih slova. Dobijeni rezultati ukazuju da se obrada teksta u dva alfabetska sistema djelimično može objasniti vizuelnim karakteristikama i grafemskom strukturom njihovih slova.

Ključne riječi: latinica, ćirilica, font, vizuelna degradacija, grafemske karakteristike

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Research Article

The effect of a dyslexia-specific Cyrillic font, LexiaD, on reading speed: further exploration in adolescents with and without dyslexia

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ABSTRACT

The current study aims to test the assumption that a specially designed Cyrillic font, LexiaD, can assist adolescents with reading problems and facilitate their reading experience. LexiaD was compared with the widely used Arial font. Two groups of adolescents with dyslexia (N = 34) and without dyslexia (N = 28) silently read 144 sentences from the Russian Sentence Corpus (Laurinavichyute et al., 2019), some of which were presented in LexiaD, and others in Arial, while their eye movements were recorded. LexiaD did not show the desired effect for adolescents at the beginning of the experiment: Arial outperformed it in reading speed in both participant groups. However, by the end of the experiment, LexiaD showed a better performance. Although the speed of the higher-level cognitive processing (e.g., lexical access) in both fonts did not differ significantly, the feature extraction was found to be better in LexiaD than in Arial. Thus, we found some positive effect of LexiaD when participants with and without dyslexia got accustomed to it. A follow-up study with an explicit exposure session is needed to confirm this conclusion.

Keywords: dyslexia, font, eye tracker, printed text, Russian

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Introduction

Dyslexia is one of the most common disabilities affecting language learning. People suffering from it experience difficulties mastering reading and writing skills (I. D. Association, 2021). Most researchers claim that the main cause of dyslexia is linked to issues with phonological processing (I. D. Association, 2021; Ramus et al., 2003; Shaywitz et al., 2004; Snowling, 2012). People diagnosed with dyslexia struggle with grapheme-phoneme associations, namely representing and activating phonemes (Ramus et al., 2003).

Nevertheless, visual origins of reading problems stemming from visual recognition and eye movement control dysfunction are also put forward by certain authors (Stein, 2018; Stein & Walsh, 1997). From the end of 19th century and till the mid-1950s, dyslexia was even called "word blindness" (Hinshelwood, 1917; Morton, 1980; Orton, 1925). The British Dyslexia Association (BDA) emphasizes that some people with dyslexia may experience visual processing difficulties (B. D. Association, 2021a). A lot of teachers who experience dyslexia firsthand in their students support the view that the main issue consists in letters changing the order inside the word during the reading process (Washburn et al., 2014). Besides, people with dyslexia themselves report letters in words being swapped or blurred and lines of text shifted, although those common difficulties are true for some people with dyslexia and not for others (Brunswick, 2012).

Altogether, it seems reasonable to believe that there is a subset of people with dyslexia that struggle with reading difficulties due to deficient visual processing only or in combination with phonological issues. Therefore, interventions addressing this issue could target the visual representation of a text, namely, eliminate or replace visually difficult features.

Several studies elaborated on the typographical features that cause difficulties for people with dyslexia. These features include small character size (O'Brien et al., 2005), standard distance between letters that results in their appearance being influenced by surrounding letters (a so-called crowding effect) (Perea et al., 2012; Zorzi et al., 2012) and cursive letter shapes (Rello & Baeza-Yates, 2013). All these features constitute the essence of a typeface — a lettering design including

variations in letter appearance. Therefore, specialized typefaces bring hope that reading will become easier at least for some people with dyslexia.

Following this logic, several Latin-based dyslexia-friendly fonts were created (i.e., Dyslexie, OpenDyslexic, Sylexiad, Read Regular, EasyReading™). Its developers claim that they enhance text readability. The first scientific (empirical) findings failed to prove a reading advantage for Dyslexie and OpenDyslexic (Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Rello & Baeza-Yates, 2013; Wery & Diliberto, 2017; Zikl et al., 2015). However, it is worth noticing that no evidence was found in these studies that specialized fonts worked worse than the control ones (Arial, Times New Roman, Times, CMU, Courier, Helvetica, Verdana, Myriad, Garamond) at least in terms of reading speed. Moreover, it was shown that EasyReading™ had positive impact on reading performance (Bachmann & Mengheri, 2018).

Moreover, OpenDyslexic is currently an optional choice on many websites, including Amazon Kindle[3], Instapaper[4], and Kobo eReader[5]. We believe that those inclusion efforts should be further supported. Further effort on the dyslexia-friendly typefaces might be rewarded in the future and such typefaces should be given a try for languages with non-Latin-based writing systems.

Cyrillic font LexiaD and other dyslexia-specific Cyrillic fonts

Specialized fonts for people with dyslexia have been developed for Cyrillic as well. For example, members of the Faculty of Philosophy in Skopje (North Macedonia) created a font Dyslexic FZF (Karovska Ristovska & Filipovska, 2018). It is a Sans Serif font that is based on Open Dyslexic font. Its main features are heavier bottoms of the letters (that are thought to prevent letters from turning upside down or rotating when the reader sees them), an increased letter size, a wider distance between lines, and a stronger contrast. In addition, Dyslexic FZF, as well as Dyslexie, features tilting of the vertical and horizontal lines of the letter and

[3] https://www.amazon.com/b/?node=11516960011

[4] https://blog.instapaper.com/post/31834532875

[5] https://help.kobo.com/hc/en-us/articles/360020048733-Use-the-OpenDyslexic-font-on-your-Kobo-eReader

increased openings (for instance, in “e”, “s”, and “a”). Dyslexic FZD font does not feature a thickening of the capital letters (Karovska Ristovska & Filipovska, 2018).

Another example is the font АнтиДислексия, a core feature of the app ПростоСлово (http://app.prostoslovo.com). The app lets people with dyslexia change the visual representation of the texts (in particular, letter size, spacing between letters, words, and lines, background color, text color). The font АнтиДислексия is inspired by the Dyslexie font (A. Minz, personal communication from November 01, 2021). It is a fixed-width font that features increased distances between characters and words, and characters with wider and heavier bottoms (that are believed to work like an anchor). Elements that are the same in regular fonts are designed as unique which is thought to prevent letters from being confused.

To the best of our knowledge, these fonts have not been empirically tested. Several books designed by A. Minz (personal communication from November 01, 2021), however, were used as an intervention in the Speech remediation center in Moscow (Russia). Based on speech therapists’ opinion from the center, these books help 50% of people with dyslexia to read more efficiently.

More recently, a special Cyrillic font, LexiaD, for people with reading disorders was developed for the Russian language (Alexeeva et al., 2020). LexiaD (see Figure 1) is a proportional sans serif font designed for larger letter sizes (starting from 14 pins); the spacing between letters, words, and lines is increased; the volume of white inside the letters is larger; the superscript and subscript elements are elongated, and the bases of the letters are thickened. Unlike its Latin-based counterparts, the font is based on letter-similarity ratings assessed objectively in a pretest eye-tracking study (Alexeeva & Konina, 2016). This study determined which Russian letters are similar in isolation and when surrounded by neighboring letters. Different letter shapes (e.g., cursive ones) were used for perceptually similar letters in LexiaD (cf. in the example in Figure 1, the letters "т" and "г" were designed as "т" and "г"). The font was created in consultation with a person diagnosed with dyslexia who uses it for prolonged reading in Cyrillic (other Cyrillic fonts do not work for her when she needs to read long texts).

Figure 1. The Russian alphabet in LexiaD font

The LexiaD font was tested in a silent reading task on primary school children (9-12 years old) with and without reading disorders (Alexeeva et al., 2020). LexiaD was compared with freely available modern fonts PT Sans (sans serif) and PT Serif (serif). These fonts are highly rated by font experts. All three fonts were unfamiliar to the children in the experiment, but the control fonts consisted of typical letter shapes. Participant eye movements were recorded during the reading task.

The LexiaD font showed an advantage over the control fonts in feature extraction (determining the letters that make up a word) and when information integration failed (demonstrated by fewer re-readings). However, the lexical access (determining the meaning of a word) in LexiaD was slower than in the control fonts. Results did not differ for children with or without reading disorders. LexiaD thus showed a positive impact on reading fluency in several aspects for primary school children.

The present study

Still, evidence from one study is not enough to draw strong conclusions. Therefore, in this study, we aimed to put the LexiaD font to a tougher test. First, we recruited adolescents with and without dyslexia who had more reading experience than primary school children meaning that they were exposed to several fonts (e.g., ones from the textbooks or online) more than others. Second, we compared reading performance of an entirely new font, LexiaD, that our participants had never seen before to a fairly familiar font (Arial) used as a control. Arial is widely used; for instance, it is the default font of the Google Docs and one of the core Microsoft fonts.

Third, we also would argue that it is probable that students with dyslexia from an older age group would have more solidified reading issues than primary school students from our previous study who could compensate for them in the future. 5-

10% of students with impaired reading resolve their problems when passing to the next grade (Law et al., 2017).

Finally, we compared silent reading speed in two fonts, whereas in most previous studies (Bachmann & Mengheri, 2018; Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Wery & Diliberto, 2017) participants were asked to read aloud. We believe that silent reading is a more dominant reading mode due to the sheer volume of silent reading adolescents do daily compared to oral reading (Van den Boer et al., 2014). Besides, our research group owns a highly accurate eye-tracker (see below in the Equipment section) that allows for precise reading speed measurements during silent reading.

When reading skills are assessed orally, measures like total reading time (of certain sentences or texts) or the number of words per minute (reading rate; wpm) are usually used. The eye-tracking allows us to investigate the reading process in detail. This methodology captures basic eye movements, that is, fixations (when the eyes are relatively still) and saccades (short movements to reposition the eyes). Since the visual intake occurs only during fixations (Rayner, 2009), fixational measures are usually of greater interest when investigating reading.

The eye-tracking provides many different fixation measures that may be divided into local (calculated for a particular target word) and global (calculated for a particular trial that corresponds to the whole sentence or text). Global measures include mean fixation duration (MFD), total sentence/text number of fixations (TSNF), number of fixations per word, average reading time per word, etc., as well as total sentence/text reading time (TSRT) and the number of words per minute (WPM) mentioned above.

Local measures include first fixation duration (FFD, the time a reader spends fixating on the target word for the first time), gaze duration (GZD, the sum of fixation durations on the target word before the reader moves forward), total viewing time (TVT, the sum of all fixation durations, including any re-readings of the target word), etc. Early measures like the first fixation duration and gaze duration are particularly informative for analyzing factors that may have an impact on the initial access to lexical representations. Later measures like total time as well as

global measures may be useful when investigating higher-order cognitive processing in reading (Rayner, 1998).

Previously, eye-tracking was successfully used to compare different fonts and other typographical features in readers with and without dyslexia (Beymer et al., 2008; Perea & Gomez, 2012; Rayner et al., 2006, 2010; Rello & Baeza-Yates, 2013; Slattery, 2016). For example, analyses of both global and local eye movement measures (Rayner et al., 2006) showed that Old English (it mimics a gothic script) is more difficult to read than Times New Roman for older and young adults without any reading disorders. Based on mean fixation duration (global analysis), it was concluded that italic fonts decreased reading performance in people with dyslexia (Rello & Baeza-Yates, 2013).

Thus, the goal of the research is to check whether the new unfamiliar but specially designed font, LexiaD, works better than a familiar font for the students with persistent reading problems and considerable reading experience while reading silently.

The font performance will be assessed via fluency measures (local and global eye movement variables), comprehension accuracy, and preference ratings. We hypothesized that sentences typed in LexiaD would be faster to read than in Arial, at least for people with dyslexia. In particular, we expected that the advantage of LexiaD would be found in First fixation duration because the input of perceptual information (letter features) seems to precede cognitive processing and First fixation duration reflects the earliest eye movements on a word.

Since previous research on the dyslexia-friendly fonts did not determine a relationship between reading comprehension and the fonts (Bachmann & Mengheri, 2018; Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Rello & Baeza-Yates, 2013; Wery & Diliberto, 2017; Zikl et al., 2015), we conducted an explorative analysis without a particular hypothesis regarding this measure.

As for preference ratings, previous studies (Kuster et al., 2018; Leeuw, 2010; Rello & Baeza-Yates, 2013) provided mixed results: a positive impact of the specialized font (but without statistical analysis) in a paper by Leeuw (2010), no difference between dyslexia-friendly and some of the control fonts (Rello & Baeza-

Yates, 2013), and preference for some of the control fonts over the dyslexia-friendly one (Kuster et al., 2018, Experiment 2; Rello & Baeza-Yates, 2013). Therefore, we did not assume that LexiaD would have advantage over Arial in preference ratings.

Method

Participants

We recruited high school students with and without dyslexia (15-17 years old), the experimental and the control group, respectively. Adolescents with dyslexia (N = 34; 14 girls) were studying at the speech remediation school No3 in Saint Petersburg, Russia. Adolescents without dyslexia (N = 28; 20 girls) were studying at the public school No491 in Saint Petersburg, Russia. Both participant groups had (a) a normal level of intellectual development; (b) normal vision; (c) no comorbid diagnoses (e.g., autism), and (d) were naive to the purpose of the experiment. Adolescents without dyslexia did not report any speech or reading problems in their childhood[6].

Written informed consent forms were signed by children's parents or legal representatives; the study was approved by the Ethics Committee at Saint Petersburg State University, Russia (protocol No. 02-173 from 20.02.2019).

Material and design

Participants read the Russian Sentence Corpus (Laurinavichyute et al., 2019) silently while their eye movements were recorded. This corpus was specifically created for eye-tracking studies in Russian. It consists of 144 sentences with different grammatical structure. For each word in the corpus, wordform frequency, length, and predictability measures are provided. Predictability is calculated based

[6] In author's study on primary school children (Alexeeva et al., 2020), the control group was recruited from the same school. As for the participants with dyslexia, there were two experimental groups: one reading in LexiaD and PT Serif and another one reading in LexiaD and PT Sans. The former consisted of the students from the same speech remediation school as in this study. Children from the latter group lived in Moscow and were diagnosed with dyslexia following the Neuropsychological Test Battery (Akhutina et al., 2016) by a specialist from the Center for Language and Brain, HSE Moscow.

on a separate predictability norming study using a cloze task (Laurinavichyute et al., 2019). Wordform frequencies were borrowed from the "Frequency grammar of Russian" project (Lyashevskaya, 2013) via the StimulStat database (Alexeeva et al., 2018). They were calculated after the morphological disambiguation of each word was completed (Laurinavichyute et al., 2019).

The sentences were created based on the seed words. The seed words were selected to cover all combinations of the three manipulated factors: lemma word frequency (high, >50 ipm / low, <10 ipm), word length (short, 3-4 letters / medium 5-7 letters / long, 8-10 letters), and grammatical category (noun, verb, and adjective). Lemma frequencies for seed words were taken from "Chastotnyj slovar' sovremennogo russkogo jazyka" (Frequency dictionary of the modern Russian language; Lyashevskaya & Sharov, 2009).

For each participant, the corpus was randomly divided into four sections (36 sentences in each section), with two presented in LexiaD and the other two in Arial (see Figure 2). Sentences in LexiaD were typed in 21 pt and sentences in Arial – in 16pt but font height was equal. As both fonts are proportional, the sheer physical width of the stimuli sentences was different. All sentences fit into one line. The order of font presentation, the order of sentences within a section, and the split of sentences into sections were random for each student. All the materials were presented as black on the white background.

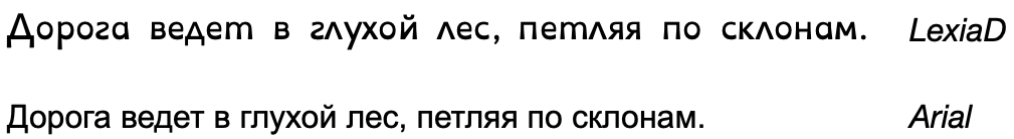

Figure 2. An example sentence (*The road leads to the dense forest, winding along the slopes.*) in LexiaD and Arial fonts.

Equipment

To record participant eye movements, we used an eye-tracker EyeLink 1000 Plus (SR-Research) in monocular mode, with a chin rest to minimize head movements. With the sampling of 1000 Hz, the eye movements were recorded every millisecond. The experiment was designed via the Experiment Builder

software, proprietary to SR-Research. We used 19' LCD monitor (Samsung SyncMaster E1920) with a refresh rate of 60 Hz (screen resolution 1280x1024). The viewing distance was 72 cm. The sentences were placed at the center of the screen in relation to the vertical axis. Horizontally, there was a margin of 100 px from the left edge of the screen.

Procedure

The researcher instructed participants to read each sentence silently as carefully as possible. Each participant underwent 9-point gaze calibration lasting approx. 5 minutes. The researcher checked calibration accuracy before every trial (sentence). If it failed, recalibration took place. After the participants finished reading every sentence, they pressed a key on the keyboard to proceed to a question or to the next sentence. 35% of sentences were followed by a forced-choice comprehension question with three options to control for participants' comprehension. To reply to a question, participants had to press a button on the keyboard.

After having read 36 sentences (after each part, see 3.1.2), participants took a break. At the end of the experiment, participants were asked to answer two preference questions: which font was easier to read (further, *readability*) and which font they liked more (further, appeal).

For the participants to get accustomed to the procedure, we introduced three practice sentences at the beginning of the experiment.

Not all participants read the whole corpus due to technical or organizational problems. One student with dyslexia and three students without dyslexia read half of the corpus and three participants with dyslexia read three quarters of the corpus. For these participants, we included all available data in the analysis (but see Preprocessing stage below).

Dependent variables and preprocessing

In our experiment, we analyzed both the global measures (TSRT, TSNF, MFD, and WPM) and local measures (FFD, GZD, and TVT). Global measures were calculated for each sentence separately, whereas local measures were determined

for each word. Following standard practice in corpus eye movement research, the first and last words in every sentence were excluded from the local measure analysis (Bai et al., 2008; Yan et al., 2014). Local measures are based only on fixation durations, whereas global measures contain both fixation and saccade durations.

Fixations were identified by SR-Research proprietary algorithms and were preprocessed in the following way. Fixations under 80 ms within one character of the next or previous fixation were combined with the respective fixation. Remaining fixations that were shorter than 80 ms and longer than 2000 ms, as well as fixations before and after a blink, were discarded. Sentences with whole or partial recording loss were removed from the analysis (33 sentences in the experimental group and 15 sentences in the control group).

In local measure analysis, we discarded words that were skipped entirely (15.6% of all observations; 14.2% for participants with dyslexia and 17.4% for students without dyslexia). First fixation duration and gaze duration were calculated only if a word was not skipped first.

In addition to eye movement measures, comprehension accuracy and preference ratings were analyzed. As for comprehension accuracy, the analysis input was the sentence ID and the answer (1 – correct; 0 – incorrect).

As for the subjective preference of the font, there could be three possible answers for each question (the first referring to readability, the second referring to appeal). Namely, Arial, LexiaD, or 'it does not matter'. Answers 'it does not matter' were discarded from the analysis (readability: participants with dyslexia – 4, the control group – 6; appeal: participants with dyslexia – 3, the control group – 3). As a result, we had 52 observations for the readability question (30 for participants with dyslexia and 22 for students without dyslexia) and 56 observations for the appeal question (31 for students with dyslexia and 25 for students without dyslexia). The number of observations for local eye movement measures, global eye movement measures, and comprehension score for students with and without dyslexia are provided in Tables 1, 2, and 3 respectively.

Data analysis

Local eye movement measures

We performed linear mixed-effects analyses (LMM) using the lme4 package (version 1-1.17; Bates et al. 2015) in R (R Core Team, 2021) on each of the measures. The fixed effects were font (LexiaD / Arial) and participant group (with / without dyslexia), as well as the interaction between them. Controlled effects were added to the analyses: word length, word frequency, word predictability, word index, trial index, sentence length, section[7], and their two-way interactions with each of the fixed effects. Random effects of the full model (see below) included intercepts for participant ID, sentence ID, and word ID, as well as by-participant slope for the font.

To ensure a normal distribution of model residuals, durations (FFD, GD, and TVT) were log-transformed (here and further natural logarithm was used). Font and Participant group factors were coded as sliding contrasts (with LexiaD and participants with dyslexia as a reference level respectively). Word length was centered and scaled; word frequency was log-transformed, predictability was logit-transformed. Trial index, sentence length, and section were centered and scaled.

The lmerTest package (version 3.0-1; Kuznetsova, Brockhoff, & Christensen, 2017) in R was used to estimate the p-values. Step procedure was conducted for the optimal model selection (*step* function in R). *Step* function uses the full model with all fixed, controlled, and random effects and goes downwards excluding one term (the most insignificant effect) per step comparing the goodness of fit of the models with and without the term. If the model with the term describes the data better, this model is considered optimal. Otherwise, the term is removed.

The final models for local eye movement measures are reported in Appendix A.

Global eye movement measures

LMM was used for each of the global eye movement measures with the same fixed effects as for the local eye movement measures. The analysis contained the following controlled effects: trial index, sentence length, section, and their two-way

[7] We thank the anonymous reviewer for the suggestion to include the section and trial index as controlled effects in the analyses (here and further).

interactions with each of the fixed effects. Full random model structure contained intercepts for participant ID and sentence ID, as well as a by-participant slope for the font, as random effects. We used the same coding scheme, transformation technique, and optimal model selection as in local eye movement analysis. See Appendix B for summaries of the final models for each of the global eye movement measures.

Accuracy

We performed generalized linear mixed-effects analyses (GLMM) for accuracy using the lme4 package (version 1-1.17; Bates et al. 2015) in R (R Core Team, 2021). The fixed effects were font (LexiaD / Arial), participant group (with / without dyslexia), and interaction between font and participant group. The controlled effects were section, trial index, and the interaction between font and section. Random effects in the full model (see below) include intercepts for participant ID and sentence ID, as well as a by-participant slope for the font. Accuracy being a binary dependent variable was fit with GLMMs with a logistic link function. The coding scheme for fixed effects was the same as for the fluency measures. The step procedure was conducted manually using *anova* function in R since *step* function works only for interval dependent variables. The final model is provided in Appendix C.

Preference ratings

Chi-square analysis for each preference variable was conducted. The analysis was performed for students with and without dyslexia separately.

Data and statistical analysis can be found at the following link: https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

Results

We will first report the results for local eye movement measures, then for global eye movement measures. Finally, accuracy and subjective preference results will be provided. For each dependent variable group, we first describe the results for the font effect; then we explore the dyslexia effect and the interaction between font and dyslexia.

Local eye movement measures

The means and standard deviations for all local eye movement variables depending on font and participant group are presented in Table 1.

Table 1.

Word-level (local) aspects of reading performance for students with and without dyslexia depending on Font[8].

Group	Font	FFD (ms)			GZD (ms)			TVT (ms)		
		M	*SD*	*Nobs*	*M*	*SD*	*Nobs*	*M*	*SD*	*Nobs*
Students with dyslexia	LexiaD	268	102	13812	412	208	13812	551	288	14768
	Arial	272	109	13912	402	214	13912	539	297	15247
Students without dyslexia	LexiaD	233	80	10709	293	128	10709	393	201	11825
	Arial	235	82	10173	283	122	10173	385	200	11608

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations, *FFD* – word first fixation duration, *GZD* – word gaze duration, *TVT* – word total viewing time.

Effect of LexiaD

We did not discover the main effect of font on FFD (see the results of the statistical analysis in Appendix A). However, we found evidence of a statistically significant interaction[9] between font and word frequency that points towards the advantage of LexiaD for high-frequency words and towards the absence of the effect for low-frequency words. In addition, LexiaD revealed an advantage over Arial at the end of the sentences; we did not find any evidence that the beginning of the sentences differed between fonts (see the significant interaction between

[8] The means and standard deviations here and further were calculated based on partial effects, with variance attributable to random and (controlled) fixed effects removed using the *keepef* function (Hohenstein & Kliegl, 2014).

[9] The plots showing this and further interactions were placed into the folder titled "interaction plots" in the OSF-repository for the project: https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

font and word index in Appendix A). More interestingly, we found an interaction between font and section to be significant (see Appendix A): by the end of the experiment, reading time in LexiaD was less than in Arial, whereas at the beginning of the experiment, we did not find evidence for the font effect.

The effect of font was significant for GZD. However, it was Arial that had advantage in reading speed: words typed in LexiaD were fixated significantly longer than words typed in Arial (see Table 1, Appendix A). We also found a significant interaction between font and word frequency (see Appendix A), meaning no significant effect for high-frequency words and a disadvantage of LexiaD for low-frequency ones. In addition, LexiaD was inferior to Arial in reading longer words. However, there was no significant difference between reading short words in both fonts (see the significant interaction between font and word length in Appendix A). As for the significant interaction between font and section (see Appendix A), we revealed that at the beginning of the experiment, Arial had advantage over LexiaD, but by the end of the experiment, the difference vanished.

For TVT, again, LexiaD worked significantly worse than Arial (see Table 1, Appendix A). However, in addition to the main effect of font, we revealed a significant interaction between font and word frequency (see Appendix A). It showed an advantage of LexiaD for high-frequency words and the absence of the effect for low-frequency ones. Moreover, the interaction between font and section was significant (see Appendix A). It replicated the results for GZD: the more familiar LexiaD became, the less pronounced the difference between Arial and LexiaD was.

Effect of Dyslexia

In all local measure analyses, students with dyslexia showed a disadvantage compared to reading-level students (see Table 1, Appendix A).

In addition, several interactions were found to be significant (see Appendix A). First, participants with dyslexia slowed down more pronouncedly than students without dyslexia while reading low-frequency words compared to high-frequency words in all local eye movement measures. Second, in FFD, participants with dyslexia showed the length effect (short words were read faster than the long ones) whereas we found no evidence of the length effect for students without reading disorders. In GZD and TVT, the length effect was more salient for students with

dyslexia than for students without dyslexia: longer words were particularly difficult for the former.

Third, when it comes to FFD, the control group slowed down more than participants with dyslexia while reading from the beginning till the end of the sentence (see significant interaction between group and word index in Appendix A). In GZD, the control group did the same, whereas participants with dyslexia sped up by the end of the sentence. In TVT, the results were similar to the ones in GZD, the only difference being that the controls barely slowed down.

Fourth, in TVT, we found a significant interaction between section and group that pointed towards a salient slow down by the end of the experiment for controls and a slight slowdown for students with dyslexia (see Appendix A). To our surprise, the significant interaction with another variable related to the experimental procedure — trial index — showed that in all local eye movement measures, both groups speed up, but participants with dyslexia did it more slowly than students without dyslexia (see significant interaction between group and trial index in Appendix A).

Font X Dyslexia interaction

The step procedure (see Data analysis section for the details) did not include Font X Dyslexia interaction into the optimal model for any of the local eye movement measures at hand. This means that we found no evidence that the fonts had a different impact on reading performance in experimental and control groups in any of the studied measures (see Appendix A).

Global eye movement measures

Table 2 presents the means and standard deviations for all global eye movement measures depending on font and participant group.

Table 2.

Sentence-level (global) aspects of reading performance for students with and without dyslexia depending on Font

			TSRT (ms)		TSNF		MFD (ms)		WPM	
Group	Font	*Nobs*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Students with dyslexia	LexiaD	2287	4499	1236	18.4	4.8	245	25	137	36
	Arial	2396	4349	1247	17.2	4.7	253	27	142	37
Students without dyslexia	LexiaD	1902	3188	862	14.5	3.7	221	24	192	46
	Arial	1899	3094	872	13.7	3.6	227	26	199	50

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations, *TSRT* – total sentence reading time, *TSNF* – total sentence number of fixations, *MFD* – mean fixation duration, *WPM* – reading rate (in words per minute).

Effect of LexiaD

We found evidence for significantly better reading performance in Arial compared to LexiaD in three (TSRT, TSNF, and WPM) out of four global measures at hand: reading rate was higher, total reading time was less, and the number of fixations was fewer in Arial. As for the mean fixation duration (MFD), the effect was the opposite (see Tables 1, Appendix B).

We also found a significant interaction between font and section in TSRT, TSNF, and WPM (see Appendix 1). In TSRT and WPM, similarly to GZD and TVT, the font effect vanished by the end of the experiment. In TSNF, the difference between the fonts became much smaller by the end of the experiment.

Effect of Dyslexia

In all global measures, students without dyslexia outperformed students with dyslexia (see Tables 1, Appendix B).

In TSRT and WPM, we saw two significant interactions, one between group and section and one between group and trial index (see Appendix A). Similarly to TVT the former showed a less pronounced slow down for participants with dyslexia than

for the controls by the end of the experiment and the latter pointed towards more salient speed-up for the controls than for participants with dyslexia by the last sentence of the experiment. In TSNF, only the interaction between group and section was significant and it replicated the results for TSRT and WPM. In MFD, on the other hand, trial index significantly interacted with the group and again, the exploration of the interaction showed the same results as for TSRT and WPM.

Font X Dyslexia interaction

No significant interactions were found in any of the studied global measures based on the step procedure (see the similar section for local eye movement analysis and Appendix B).

Accuracy

The means and standard deviations for comprehension accuracy depending on font and participant group are presented in Table 3.

Table 3.

Sentence comprehension accuracy for students with and without dyslexia depending on Font.

Group	*Font*	Accuracy (%)		
		M	*SD*	*Nobs*
Students with dyslexia	LexiaD	83.0	38	792
	Arial	86.6	34	867
Students without dyslexia	LexiaD	88.4	32	674
	Arial	89.9	30	675

Note. *M* – mean, *SD* – standard deviation, *Nobs* – number of observations.

Effect of LexiaD

No effect of font on comprehension accuracy was revealed (see Table 1, Appendix C).

Effect of Dyslexia

Participants with dyslexia answered comprehension questions worse than students without dyslexia (see Table 1, Appendix C).

Font X Dyslexia interaction

The results did not show that comprehension accuracy in experimental and control groups differed depending on font since the step procedure (see Data analysis section for details) excluded the term during optimal model selection (see Appendix C).

Subjective preference

We performed separate analyses in experimental and control groups for each preference question (see Data Analysis section).

Effect of LexiaD in students with and without dyslexia

As for the readability question, more students with dyslexia preferred Arial over LexiaD font (20 vs. 10), but the effect of font did not reach significance ($X^2(1, N = 30) = 3.33$, $p = .07$). There was no evidence that the preference choice of the students without dyslexia (14 voted for Arial, 8 – for LexiaD) was dependent on the font ($X^2(1, N = 22) = 1.64$, $p = .20$). For the appeal question, the font effect was insignificant for both groups: participants with dyslexia, $X^2(1, N = 31) = 0.03$, $p = .86$ (Arial – 15, LexiaD – 16); the control group, $X^2(1, N = 25) = 0.36$, $p = .55$ (Arial – 11, LexiaD – 14).

Discussion

The majority of studies attribute reading and writing issues that people diagnosed with dyslexia encounter to the underdeveloped phonological processing. It has been attested by some studies (Stein, 2018; Stein & Walsh, 1997) and the firsthand experience of professionals working with students with dyslexia that at least some portion of this population struggles with the visual component

as well, for instance, letters interchanging inside a word. To address this issue, several designers came up with dyslexia-friendly fonts (Dyslexie, Opendyslexic, etc.). The majority of them are Latin-based, but we could also find examples tailored specifically to Cyrillic alphabets. These fonts usually stem from personal experience with dyslexia and are not based on empirical studies nor tested before release. The efficacy of these fonts has been investigated on the basis of reading speed and was deemed to be insufficient.

In the current study, we further investigated LexiaD, a Cyrillic dyslexia-friendly font that has the advantage of being developed based on letter recognition studies. We recruited adolescents with and without reading disorders and compared LexiaD with the popular Arial font in a silent reading task.

Comparing LexiaD with Arial

The results for five fluency measures out of seven (word gaze duration, GZD; word total viewing time, TVT; total sentence reading time, TSRT; total sentence number of fixations, TSNF; reading rate, WPM) showed that Arial is more readable than LexiaD. In the sixth fluency measure — mean fixation duration (MFD), — LexiaD outperformed Arial[10]. Finally, our data did not provide evidence that fonts differed in the first fixation duration on a word (FFD). In reading comprehension score, subjective readibility preference, and subjective appeal ranking, the fonts did not differ significantly. These results are valid both for participants with dyslexia and the control group: there was no evidence that the font effect was dependant on the participant group.

Arial is a well-known font that is most commonly seen on screen compared to other fonts (Rello & Baeza-Yates, 2016). The British Dyslexia Association (B. D. Association, 2021b) and other researchers (Evett & Brown, 2005; Lockley, 2002) recommend people with dyslexia to use it when reading. In spite of this, we also

[10] It is worth noticing that this advantage is illusory. Both TSRT and TSNF were higher in LexiaD than in Arial and mean fixation duration is calculated as TSRT divided by TSNF. The true positive effect of LexiaD in MFD could be confirmed if both TSRT and TSNF were less in LexiaD or if TSRT was less and TSNF did not differ or TSNF was less and TSRT did not differ.

found that font effect in six out of the seven fluency measures (FFD, GZD, TVT, TSRT, TSNF, and WPM) changed by the end of the experiment. The more familiar LexiaD became, the less salient the difference between Arial and LexiaD was. By the end of the experiment, LexiaD outperformed Arial in FFD; in GZD, TVT, TSRT, and WPM, the difference vanished; in TSNF, it became much smaller.

Following our own previous study (Alexeeva et al., 2020), we assume that first fixation duration mainly reflects feature extraction (determining the letters that make up a word), gaze duration is primarily related to lexical access (determining the meaning of a word), and total viewing time captures text integration (recovering from any semantic or structural failure that causes re-readings). Also, we believe that global eye movement measures reflect general processing across the text/sentence. In line with these assumptions, we can conclude that once participants get accustomed to LexiaD, it helps the readers to extract letter features faster and stops worsening the speed of the higher-level cognitive processing (e.g., lexical access or text integration).

It is worth noticing that better performance of LexiaD in relation to the feature extraction was revealed for high-frequency words even at the beginning of the experiment. Since letters in LexiaD were designed differently (where possible), several letters have untypical shapes. Uncommon letter shapes are perhaps more salient in rarer letter combinations that occur more often in low-frequency words compared to high-frequency ones (Rice & Robinson, 1975). Therefore, we suggest that participants need to get used to unusual letter repsesentation in low-frequency words. This is probably the reason why our data did not provide evidence for the font effect for words of this frequency range at the beginning of the experiment.

Comparing LexiaD with PT font family

In the previous study involving *primary* school students with and without dyslexia (Alexeeva et al., 2020), LexiaD was compared with another Sans Serif font — PT Sans. It is a modern freely distributed font that is highly rated by the font experts. It was also unfamiliar to participants but consists of typical letter shapes. Confirming our familiarity hypothesis regarding FFD results, LexiaD outperformed PT Sans (both for high- and low-frequency words) in this measure both for the

controls and participants with dyslexia. However, when we compared LexiaD with PT Serif (a Serif analogue of PT Sans) in an experiment with primary school children (Alexeeva et al., 2020), the results for FFD were the same as in the present study.

Several explanations come to mind as for why the FFD results of the present study on adolescents resemble the ones for primary school children reading PT Serif and LexiaD and are slightly worse than the ones for primary school children reading PT Sans and LexiaD. First, for primary school children, serif fonts could be more readable than sans serif fonts (resulting in an advantage for low-frequency words compared to LexiaD). However, as far as we know, no significant difference was previously registered for reading performance speed between serif and sans serif fonts in primary school children (Bernard et al., 2002) and adults without reading disorders (Beymer et al., 2008; Perea, 2013). In adults with dyslexia, overall text reading duration (Rello & Baeza-Yates, 2013) did not differ significantly between serif and sans serif fonts, but mean fixation duration showed an advantage for sans serif fonts over the serif ones (but see note 10).

Second, children with dyslexia from PT Sans and PT Serif groups study in different schools. Children from the former group study in ordinary Moscow schools (see note 4) whereas the ones from the latter group go to the same remediation center as adolescents with dyslexia from the present study. Therefore, LexiaD could work better for children with less severe reading problems. However, all primary school children and adolescents that were invited as controls were from the same ordinary school in Saint Petersburg, and the results for the controls and the participants with dyslexia did not differ significantly between age groups. Thus, it is not clear why the results for FFD for adolescents (LexiaD / a Sans Serif Arial) are the same as for the primary school children in LexiaD / PT Serif subgroup and slightly worse than the ones for the primary school children in LexiaD / PT Sans subgroup.

Font familiarity

Contributing to the discussion on font familiarity (the key finding of the present study), typographers suggest that familiar typefaces are processed faster (Wang, 2013). The issue of the typeface familiarity is raised in typography when designers discuss appropriateness of letterform change in new and old fonts. For some designers, familiarly can be quantified as the amount of time readers have

spent using a particular typeface. They tend to support the exposure hypothesis that states that the more exposed the reader is to the typeface, the more familiar they are with it. New uncommon typefaces thus can be designed, and readers will get used to them in time. Other designers support the prototype hypothesis suggesting that typeface familiarity is rooted in common letter shapes. Typeface design then must not deviate from strict parameters, and new typefaces are frowned upon.

Beier (2009) and Beier and Larson (2013) tested these hypotheses by measuring reading speed in a test[11] and subjective preferences prior to and after reading a 20-minute story. The experiment had three conditions: a known font with common letter shapes (Times/Helvetica), a new font with common letter shapes (Spencer/PykeText), and a new font with uncommon letter shapes (SpencerNeue/PykeTextNeue). Future designers without reading problems were recruited as participants. It was shown that the reading speed increased after the exposure session, but the effect of the letter shape commonality did not reach significance (both before and after the exposure session). The authors concluded that the exposure hypothesis is thus more plausible. In addition, they found that participants assessed new fonts with uncommon letter shapes as less appealing for reading in the future, taking more attentional recourses, and less comfortable to read.

The results of these studies have the following implications for our data. First, unfamiliar fonts become more readable after some exposure. This means that a longitudinal study of the LexiaD font is needed to check how it will perform when participants are familiarized with it even more. To reiterate, in almost all fluency measures, LexiaD caught up with Arial in speed efficiency by the end of our experiment (during an exposure of just 144 sentences).

Second, in Beier (2009) and Beier & Larson (2013) studies, there was no evidence found that reading speed differs between known-common fonts and new-uncommon fonts even before the exposure session. In our study, LexiaD (a new font with uncommon letter shapes) clearly performed worse than Arial (a

[11] The reading test consisted in finding an absurd word in several short paragraphs within two minutes. The number of successfully completed paragraphs was measured.

known font with common letter shapes) at the beginning of the experiment. But it is worth noticing that fonts used in Beier (2009) and Beier & Larson (2013) contain only regular letters whereas in LexiaD, the designer used italic to create several letter shapes in the regular typeface (for example, "*m*") to disambiguate often confused letters. Italic typefaces are more difficult to read both for people with dyslexia (Lockley, 2002; Rello & Baeza-Yates, 2013) and people without reading difficulties (Slattery & Rayner, 2010) compared with regular typefaces.

In addition, it is easier to process strings typed in one font (gothic font or serif font) than strings made up of letters from two different typefaces (gothic letters mixed with serif letters; Sanocki, 1988). In our case, some words in LexiaD could be considered mixed letter strings combining regular and italic letters. Perhaps, these are the two reasons why LexiaD showed worse performance compared to Arial at the beginning of the experiment.

However, it is worth noticing that in previous studies (Beier, 2009; Beier & Larson, 2013), the difference between known-common fonts and new-uncommon fonts before the exposure session could be hidden due to the difficulty of their reading test (see note 11). In fact, their test measured reading performance speed (as it was assessed by our fluency variables) plus the time to complete the comprehension task. If we compared the results of these studies (Beier, 2009; Beier & Larson, 2013) for this test with our comprehension score results, then they would be alike.

The difference in the reading task could also explain why there was no evidence that Latin-based dyslexia-friendly fonts differed from the control ones in terms of reading speed (see Introduction) and why we obtained an opposite result for most of the measures at the beginning of the experiment. All the studies of Latin dyslexia-friendly fonts (Duranovic et al., 2018; Kuster et al., 2018; Leeuw, 2010; Marinus et al., 2016; Wery & Diliberto, 2017) except one (Rello & Baeza-Yates, 2013) use reading aloud as the task whereas we used silent reading. Mean fixation duration in oral reading is usually 20-25% longer than in silent reading due to word articulation and related eye repositioning (Rayner, 2009). Extra time that was needed for articulation could thus cover the processing difference between fonts in an oral reading task.

Preference rankings

In the preference rankings (both regarding subjective readability and subjective appeal), we did not find significant preference for any of the fonts used in the experiment in any participant group. LexiaD was new to participants but many of participants with dyslexia (half in the appeal question and one third in the easiness-to-read question) preferred this font. In (Rello & Baeza-Yates, 2013), participants with dyslexia assessed OpenDyslexic to be less likable than Verdana and Helvetica but did not articulate a preference between OpenDyslexic and Arial, Times, CMU, Courier, Myriad, and Garamond. In Experiment 1 of (Kuster et al., 2018), where the participants were diagnosed with dyslexia, no statistical information was provided on how Dyslexie compares to Arial. In the Experiment 2, given the choice between Arial, Times New Roman, and Dyslexie, participants with dyslexia and the control group together were fewer than expected to show a preference for Dyslexie or no preference at all. At the same time, more participants showed a preference for Arial and Times New Roman than expected. Also, it was mentioned that the distribution of the preferences choices for the students with and without dyslexia differed, but no statistical analysis was provided showing where the difference lies.

In a study by Leeuw (2010), a more positive attitude towards the Dyslexie font than Arial in participants with dyslexia compared to readers without dyslexia was mentioned, but no statistical analysis was provided to support the claim. More importantly for us, Kuster and colleagues (2018) did not provide any evidence that subjective preference has in impact on reading performance. Even though a participant could subjectively prefer the control font over the dyslexia-friendly one, it does not necessary mean that s(he) will read faster in it. Following that, our conclusion is based on reading speed results.

Conclusion

All in all, a previous study (Alexeeva et al., 2020) in primary school chidren with and without dyslexia who obviously had less reading experience than adolescents showed some advantages of LexiaD over unfamiliar but highly rated control fonts, PT Sans and PT Serif. In the present study, we found some positive effect of LexiaD

compared to very common onscreen font, Arial, when adolescents with and without dyslexia got accustomed to LexiaD. Thus, it seems that LexiaD has the potential to be a supporting font for these age groups. However, follow-up studies with an exposure session are needed to confirm our conclusion. Moreover, it is interesting to explore how LexiaD will perform when adults who had even more reading experience than adolescents are recruited. Do they need more time than adolescents to get used to LexiaD? In addition, other familiar Serif fonts (e.g., Times New Roman) need to be tested in comparison with Sans Serif LexiaD. The last but not the least, although Arial is very widespread, font experts (e.g., Danilova, 2021) point out that Cyrillic letters in Arial are of low quality. Therefore, more modern analogues of Arial (e.g., Roboto) should be examined.

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Conflict of interest

The author of the study commissioned the font in question. I have disclosed those interests fully to Primenjena psihologija, as well as the plan for managing any potential conflicts arising from that.

Data availability statement

The dataset is deposited in the online repository:
https://osf.io/x87e2/?view_only=ed270510898e4b5fa908176f4523ff6f.

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Appendix A

Mixed-effect modelling results for local eye movement measures.

	First Fixation Duration				Gaze Duration				Total Viewing Time			
Optimal model	FFD ~ font + group + f + l + p + sect + tr_id + sent_l + w_id + font:f + font:sect + font:w_id + group:f + group:l + group:tr_id + group: w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)				GZD ~ font + group + f + l + p + sect+ tr_id + w_id + font:f + font:l + font:sect + group:f + group:l + group:tr_id + group:w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)				TVT ~ font + group + f + l + p + sect + tr_id + w_id + font:f + font:sect + group:f + group:l + group:sect + group:tr_id + group:w_id + (1 + font | subj) + (1 | sentence_id) + (1 | word)			
Predictors	Model estimates				Model estimates				Model estimates			
	b	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*
Intercept (Int)	5.470	.015	366.31	**<.001**	5.742	.026	223.76	**<.001**	6.015	.033	182.72	**<.001**
Font	.009	.007	1.35	0.179	-.032	.011	-2.97	**.003**	-.029	.012	-2.38	**.020**
Group	-.129	.027	-4.73	**<.001**	-.314	.046	-6.81	**<.001**	-.325	.059	-5.55	**<.001**
Frequency (f)	-.013	.001	-10.91	**<.001**	-.029	.002	-14.55	**<.001**	-.039	.003	-15.19	**<.001**
Length (l)	-.007	.003	-1.93	.053	.163	.006	27.27	**<.001**	.183	.008	23.78	**<.001**
Predictability (p)	-.016	.003	-6.07	**<.001**	-.036	.004	-8.75	**<.001**	-.054	.005	-11.06	**<.001**
Section (sect)	.016	.006	2.63	**.008**	.011	.008	1.35	.176	.032	.009	3.75	**<.001**
Trial index (tr_id)	-.013	.006	-2.21	**.027**	-.022	.008	-2.79	**.005**	-.067	.009	-7.85	**<.001**
Sentence length (sent_l)	-.007	.003	-2.60	**.010**								
word index (w_id)	.033	.003	10.90	**<.001**	.010	.005	2.15	**.032**	-.014	.005	-2.62	**.009**
font:f	.003	.001	3.35	**.001**	.005	.002	2.52	**.012**	.006	.001	4.64	**<.001**
font:l					-.019	.006	-3.29	**.001**				
font:sect	.010	.004	2.60	**.009**	.020	.005	3.84	**<.001**	.017	.005	3.20	**.001**
font:w_id	.010	.004	2.53	**.011**								
group:f	.006	.001	4.04	**<.001**	.017	.002	9.19	**<.001**	.017	.002	8.95	**<.001**

group:l	.013	.004	2.85	**.004**	-.065	.006	-11.20	**<.001**	-.052	.006	-8.40	**<.001**
group:sect									.052	.017	3.01	**.003**
group: tr_id	-.015	.004	-4.17	**<.001**	-.015	.005	-3.18	**.002**	-.043	.017	-2.53	**.012**
group: w_id	.009	.004	2.29	**.022**	.041	.005	7.58	**<.001**	.046	.006	8.25	**<.001**
Random effects												
	Var	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*	
Word (int)	.003	.05			.010	.10			.019	.14		
Sentence (int)	<.001	.02			.002	.04			.007	.08		
Subject (int)	.011	.10			.032	.18			.052	.23		
Subject (slope:font)	.002	.04	-.04		.003	.05	.09		.006	.08	-.06	
Residuals	.112	.33			.193	.44			.237	.49		

Note. Significant effects are in bold.

Appendix B

Mixed-effect modelling results for global eye movement measures.

	Total Sentence Reading Time	Total Sentence Number of Fixation	Mean Fixation Duration	Reading rate (wpm)
Optimal model	TSRT ~ font + group + sect + tr_id + sent_l + font:sect + group:sect + group:tr_id + (1 + font | subj) + (1 | sentence_id)	TSNF ~ font + group + sect + tr_id + sent_l + font:sect + group:sec + (1 + font | subj) + (1 | sentence_id)	MFD ~ font + group + sect + tr_id + group:tr_id + (1 + font | subj) + (1 | sentence_id)	WPM ~ font + group + sect + tr_id + sent_l + font:sect + group:tr_id + group:sec + (1 + font | subj) + (1 | sentence_id)

Fixed effects

Predictors	Model estimates				Model estimates				Model estimates				Model estimates			
	b	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	*p*	*b*	*SE*	*t*	p
Intercept (int)	8.189	.040	206.27	**<.001**	2.730	.036	76.41	**<.001**	5.459	.013	417.91	**<.001**	5.075	.040	127.87	**<.001**
Font	-.034	.013	-2.71	**.009**	-.065	.011	-6.13	**<.001**	.031	.005	6.40	**<.001**	.034	.013	2.72	**.009**
Group	-.340	.075	-4.52	**<.001**	-.229	.068	-3.37	**.001**	-.107	.026	-4.18	**<.001**	.340	.075	4.52	**<.001**
Section (sect)	.049	.012	4.19	**<.001**	.020	.011	1.82	.069	.027	.005	5.69	**<.001**	-.049	.012	-4.19	**<.001**
Trial index (tr_id)	-.092	.011	-8.01	**<.001**	-.061	.011	-5.55	**<.001**	-.029	.005	-6.24	**<.001**	.092	.011	8.01	**<.001**
Sentence length (sent_l)	.086	.012	7.43	**<.001**	.087	.011	8.16	**<.001**					.063	.012	5.49	**<.001**
font:sect	.018	.007	2.52	**.012**	.017	.007	2.48	**.013**					-.018	.007	-2.51	**.012**
group:sect	.060	.023	2.58	**.010**	.025	.007	3.83	**<.001**					-.060	.023	-2.58	**.010**
group: tr_id	-.051	.023	-2.22	**.026**					-.015	.003	-5.41	**<.001**	.051	.023	2.22	**.026**
Random effects																
	Var	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*		*Var*	*SD*	*Cor*	
Sentence (int)	.020	.014			.017	.013			<.001	.03			.020	.01		
Subject (int)	.088	.030			.071	.027			.010	.01			.088	.03		

Subject (slope:font)	.008	.09	.013	.005	.07	.06	.001	.03	.09	.008	.09	.013
Residuals	.069	.26		.064	.25		.011	.01		.069	.03	

Note. Significant effects are in bold.

Appendix C

Mixed-effect modelling results for accuracy.

	Accuracy			
	Fixed effects			
Model	Accuracy ~ font + group + (1 | subj) + (1 | sentence_id)			
Predictor	Model estimates			
	b	SE	z	p
Intercept (int)	2.510	.205	12.28	<.001
Font	.180	.118	1.53	.126
Group	.436	.216	2.02	**.043**
Random effects				
	Var	SD		
Sentence (int)	.477	.69		
Subject (int)	1.380	1.76		

Note. Significant effects are in bold. The font effect was preserved during optimal model selection since it is of the main interest to the research.

Efekat ćiriličnog fonta specifičnog za disleksiju, LexiaD, na brzinu čitanja: dalje istraživanje kod adolescenata sa i bez disleksije

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SAŽETAK

Ova studija ima za cilj da testira pretpostavku da specijalno dizajnirani ćirilični font, LexiaD, može pomoći adolescentima sa problemima u čitanju i olakšati njihovo iskustvo čitanja. LexiaD je upoređena sa široko korišćenim fontom Arial. Dve grupe adolescenata sa disleksijom (N = 34) i bez disleksije (N = 28) u tišini su čitale 144 rečenice iz ruskog korpusa rečenica (Laurinavichiute et al., 2019), od kojih su neke predstavljene u LexiaD, a druge u Arialu, dok su im zabeleženi pokreti očiju. LexiaD nije pokazao željeni efekat za adolescente na početku eksperimenta: Arial ga je nadmašio u brzini čitanja u obe grupe učesnika. Font LexiaD pokazao se uspešnijim of fonta Arial, iako se brzina kognitivne obrade višeg nivoa (npr. leksički pristup) u oba fonta nije značajno razlikovala, pokazalo se da je izdvajanje karakteristika bolje u LexiaD nego u Arial. Pronađen je pozitivan efekat LexiaD kada su se učesnici sa i bez disleksije navikli na njega. Da bi se potvrdio ovaj zaključak, potrebna je dodatna studija sa eksplicitnom sesijom izlaganja

Ključne reči: disleksija, font, pokreti očiju, štampani tekst, ruski

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Research Article

Structure of Darkness: The Dark Triad, the „Dark" Empathy and the „Dark" Narcissism

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ABSTRACT

While it is universally agreed that empathy deficit is a necessary condition for the dark roster membership, the literature reports differential associations between individual Dark Triad traits, especially narcissism, with cognitive and affective empathy. With this in mind, we have investigated topology of the network consisting of Affective and Cognitive Measure of Empathy, Narcissistic Admiration and Rivalry Questionnaire, and Short Dark Triad traits (SD3). The additional model of Narcissism was included in the analysis due to the accumulated evidence questioning antagonistic nature of Narcissism as defined by SD3. The standard paper and pencil testing procedure was utilized on an *ad hoc* sample of 263 senior high school and university students (M_{age} = 18.30; SD_{age} = 1.65). The network analysis disclosed cohesive configuration of multiply connected study variables, thus confirming their aversive coaction. Two main axes of study variables were identified: the "dark" affective dissonance-rivalry-psychopathy axis, and the "brighter" admiration-SD3 narcissism axis; each characterized by its specific manifestation of empathic deficit. Affective dissonance was the most central while affective resonance was the most redundant node of the network. Rivalry — a node connecting the two axes — had the greatest strength in the network and was closer to affective dissonance than to psychopathy. Involvement of affective dissonance uncovered the dual nature of Machiavellianism by shifting it away from psychopathy and closer to narcissism. By use of structural information not accessible by other means, this study substantiates the proposition about the essential role of distinct empathic deficits in the constellation of antagonistic traits.

Keywords: network analysis, empathic deficits, the Dark Triad, rivalry, admiration

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Introduction

The concept of Dark Triad (DT; Paulhus & Williams 2002) is based on the idea that human malevolence is best understood as a constellation of three unique but overlapping malevolent traits: psychopathy, Machiavellianism, and narcissism. Since its inception, the Short Dark Triad (SD3; Jones & Paulhus 2014) has become the most popular DT measurement instrument as it has repeatedly demonstrated its value for study of socially undesirable personality traits. Being a concise and reliable estimate of the DT, it has been translated to various languages and has been used in numerous empirical studies worldwide. As such, it has stimulated debates about the dark core of personality and its relations with fundamental personality traits (Hodson et al., 2018; Moshagen et al., 2018). However, divergent linear associations of narcissism with psychopathy and Machiavellianism questioned not only the antagonistic nature of narcissism but also the very concept of the DT (Miller et al., 2017; Persson et al., 2019). As more studies have repeatedly indicated the multifaceted nature of DT constructs (Watts et al., 2017), it seems plausible to assume that a more elaborated approach to each individual DT trait – such as narcissism – should be helpful for our understanding of dark personalities.

Nevertheless, in majority of studies on the DT data were analyzed under the standard latent variable model i.e., the assumption that manifest covariance among the traits is due to the underlying effect of a shared latent variable. Though they have greatly improved our knowledge, these studies fall short in providing information on structural relationships of DT traits with personality traits that are closely embroiled in the very conceptualization of DT, such as empathy.

While empathy deficit is a necessary condition for the dark roster membership (Paulhus, 2014), it was not uniformly confirmed across all DT traits since differential associations between individual DT traits (above all, narcissism) with cognitive and affective empathy have been reported in the literature (Jonason & Kroll, 2015; Kajonius & Björkman, 2019). Incongruence of these reports can be explained by the dual nature of narcissism as defined by SD3 (SD3N;

Rogoza et, al. 2018), but can also be attributed to the dual nature of empathy that is not captured by either Interpersonal Reactivity Index (IRI; Davis, 1983) or Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004), by far the most widely used empathy scales (Hall & Schwartz, 2019). Contrary to the standard latent variable model, the network analysis model rests on the assumption that psychological variables directly affect each other and that their covariance is not rooted in the veiled existence of an underlying construct (Epskamp et al., 2017). So far, there are no studies investigating structural constellation of DT traits in the context of divergent manifestations of empathy and the dual manifestations of narcissism. The present study was conducted to fill this void.

Heterogeneity of the SD3 narcissism: the bright and the dark face of SD3 narcissism

While there is strong evidence about empirical overlap of all DT traits there is also sufficient evidence indicating consistent and substantial divergence of narcissism from psychopathy and Machiavellianism. Heterogeneity of the SD3N has been repeatedly demonstrated by its divergent correlation with empathy and other external criteria (Muris et al., 2017). This led some authors to question equal importance of narcissism's contribution to the DT construct since– in the company of psychopathy and Machiavellianism – narcissism is viewed as the „the lightest" (Egan et al., 2014) or the „brightest" DT trait (Rauthmann & Kolar, 2012). Furthermore, narcissism's nomological network was found to be meaningfully different from a substantial overlap between nomological networks of psychopathy and Machiavellianism (Vize et al., 2018). Divergent status of narcissism vis-à-vis two other DT traits is also evident with respect to relations to basic personality traits and different psychosocial outcomes (Jonason et al., 2015; Muris et al., 2017; Prusik & Szulawski, 2019). In contrast to two other DT traits, narcissism is a poor predictor of antisocial and asocial online behaviors (Moor & Anderson, 2019), is even positively related to motivation at work and burnout resilience (Prusik & Szulawski, 2019), and is positively related to emotional intelligence and leadership/authority (Szabó & Bereczkei, 2017). This discrepancy is especially evident after controlling for the

common variance of DT traits as residualized narcissism, as opposed to residualized psychopathy and Machiavellianism, positively correlates with Extroversion, Conscientiousness and Openness (Muris et al., 2017).

Dual nature of narcissism: admiration and rivalry

Although there is a universal agreement about its maladaptive nature, there is also convincing evidence that contrary to two other DT traits narcissism has the essential features of not only antagonism, but also agency (Back, 2018). In their theoretical model of grandiose narcissism Back and his colleagues (Back et al., 2013) postulated two contrasting yet correlated dimensions of grandiose narcissism: admiration (self-promoting, agentic, self-enhancing) and rivalry (aggressive, derogating, antagonistic, self-protective). Admiration (the interpersonal component) and rivalry (the intrapersonal component) supplement each other to form a more inclusive picture of grandiose narcissism. This approach, operationalized by the Narcissistic Admiration and Rivalry Questionnaire (NARQ), has demonstrated its utility in studies on social consequences of narcissism, as initial admiration-driven popularity of narcissists is quenched by their manifestations of rivalry (Leckelt et al., 2015) eventually affecting quality and stability of romantic relationships (Wurst et al., 2017). Furthermore, admiration is positively correlated while rivalry is negatively correlated with forgiveness (Fatfouta et al., 2017) and willingness to apologize (Leunissen et al., 2017). The difference between agentic and antagonistic dimensions of narcissism is also documented by the finding that admiration is positively, and rivalry is negatively associated with prosocial and self-improving dimensions of consumption behavior (Martin et al., 2019). Admiration is positively correlated with Extroversion while Rivalry is negatively correlated with Agreeableness (Rogoza et al., 2016). Rogoza, Kowalski, and Schermer (2019) report that SD3N is closely related to admiration, a finding suggestive of predominately agentic nature of SD3N. Recently it was reported that admiration, similar to SD3N, is positively while rivalry is negatively associated with measures of trait empathy (Burgmer et al., 2021). However, the evidence on structural relationship between the SD3N/admiration cluster and empathy as

operationalized by Affective and Cognitive Measure of Empathy (ACME; Vachon & Lynam, 2016), is still wanting. This evidence should provide critical information regarding agentic/antagonistic nature of the SD3N.

Lack of empathy: the dual nature of empathy

In spite of remarkable disagreements among conceptual and operational definitions in the literature, empathy has been central to explanation of human nature (Hall & Schwartz, 2019) as our hardwired (Bernhardt & Singer, 2012) capacity for cognitive (knowing what others feel) and affective empathy (feeling what others feel) is so fundamental for social bonding and cooperation. While absence of empathic responding has been recognized as the common feature of all DT traits (Heym et al., 2019), there is no universal agreement on how lack of empathy is associated with the DT.

Heartless and dispassionate face of dark personalities was not uniformly confirmed across all DT traits since differential associations between individual DT traits with cognitive and affective empathy were reported in the literature. Jonason and Krause (2013) found that narcissism was linked to empathy skills, whereas psychopathy and Machiavellianism were linked to empathy deficits. In a more recent study (Turner et al., 2019) psychopathy was unrelated to cognitive empathy, whereas narcissism and Machiavellianism were both positively related to cognitive empathy. The picture was additionally complicated by Kajonius and Björkman (2019) who reported a very strong negative relationship between dispositional trait-based empathy with all DT traits and absence of any relationship between DT traits with ability-based empathy.

This inconsistent relationship between dark traits and various indices of empathy might be accounted for by inadequacy of traditional measures of empathy as all three studies relied on psychometric scales that were not sensitive to difference between resonant and dissonant manifestations of affective empathy (Basic Emphaty Scale - BES; Jolliffe & Farrington, 2006; EQ; Baron-Cohen & Wheelwright, 2004; IRI; Davis, 1983).

Affective empathy is commonly understood as sharing the same emotional state with another person. This definition is limited in its scope since

it refers only to positive, resonant manifestations of affective empathy. However, empathy deficits observed in antisocial personalities also entail dissonant or „contrast empathy" (Stotland et al., 1971), that is experiencing hatred and even joy in situations where most people feel compassion and concern when witnessing the pain of others. Accordingly, empathy deficits are not limited only to absence of appropriate emotions but also entail presence of inappropriate emotions. Therefore, empathy — as a vital ingredient of human affective resources— may be distorted both in a quantitative (an attenuated capacity for an appropriate resonant affective response) and/or in a qualitative (a deviant, contradictory affective response) manner. Thus, it seems plausible to assume that measures of empathy sensitive to dissimilarity between absence of resonant and presence of dissonant affective empathy would provide additional insights on empathy's relationship with dark traits.

Vachon and Lynam (2016) redefined affective empathy by adding a complementary dimension of affective dissonance (enjoying the pain and humiliation of others, getting angry when others are having a good time, schadenfreude) as this self-centered and anomalous affect is one of the hallmarks of psychopathy and the related personality traits (Baron-Cohen, 2012; Hare & Neumann, 2009). Addition of this negative dimension of affective empathy opens a new and promising angle for study of antisocial behavior. This novel approach to empathy has been operationalized through the Affective and Cognitive Measure of Empathy psychometric scale (ACME; Vachon & Lynam 2016). Recently, Murphy et al. (2018) reported ACME's superiority over IRI – by far the most widely used empathy scale (Hall & Schwartz, 2018) – with respect to its predictive relations with interpersonally malevolent traits.

Scrutiny of structural relationship between ACME-defined empathy and the Dark Tetrad traits revealed that psychopathy and sadism are primarily linked to deficits in affective empathy (Dinić & Wertag, 2017). Recently, a person centered approach (Heym et al., 2021) identified the distinct cluster (Dark Emapths) presenting high empathy and elevated levels of DT traits, quite distinct from the cluster characterized by elevated DT traits and low empathy (Traditional Dark Triad). The very concept of the Dark Empath is in line with the

view that besides its obvious prosocial contribution empathy may also be harmful (Murphy et al., 2018). Thus, it seems plausible to assume that measures of empathy sensitive to distinction between the absence of resonant and the presence of dissonant affective empathy would provide additional insights on empathy's relationship with the DT.

Network analysis of malevolent traits

Network analysis provides structural information and visualization of bivariate relationships among the variables with respect to their centrality (how essential is a trait for the overall network topology) and redundancy (a degree to which a trait is replaceable with other traits from the network). Admittance of network analysis opened a new perspective for research on antagonistic personalities by providing relevant information not accessible by other statistical analyses. The existing knowledge on nomological framework of DT and DT-related variables is thus advanced by new insights into pairwise interactions of study variables and their spatial arrangements. Through different metrics of centrality and redundancy, network analysis presents distinctive information about importance of individual traits for the general network topology.

Use of the network analysis has established multidimensionality of each DT trait and high centrality of Antagonism, a facet of grandiose narcissism (Truhan et al., 2020). The central position of psychopathy and isolated position of narcissism was reported in the spatial arrangement of Dark Tetrad traits, but also that psychopathy's facet callousness is a key common feature of all Dark Tetrad traits (Dinić et al., 2020). Application of the same analytic methodology indicated a strong spatial connection (constituting the core of the evil) between psychopathy and Machiavellianism but also revealed that SD3N is mostly agentic and only indirectly linked with two other DT traits via its narrow antagonistic component (Trahair et al., 2020). An earlier study (Papageorgiou et al., 2019) reported central position of SD3N among prosocial traits, suggestive of its strategic position for coupling prosocial and antisocial personality traits. Nevertheless, analysis of a network constellation encompassing DT traits, and dual natures of empathy and narcissism is still wanting.

Present study

The main objective of the current study was to investigate collective structure of empathy (as defined by ACME), DT traits (as defined by SD3), and narcissism (as defined by NARC) by use of network analysis. This goal was built on the following rationale: first, empirical evidence for empathic deficit as connective component of DT traits is still incomplete. Disagreement among the existing reports (utilizing the latent variable approach) on relationship between DT traits (particularly narcissism) and empathy deficits challenges the homogeneity of the DT construct but also questions the antagonistic nature of narcissism as operationalized by SD3. Secondly, quantitative and qualitative empathic deficits have not been studied alongside multidimensional definition of grandiose narcissism and their joint interaction with the DT. Network modeling should provide unique information pertaining to importance and relative positioning of study variables in a connective structure of antagonistic traits. This new approach to personality data may supplement our knowledge about the status of quantitative and qualitative empathic deficits, and the status of agentic and antagonistic narcissism in the comprehensive constellation of malevolent traits.

We predict:

H1: The highest centrality of affective dissonance in a coherent constellation of an antagonistic network. According to Vachon & Lynam (2016) distinction between affective dissonance and affective resonance delivers stronger predictive associations with all measures of aggression and externalizing psychopathology relative to any other measure of empathy that is focused on resonant responses alone. As a matter of fact, in their study the strongest incremental predictive contribution was displayed by affective dissonance. Thus, it is quite reasonable to assume that the network analysis will confirm the highest centrality of affective dissonance in a network of antagonistic traits.

H2: Strong pairwise connection with affective dissonance accompanied by a negative or absent pairwise connection with affective resonance is then a

critical evidence of a trait's malevolence. If so, structural proximity/remoteness vis-a-vis affective resonance/affective dissonance may provide singular information about the nature of empathic deficit characterizing each study variable of the network.

H3: Psychopathy will have the strongest pairwise connection with affective dissonance and affective resonance, although in opposite directions. According to Paulhus (2014) cruelty and sadism are essential features of psychopathy. Of all DT traits, psychopathy has the highest correlation with both affective resonance and affective dissonance (Dinić & Wertag, 2017). Among the Dark Tetrad traits, psychopathy is most closely associated with sadism (Johnson et al., 2019).

H4: Consequently, psychopathy will be the main source of information about the DT affective deficit, while Machiavellianism — as the „cold personality syndrome"—will become redundant. We assume that inclusion of affective dissonance in the measurement space will weaken the frequently confirmed association between Machiavellianism and psychopathy (Vize et al., 2018), the overlap that is usually referred as „the core of the evil".

Earlier studies, utilizing the latent variable approach, report similar pattern of psychopathy's and Machiavellianism's correlations with affective resonance and affective dissonance (Dinić & Wertag, 2017). However, this similarity may be somewhat surprising as dissonance implies patent display of contradictory affective tone, which is quite conflicting with Machiavellian calculated suppression of emotional expression (Christie & Geis, 1970). Therefore, should affective dissonance be verified as the central antagonistic trait and should psychopathy be established as the main information carrier about the empathic deficit of DT traits, we assume that Machiavellianism will become redundant. That is, removal of Machiavellianism will not result in a considerable loss of information about the status of empathic deficits in the network.

H5: Both the latent variable approach and the network analysis report a strong direct connection between SD3N and admiration (Rogoza et al., 2019; Trahair et al., 2020). Results of the latent variable approach also indicated similar association of these two expressions of narcissism with empathy. As the latent

variable approach provides no insight into structural relationships of the study variables, the absence of the expected negative association with affective empathy was explained by the „prosocial/ agentic" side of SD3N. However, we assume an indirect link of the SD3N/admiration cluster with affective empathy, a link mediated by psychopathy and rivalry, which would be in accordance with the existing theoretical models (DT; Paulhus & Williams, 2002; NARC; Back et al., 2013).

Method

Participants and procedure

The study was conducted on a sample of 263 participants, senior high school and university students from Vojvodina, Serbia *(M_{age} =18.3; SD_{age} =1.65)* of whom 155 (59%) were females and 108 (41%) were males. The data were collected with the standard paper and pencil testing procedure not causing any reasonably anticipated distress to the participants. All participants provided informed consent for their voluntary participation in the study. The study was approved by the Ethical Committee of the Faculty of Legal and Business Studies Dr Lazar Vrkatić.

Measures

Short Dark Triad (SD3)

The Dark Triad was assessed by the Short Dark Triad (SD3; Jones & Paulhus, 2014; Serbian adaptation Dinić et al., 2018). This 5– point Likert-type scale was composed of 27 items, 9 for each trait: Machiavellianism, Narcissism, and subclinical Psychopathy. Higher score on each SD3 dimension reflects more pronounced presence of a given trait.

Empathy (ACME)

Empathy was assessed by ACME (Vachon & Lynam, 2016) which included 36 self-report items. ACME entailed 3 subscales: cognitive empathy, affective resonance, and affective dissonance. The items were administered using a 5-

point Likert scale. For calculation of the total ACME score affective dissonance scores have been reversed so that the total ACME score represents the overall measure of empathy, with higher ACME scores reflecting higher empathy.

The Narcissistic admiration and rivalry (NARQ)

The Narcissistic admiration and rivalry were assessed by the NARQ scale consisting of eighteen 5-point Likert-type items that measure two dimensions of narcissism (Back at al., 2013): narcissistic admiration and narcissistic rivalry. The original 6-point Likert type rating was replaced with a 5-point rating scale. This was done in order to secure equidistance as an essential feature of interval measurement since 1-5 grading is uniformly used in the Serbian school system and therefore was more familiar to our respondents. Higher score on each NARQ dimension reflects more pronounced presence of a given trait.

Statistical analysis

In the first stage, by use of SPSS software version 25, linear associations of the study variables were analyzed by means of bivariate Pearson product moment correlations. In the second stage, network analysis was used to assess topology of the data set based on direction and strength of mutual linear associations among individual study variables. We relied on the network where nodes represent observed variables and edges represent regularized partial correlations between two variables after controlling for all other variables. Regularized EBICglasso estimation method was used in order to minimize spurious correlations, emphasize unique pairwise interactions and map predictive mediations among the variables (Epskamp et al., 2017). Centrality of variables was assessed via indices of strength, closeness, and betweenness, accompanied by a centralized Zhang clustering coefficient indicating node redundancy (Costantini et al., 2019). Nonparametric bootstrap on 1000 samples was used for assessing edge-weight accuracy. All estimates were performed using R package "qgraph" (Epskamp et al., 2012) and "bootnet" package (Epskamp et al., 2017). The R script and the sample data are available at https://osf.io/7jcks/.

Results

Descriptive statistics, zero-order correlation and internal consistency

We report descriptive statistics and internal consistency for the whole 11-variable data set (Table 1). Reasonable internal consistency was demonstrated for the three psychometric scales and their respective subscales, with Cronbach's alpha ranging from .69 for SD3N to .88 for cognitive empathy, affective dissonance, and the total ACME score. Table 1 displays 55 zero-order correlations among SD3, NARQ, ACME, and their respective components. Since simultaneous presentation of so many inter-correlations is beset by a high probability of Type I error they are primarily inspected for descriptive purposes.

Table 1

Descriptive Statistics, Reliability, Zero-order correlation for SD3, NARQ, and ACME dimensions

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	α	*M*	*SD*
1. SD3M											.72	3.52	0.66
2. SD3N	.37***										.69	3.07	0.68
3. SD3P	.45***	.40***									.72	2.46	0.73
4. Adm	.31***	.68***	.41***								.81	2.27	0.71
5. Riv	.38***	.34***	.58***	.44***							.80	2.68	0.62
6. CEm	.13* (p=.040)	.24***	-.05	.18** (p=.003)	-.22***						.88	3.98	0.65
7. ARe	-.29***	-.18**(p=.004)	-.52***	-.27***	-.63***	.31***					.83	2.16	0.59
8. ADi	.37***	.26***	.64***	.33***	.76***	-.20** (p=.001)	-.66***				.88	3.52	0.66
9. SD3	.77***	.75***	.81***	.56***	.60***	.44***	-.29***	.55***			.83	3.09	0.74
10. NARQ	.40***	.60***	.58***	.86***	.84***	-.02	-.52***	.64***	.68***		.85	2.86	0.67
11. ACME	-.24***	-.09	-.53***	-.19** (p=.002)	-.71***	.64***	.84***	-.83***	-.37***	-.52***	.88	3.86	0.50

Notes. * p<.05; **p<.01; *** p<.001;

Exact p values are shown for all coefficients where p ≥ .001;

α = Cronbach' s alfa; SD3M = the Short Dark Triad measure of Machiavellianism; SD3N = the Short Dark Triad measure of narcissism; SD3P = the Short Dark Triad measure of psychopathy; Adm = admiration; Riv = rivalry; CEm = cognitive empathy; ARe = affective resonance; ADi = affective dissonance; SD3 = the total Short Dark Triad score; NARQ = the total NARQ score; ACME = the total ACME score.

Network analysis

The network analysis represented the study variables as 8 nodes connected by 21 (out of 28 possible) non-zero edges illustrating strength and direction of pairwise partial correlations. The network topology is illustrated in Figure 1. Positive associations were colored by blue while negative associations were colored by red lines. The thickness of an edge corresponds with the strength of the association. The obtained network configuration speaks for integrity of each measuring domain as all nodes from the same measurement domains were directly connected (save for the edge between cognitive empathy and affective dissonance that was estimated close to zero by the EBICglasso methodology). It also speaks for integration of those specific domains into a unique measuring space since the thickest positive edges were observed connecting the nodes from different measurement domains: SD3N – admiration, affective dissonance - rivalry, and affective dissonance – psychopathy.

Twenty-eight regularized partial correlations that were taken into consideration for construction of the network structure depicted in Figure 1 are presented in Table 2. Seven correlations (admiration - affective dissonance; admiration - affective resonance; admiration – Machiavellianism; SD3N - affective dissonance; SD3N - affective resonance; SD3N – rivalry; and psychopathy – cognitive empathy) were limited to zero by the regularized EBICglasso estimation method. However, 95% confidence intervals of eight additional regularized partial correlations included zero (Machiavellianism – rivalry; Machiavellianism - cognitive empathy; Machiavellianism - affective resonance; Machiavellianism - affective dissonance; psychopathy – admiration; psychopathy – rivalry; cognitive empathy - admiration; cognitive empathy - affective dissonance), indicating at uncertainty of those edges (Table 2). The two highest positive regularized partial correlations were between SD3N and admiration and between rivalry and affective dissonance relating to 30% and 22% of the unique shared variance, respectively. The third highest positive regularized correlation was between affective dissonance and psychopathy,

followed by the positive partial correlation between Machiavellianism and psychopathy.

The thickest negative edge was observed between affective resonance and affective dissonance, quite in accordance with the specific measurement domain. Rivalry and SD3N were connected only indirectly via admiration as there was no direct connection between rivalry and SD3N. In addition, rivalry indirectly connected affective resonance and affective dissonance with admiration as there were no direct connections between either affective resonance or affective dissonance with admiration. SD3N was only remotely connected with the two measures of affective empathy, either through the rivalry-admiration or through the Machiavellianism - psychopathy pathways. The shortest connection between psychopathy and cognitive empathy was via rivalry. According to the network analysis, psychopathy and rivalry were also indirectly connected by way of affective dissonance and more remotely by affective resonance.

Relevance of rivalry and affective dissonance for the network configuration was emphasized by the highest frequency of their regularized partial correlations with other variables that exceeded or were equal to the absolute .20 value (Table 2). Regularized partial correlations of Machiavellianism (except with psychopathy) and of cognitive empathy (except with affective resonance) were always bellow the absolute .20 value. The regularized partial correlation between psychopathy and rivalry was close to zero, quite incongruous with their moderate to high zero-order correlation (Table 1), indicating the direct mediating effect of affective dissonance that was observed in Figure 1. On the other hand, the relatively unimpressive regularized partial correlation between Machiavellianism and psychopathy cannot be attributed to any direct mediating effect since the two nodes were connected via the straight edge. Rather, it seems that once direct measures of affective deficits were included in the measurement space their presence – accompanied by the considerable unique variance that was shared between affective dissonance and rivalry (22%) – eclipsed the often-cited link between Machiavellianism and psychopathy.

Nodes' centrality indices: betweenness, closeness, and degree (strength) given in Figure 2 suggest that affective dissonance and rivalry occupied dominant positions of the network. This was evidenced by superiority of affective dissonance in terms of betweenness and closeness, and rivalry's superiority in terms of the degree relative to other nodes of the network. Conversely, the least central positions of the network were occupied by Machiavellianism and cognitive empathy. Nevertheless, based on their respective Zhang clustering coefficients neither Machiavellianism nor cognitive empathy should be labeled as redundant. Affective resonance was the most redundant node of the network as was evidenced by its highest Zhang clustering coefficient accompanied with its low centrality indices. Redundancy of affective resonance is readily explained by its close inverse relationship with affective dissonance. Additional details of the network analysis are provided in the Supplementary materials.

Table 2.

EBICglasso regularized partial correlation for SD3, NARQ, and ACME dimensions

	1.	2.	3.	4.	5.	6.	7.
1. SD3M							
2. SD3N	.14 [.03, .25]						
3. SD3P	.22 [.10, .34]	.12 [.01, .22]					
4. Adm	0	.55 [.46, .64]	.06 [-.03, .15]				
5. Riv	.10 [-.01, .20]	0	.08 [-.03, .19]	.20 [.11, .30]			
6. CEm	.13 [-.01, .26]	.16 [.04, .27]	0	.11 [-.01, .23]	-.13 [-.25, -.01]		
7. ARe	-.02 [-.11, .06]	0	-.13 [-.25, -.02]	0	-.20 [-.32, -.08]	.21 [.10, .32]	
8. ADi	.03 [-.06, .11]	0	.29 [.17, .40]	0	.47 [.37, .58]	-.01 [-.10, .08]	-.29 [-.41, -.17]

Notes. 95% Confidence Intervals are given in square brackets; SD3M = the Short Dark Triad measure of Machiavellianism; SD3N = the Short Dark Triad measure of narcissism; SD3P = the Short Dark Triad measure of psychopathy; Adm = admiration; Riv = rivalry; CEm = cognitive empathy; ARe = affective resonance; ADi = affective dissonance.

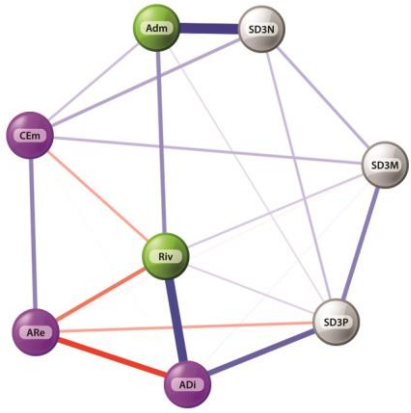

Figure 1. Estimated network structure of SD3, NARQ, and ACME dimensions.

Note. SD3M = Machiavellianism, SD3P = psychopathy, Adm = admiration, Riv = rivalry, CEm = cognitive empathy, ARe = affective resonance, ADi = affective dissonance.

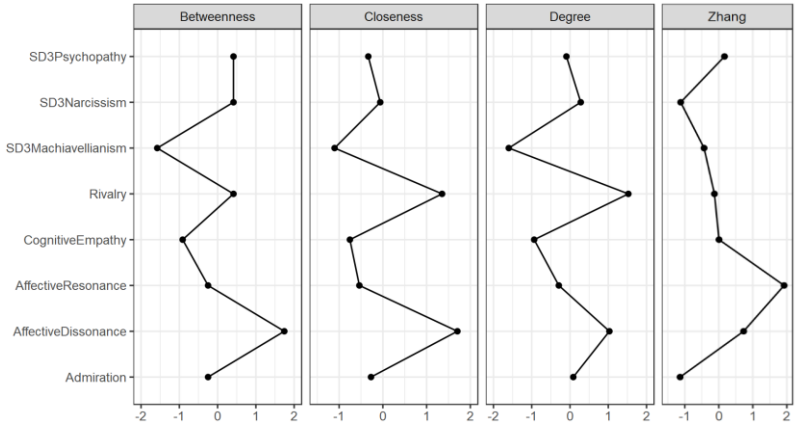

Figure 2. Centrality plot and Zhang clustering coefficient.

Note. Betweenness = number of times a given node lies on shortest path between any two other nodes. Closeness = average distance between a given node and all other nodes, calculated from the inverse of the weighted sum of shortest path from a given node to all other nodes. Degree (strength) = the sum of the absolute input weights of that node. Zhang = the number of connections among the neighbors of a focal node over the maximum possible number of such connections.

Discussion

Structural connectedness of the study variables: affective empathy as a criterion of antagonism

Coherent structure of the present measurement space has been validated by the fact that no study variable was disconnected from the variables of its own measurement domain and from the variables of two other measuring domains. Two mutually remote axes interconnected via rivalry dominated the network topology. Affective dissonance was the most central node of the network, according to both closeness and betweenness criteria. However, according to the strength (degree) criterion the most central position was occupied by rivalry but not by psychopathy, as we have expected. Apparently, overshadowed by affective dissonance and rivalry, psychopathy loses much of its information value. Affective resonance was the most redundant node — as evidenced by its highest Zhang clustering coefficient — contrary to our expectation about Machiavellianism's redundancy given the presence of affective dissonance in the network. In the present pattern of antagonistic traits affective resonance deficit was, most likely, offset by affective dissonance; its opposite and complementary disposition (Vachon & Lynam, 2015). Removal of affective resonance would be least consequential for the topology and the amount of information conveyed by the present network.

So, high extent of antagonism is better defined by the presence of the contradictory affect than by the absence of an appropriate compassionate affect. Absence of affective resonance was a common feature of all study variables, suggesting their malevolent nature. However, high centrality of affective dissonance and redundancy of affective resonance — accompanied by the peripheral position of cognitive empathy in the network — supports the notion about the dual nature of empathy, quite in line with the report on the Dark Empath personality profile (Heym et al., 2021). From this perspective, the proximity and the strength of association with affective dissonance defines the dark roster (affective dissonance, rivalry, and psychopathy), whereas the

remoteness and the absence of direct association with affective dissonance defines the brighter or the duplicitous SD3N – admiration axis. Thus, the data supported both the H1 and the H2 predicting the focal position of affective dissonance in a congregation of toxic traits. Strong positive association with affective dissonance is a critical evidence of trait's malevolence.

Psychopathy as overshadowed by rivalry: the dark (affective dissonance – rivalry – psychopathy) axis

Contrary to our assumption that presence of affective dissonance will further augment psychopathy's position at the dark core, our data pointed at priority of rivalry. Rivalry, but not psychopathy, was the strongest trait in the network, and it was directly connected to all three empathy components. Antagonistic narcissism embedded in rivalry is the vital element of callousness and at the same time the bridge towards the brighter side of antagonism. Thus, rivalry predicts not only the absence of an adequate emotional response and the ability for recognizing the feelings of others, but also the presence of the contradictory affect. It seems that qualitative empathic deficit accompanied with the antagonistic narcissism is located at the core of the evil (Baron-Cohen, 2012).

Proximity between psychopathy and rivalry (high zero-order correlation) was almost entirely mediated by affective dissonance, stressing again the highest strength of rivalry in the network. This mediation suggests that affective dissonance is a common constituent of both rivalry and psychopathy, quite in line with a close parallel between Hare's aggressive and antisocial characterization of psychopathy and antagonistic characterization of rivalry. According to Hare (Hare et al., 1991), manifestations of narcissistic personality disorder and subclinical narcissism have much in common with interpersonal-affective component (Factor I) psychopathy. According to our data, propensity for hurting others and for „sadistic pleasure" is not contained only to psychopathy and sadism (Dinić & Wertag, 2017), as it is also related to antagonistic side of narcissism. Similarly, Truhan et al. (2021) report that antagonism — a facet of grandiose narcissism — is the central feature in the

measurement space encompassing different forms of narcissism, Machiavellianism, and psychopathy. While our findings did not support the H3 — predicting the highest strength of psychopathy — they demonstrated the importance of rivalry for the essence of evil since rivalry was detected as the strongest trait in the whole network.

Machiavellianism

Machiavellianism was the most peripheral and the weakest node of the network, but was not redundant. Removal of this node would considerably affect the overall network composition. Together with cognitive empathy — the second most peripheral node of the network — Machiavellianism is close to the SD3N – admiration axis. It has been established that in the same measurement space with rivalry, Machiavellianism and psychopathy form the common nucleus (Trahair et al., 2020). Our data suggest that the presence of affective dissonance weakens this close connection between Machiavellianism and psychopathy and moves Machiavellianism to a less central position in the network.

This is quite in line with cold and manipulative, characterization of Machiavellianism (Paulhus, 2014). One should keep in mind that Machiavellianism — just like narcissism — can have socially desirable outcomes (Paulhus & Williams, 2002), especially when clear of manifestations that it shares with psychopathy (Sleep et al., 2017). However, in the present data set Machiavellianism's and cognitive empathy's close connections with the SD3N-admiration axis speak of manipulative and duplicitous quality of this four-trait cluster. Although the H4 —predicting redundancy of Machiavellianism —was not supported by our data it was instrumental for structural detection of the dual nature of Machiavellianism.

Duplicity and the dual nature of antagonism: the „brighter" (SD3N – admiration) axis

Another focal point of the network was occupied by the SD3N – admiration axis. These two manifestations of narcissism articulated the strongest conjunction in the network. Like Machiavellianism, both nodes had no direct

connections with either index of affective empathy and positively correlated with cognitive empathy. Besides, SD3N and admiration (agentic narcissism) were strongly connected and had comparable centrality and redundancy coefficients. This is consistent with previous reports on the heterogenic nature of narcissism and on the agentic rather than antagonistic nature of SD3N (Rogoza et al., 2019). However, there are several reasons why the SD3N – admiration axis stands as a reminder of antagonistic duplicity. Firstly, it carried unique information since according to Zhang clustering coefficient the overall network configuration would be more affected by the removal of SD3N than by the removal of psychopathy. Secondly, at the zero-order correlation level of analysis, both SD3N and admiration positively correlated with psychopathy, Machiavellianism, rivalry, and affective dissonance, and negatively with affective resonance indicating that SD3N's nature is not entirely agentic. Direct link of SD3N- admiration nodes with cognitive empathy but not with either index of affective empathy additionally supports the premise about the duplicitous face of narcissism (Back et al, 2013). Through its positive association with cognitive empathy, narcissism camouflages its fundamentally aversive character since the absence of the resonant affective response unequivocally conveys the antagonistic nature of SD3N. In the narcissists, presence of cognitive empathy is primarily indicative of instrumentally refined proficiency for reading emotional states of others. Thus, both narcissism and Machiavellianism disguise their fundamentally aversive character since the absence of the resonant affective response unequivocally conveys the antagonistic nature of SD3N. From this perspective, it could be argued that narcissism provides plasticity to the dual nature of antagonism (Rogoza et al., 2019). With caution, the SD3N – admiration axis can be described as „brighter" since it was not directly connected to contradictory affective deficits, quite in line with the H5 – predicting an indirect link between the SD3N/admiration cluster with affective empathy, a link mediated by psychopathy and rivalry.

In this context, the place and role of cognitive empathy in the constellation of aversive traits deserves additional comments. In their seminal paper, Vachon and Lynam (2016) likewise report that cognitive empathy bore

little association with externalizing psychopathology. Thus, position of cognitive empathy vis-à-vis different dimensions of affective empathy and vis-à-vis malevolent personality traits remains unclear and should be a subject of future studies.

The Dark Triad and empathy

Structural analysis of the present measurement space confirmed consistency of the DT but also the dual nature of both narcissism and Machiavellianism. The DT traits were divergently related to distinct forms of empathic deficit, quite in alignment with the original paradigm (Paulhus & Williams, 2002). Psychopathy was the linchpin connecting affective deficit and two other DT traits, a clear manifestation of its central position in the DT. This finding may throw additional light on the incongruous reports on the connection between DT and empathy (Wai & Tiliopoulos, 2012). Psychopathy is the mainstay of the variance shared by DT traits (Glenn & Sellbom, 2015). It seems that affective dissonance is the central point of antagonism or the core of evil, and psychopathy is the core of the DT.

Contributions and implications

The foremost novelty of the study arises from the application of a structural viewpoint and the ensuing importance of rivalry (the dark narcissism) and affective dissonance (the dark empathy) in the constellation of antagonistic traits. This change of perspective was enabled by the relatively novel and more nuanced approaches to empathy as defined by ACME, and narcissism as defined by NARQ. According to Jonason and Kroll (2015), one- and two-dimensional approaches to empathy fall short of demonstrating any compelling moderation effect between empathy and the DT traits. This study has successfully overcome this deficiency by revealing an intricate web bridging ACME and SD3 dimensions. The network analysis identified both direct and indirect structural relationships among the study variables, an information exceeding the scope of the traditional latent variable approach. In addition to original insights about the roles of qualitative empathic deficit and toxic narcissism in the pattern of antagonistic

traits, the network analysis supported the notion about the heterogeneous nature of DT, with psychopathy as the mainstay of the joint nucleus. The use of the ACME model was justified by findings pointing at the prominence of qualitative distortion of empathic response. While this is in line with previous reports on presence of inappropriate emotions among the psychopaths, this study recommends simultaneous assessment of antagonistic narcissism in the forthcoming studies of socially aversive behaviors.

Limitations

Several imperfections hinder contributions of this study. It was based on self-reports from a relatively small, non-clinical and non-representative sample of mostly adolescents from a geographically limited area, potentially restricting variability of their responses and power of statistical analyses. We relied on the validated Serbian version of SD3 (Dinić et al., 2018) and on non-validated translations of NARQ and ACME. While both NARQ and SD3 have been used in studies including adolescents (Rogoza et al., 2019) they were originally developed and validated on adult respondents. Another important limitation originates from the relatively modest reliability of SD3N. Relatively low reliability of this measure has been reported in other studies utilizing SD3 (Dinić et al., 2020). Nevertheless, the soundness of our data was demonstrated by their overall interpretability and internal consistency.

Conclusion

Network analysis disclosed critical position of affective dissonance and rivalry in the overall network composition, and pointed at predictive mediations among the variables, an information that was inaccessible by other statistical methods. Our data support the notion that empathic deficit is the mainstay of antagonism. Accordingly, divergent forms of empathic deficit may explain different manifestations and intensity of antagonism. It seems that the critical empathic deficit is not the absence of an adequate affective response but rather the presence of a contradictory affective response. If so, as suggested by our

data, affective dissonance (additionally endorsed by its strong association with rivalry) is a strong candidate for the dark core of personality.

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Conflict of Interest

There is no conflict of interest to report.

Data availability statement

The dataset, R code and Supplementary Materials are publicly available at: https://osf.io/7jcks/.

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Struktura mraka: mračna trijada, „mračna" empatija i „mračni" narcizam

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SAŽETAK

Uprkos opšte saglasnosti da je empatski deficit osnovna karakteristika mračnog karaktera, savremena istraživanja ukazuju da su osobine mračne trijade, posebno narcizam, različito povezane sa kognitivnom i afektivnom empatijom. Imajući to u vidu, istraživali smo strukturu mrežnog prostora definisanog upitnicima za merenje afektivne i kognitivne empatije, narcističkog divljenja i rivaliteta i mračne trijade (SD3). Dodatni model narcizma je uključen u merni prostor, jer su mnogobrojni nalazi doveli u pitanje antagonističku prirodu narcizma SD3. Primenom metoda olovka-papir testiran je *ad hoc* uzorak koji se sastojao od 263 maturanata i studenata,

prosečno starih 18.3 godine. Analizom mreže utvrđeno je da sve merene varijable pripadaju jedinstvenom prostoru, čime je potvrđena njihova antagonistička priroda. Izdvojene su dve osovine koje su se razlikovale prema specifičnom tipu afektivnog deficita: osovina „mraka" koju su činile afektivna disonanca, rivalitet i psihopatija, i „svetlija" osovina koju su činile narcizam SD3 i divljenje. Centralno mesto u mreži je imala afektivna disonanca, dok je afektivna rezonanca bila redudantna. Rivalitet – most koji povezuje dve osovine – je imao najveću snagu u mreži i bio je bliži afektivnoj disonanci od psihopatije. Uključivanje afektivne disonance udaljilo je makijavelizam od psihopatije i približilo ga narcizmu, čime je potvrđena dvolična priroda makijavelizma. Mrežnom analizom došlo se do informacija koje su nedostupne tradicionalnim statističkim metodama i ukazano je na značajnu distinktivnu ulogu različitih tipova empatskog deficita u konstelaciji antagonizma.

Ključne reči: analiza mreže, empatski deficit, mračna trijada, rivalitet, divljenje

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Research Article

Temperament and character differences in psychopathic and non-psychopathic antisocial adolescents

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ABSTRACT

The present study tested the possibility of distinguishing between different types of antisocial adolescents based on psychopathic characteristics, and the differences between antisocial adolescents of different ages and subtypes in relation to the Cloninger's personality dimension. The sample included 101 antisocial male adolescents, divided into two age groups (71 respondents in the 13-17 age group and 30 in the 18-25 age group). After conducting model-based cluster analyses, non-psychopathic type (without pronounced signs of psychopathy) and psychopathic type (with pronounced antisocial, lifestyle and interpersonal facet) (Hare's model) were singled out in the whole sample. Within the psychopathic type, in comparison with juveniles, older adolescents showed a significantly lower expression of character dimensions of Self-directedness and Cooperativeness, which are key in determining all personality disorders. Within the group of juvenile offenders, members of the two subtypes did not differ significantly in temperament and character, which indicates that juveniles are in the process of personality development, especially when it comes to their character, so they are more susceptible to treatment and their outcomes are uncertain. The results suggest that

the inflation of psychopathic scores may occur in juveniles due to the identification of developmental features of adolescence (impulsivity, immaturity) as psychopathic, which implies the need to apply basic personality models in the assessment of antisocial adolescent.

Keywords: antisocial behavior, personality traits, youth psychopathy, juvenile offenders, psychopathy assessment

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Introduction

Antisocial behavior and psychopathic traits in adolescence

Antisocial behavior is usually defined as a behavior that violates social norms and harms the rights of others (Álvarez-García et al., 2019). Developmental changes during adolescence, which are reflected in the increased risk-taking and sensation seeking, still-developing self-control, weakening ties with parents and strengthening peer influences are important for the emergence and increase of antisocial behavior of some adolescents (Álvarez-García et al., 2019; Romer et al., 2017; Rudolph et al., 2017; Taylor et al., 2015). Adolescents with conduct disorders (CD) represent a heterogeneous group with respect to the different outcomes of their antisocial behavior (Bevilacqua et al., 2018). Although most adolescents show a cessation or decline in the rate of antisocial behavior in adulthood (Kazemian, 2021; Steinberg et al., 2015), the subtype of children and adolescents with psychopathic traits was separated within the population of children and adolescents with CD, associated with a special path of antisocial behavior characterized by early onset, more serious, diverse, and persistent antisocial behavior. This psychopathic subtype in youth has poorer prognosis, as a tendency to develop antisocial personality disorder (APD), substance related disorders and chronic crime in adulthood (Asscher et al., 2011; Goulter et al., 2018; Hemphälä & Hodgins, 2014). Early psychopathic traits can most likely be identified within the developmental path of delinquency with an early onset and throughout the entire life cycle (Moffit, 2018; Moffitt et al., 2008).

Psychopathy refers to a specific construct of antisocial personality that has a long history in psychological and biomedical sciences. Although it is not part of existing diagnostic classifications, DSM-5 recognized psychopathy as a "specifier" of clinical APD (Conti, 2016; Drislane et al., 2019). Robert Hare developed a model according to which psychopathy represents a personality disorder consisting of affective, interpersonal and behavioral characteristics and defines four-facet model of psychopathy (Hare & Neuman, 2008, 2010). Interpersonal (e.g., glibness/superficial charm) and Affective facets (e.g., callousness/lack of empathy), refer to personality traits and together form a

higher order factor, called Interpersonal/affective, while Lifestyle (e.g., impulsivity/irresponsibility) and Antisocial facets (e.g., criminal tendencies) make up another higher order factor – Socially deviant lifestyle, which refers to antisocial behavior patterns (Newman et al., 2014).

In the last three decades there has been a growing interest in adapting and expanding the concept of psychopathy to children and adolescents (Pisano et al., 2017). The research singles out a subgroup of children and adolescent called psychopathic, who have pronounced callous-unemotional traits, extreme behavioral problems, special neurocognitive profile, higher genetic risk, poor prognosis and serious criminal career (Andershed et al., 2018; Byrd et al., 2018; González Moraga et al., 2019; Frick, 2009; Frick et al., 2014; McCuish et al., 2015; Moore et al., 2019; Soma et al., 2018; Viding et al., 2008). Callous-unemotional (CU) traits, related to lack of empathy and remorse, insensitivity to others' feelings, and shallow and deficient affect, are considered a key factor in psychopathy in young people (Baskin-Somers et al., 2015; Frick et al., 2014; Squillaci & Benoit, 2021). DSM-5 added a "limited prosocial emotions" (LPE) specifier for the CD, which is based on CU traits (Colins et al., 2020).

Questionnaires for assessing psychopathy in children and young people are mostly a modified version of the Hare's scale for adults (Psychopathy Check List-Youth Version (PCL-YV; Forth, Kosson & Hare, 2003) (Forth & Brazil, 2019; Neumann et al., 2006). The results of previous research confirm that child and adolescent psychopathy have structural homogeneity and a similar factor structure as psychopathy in adults, but with some developmental differences (Andershed et al., 2018; Frick & Morris, 2004; Hawes et al., 2014; Luo et al., 2021; Lynam et al., 2008; Salekin et al., 2006).

Previous studies suggest reduction in maladaptive psychopathic personality traits from adolescence to adulthood, which is consistent with the well-documented decrease in offending that occur during early adulthood (Hawes et al., 2014; McCuish & Lussier, 2018). Also, studies show that levels of psychopathic traits have the potential to change over time under the influence of certain predictors (e.g., delinquent peer association, parental warmth, exposure to violence) (Kerr et al., 2012; Pauli et al., 2020; Ray et al, 2018; Viding &

McCrory, 2018; Waller et al., 2016). These results are consistent with the understanding of some authors that perceived psychopathic traits in youth are subject to change and may reflect typical developmental characteristics in adolescence (immature behavioral controls, sensation seeking, impulsivity) which usually improve with time and guidance (Seagrave & Grisso, 2002; Simões & Conçalves, 2017). Callous-unemotional traits appear to show greater stability over time and relate to primary emotional deficits underlying psychopathy, whereas poor behavioral control and even social deviance are likely more natural developmental stages, that some youth may outgrow (Anderson & Kiehl, 2014). As personality is not fully structured and defined in adolescence and as it is in the process of development, the question arises whether we can speak of psychopathy as a fully structured personality disorder in adolescence.

The researchers' interest in adolescent psychopathy focus on developing measures that will be dimensional instead of categorical (Markus, 2017; da Silva et al., 2012), and thus growing interest in the possibility of conceptualizing psychopathy within basic personality models, mostly within Big Five Model (Simões & Conçalves, 2017). Since some psychopathic traits have a neurobiological basis, we believe that attempts to conceptualize psychopathy within psychobiological personality models, such as Cloninger's psychobiological model, may be useful. Personality traits within this model refer to developmental constructs.

We can conclude that the concept of psychopathy in children and adolescents is still the subject of numerous controversies and disagreements. There is a danger of labeling children and adolescents as psychopaths, due to possible stigmatization and adverse impact on court decisions and the availability of treatment and other social measures (Murrie et al., 2005; Simões & Conçalves, 2017; Viding & McCrory, 2018). There are numerous problems in the field of conceptualization and measurement of psychopathy in adolescence and they concern the stability of psychopathic traits in the developmental period and dimensional versus categorical nature of psychopathy (Cauffman et al., 2016; Simões & Conçalves, 2017; Markus, 2017). According to some authors, future research should broaden its focus from CU traits to other dimensions of the

construct (grandiose-manipulative and daring-impulsive) and interactions of dimensions, as well as to enhance measurement precision (Andershed et al., 2018; Salekin, 2017). Despite these problems, isolation of the subgroup of children and adolescents with psychopathic traits would be important for prevention, prediction of outcomes and construction of appropriate treatments (Frick et al., 2014; Pisano et al., 2017; Viding & McCrory, 2018; Wilkinson et al., 2016).

Cloninger's model of personality

Cloninger's psychobiological model of personality is intended primarily for the assessment of normal personality, but it also has a special application in the diagnosis and differentiation of personality disorders, including APD and/or psychopathy (Cloninger, 2005, 2008; Svrakic et al., 2002). According to Cloninger, personality is a complex neurobiological and neurogenetically based adaptive system composed of different but interactive domains of temperament and character (Cloninger, 2005). Cloninger's model is called the Seven-Factor because it encompasses four dimensions of temperament: Harm Avoidance, Novelty Seeking, Reward Dependence, and Persistence, and three-character dimensions: Self-Directedness, Cooperativeness and Self-Transcendence. The dimensions of temperament are universal and independent of culture or ethnicity. They are genetically based, reflect individual differences in the strength of associative learning, manifest in early childhood and are relatively stable throughout life, while character dimensions appear later in life, influenced by socio-cultural factors and maturation (Svrakic et al., 2002; Zohar, 2007). Harm Avoidance refers to the tendency to inhibit behavior in response to adverse stimuli and danger/punishment; Novelty Seeking refers to the tendency to initiate exploratory behavior in response to novelty and to react impulsively; Reward Dependence represents a bias to respond to reward and social approval strongly; and Persistence represents the tendency to persevere despite frustration or fatigue. In terms of character dimensions, Self-Directedness refers to a person's degree of responsibility, independence, self-esteem, and goal-oriented behavior; Cooperativeness refers to the level of empathy and compassion for other people, and the degree to which an individual sees himself

as part of the community; finally, Self-Transcendence implies the extent to which a person sees himself/herself as part of the universe and the extent to which they are religious.

Within the Cloninger's model, all personality disorders, regardless of type, are characterized by lower levels of character development, especially the dimensions of Self-Directedness and Cooperativeness (Cloninger, 2005; Cloninger & Svrakic, 2008; Snowden & Gray, 2010), while individual temperament types can be distinguished based on temperament dimension configurations (Cloninger & Svrakic, 2008; Richter & Brändström, 2009). APD is characterized by low Harm Avoidance, and Reward Dependence dimensions, as well as a high Novelty Seeking dimension (Cloninger, 2005; Martínez-López et al., 2019; Snowden & Gray, 2010; Svrakic et al., 2002). Basoglu with associates (2011) partially confirmed this model in the group of 68 young adults male with APD and the control group of 65 healthy male, showing that PCL-R Factor 1, Factor 2 and Total scores were positively correlated with Novelty Seeking and unexpectedly with Harm Avoidance, and were negatively correlated with Reward Dependence, Persistence, Self-Directedness and Cooperativeness in the whole sample, but when each group was analyzed separately, the correlations were not significant. The authors believe that reduced variance of PCL-R scores in each group might lead to nonsignificant associations within groups. Lenox and Dolan (2014) state that they conducted the first study of the relationship between Temperament and Character Inventory (TCI) and the PCL-YV in juveniles. In a sample of 121 incarcerated juvenile male offenders, they found that PCL-YV total score was positively correlated with Novelty Seeking but negatively correlated with Cooperativeness and Harm Avoidance.

Cloninger's model of personality, which in addition to relatively hereditary and stable temperament traits includes character aspects, which may be influenced by learning and environment, may provide the theoretical grounds for intervention in prevention and treatment of antisocial behavior and psychopathy in children and adolescents (Lee et al., 2018).

Aims of the Study

In this study, we were interested in determining whether antisocial adolescents formed a homogeneous group or whether a psychopathic subtype could be distinguished according to Hare's model of psychopathy, and whether the concept of psychopathic traits could be extended to the age below eighteen. Also, the subject of the present research was the relationship between psychopathic characteristics and personality dimensions within the Seven-Factor model in adolescence. We investigated whether antisocial adolescent of different subtypes (psychopathic and non-psychopathic) and different ages (younger – 13 to 17 years and older – 18 to 25 years) differ in temperament and character dimensions, bearing in mind the developmental changes during adolescence that may be reflected in the manifestation of psychopathic traits.

In accordance with the objectives of the research, the following hypotheses were formulated:

Hypothesis 1.

We expect that a psychopathic subtype of adolescents can be singled out, which will include adolescents younger than 18 and adolescents aged 18 and older based on the severity of Hare's psychopathy factors. The psychopathic subgroup of adolescents will show significantly higher scores on the four facets of psychopathy compared to the members of the non-psychopathic group of adolescents.

Hypothesis 2.

a) In the case of isolating the psychopathic type among adolescents under the age of 18, we expect that this subtype will not differ significantly from the group of older psychopathic adolescents in relation to Cloninger's personality dimensions.

b) The psychopathic group of younger adolescents will differ significantly from the group of non-psychopathic adolescents from the same age group in relation to Cloninger's personality dimensions.

Method

Participants

101 male antisocial adolescents were examined in a cross-sectional study. Participants were divided into two age groups: 71 subjects in the 13-17 age group met the DSM-IV diagnostic criteria for conduct disorder (CD) based on clinical or criminal personal files, and 30 subjects in the 18-25 age group met diagnostic criteria for APD based on criminal personal files and achieved T score ≥ 70 on MMPI-202 Psychopathic Deviation subscale (Pd, MMPI-202, Biro, 2001). We decided to include respondents with CD and APD diagnostic categories depending on age, since psychopathy is a subgroup within these diagnostic categories, so it is expected that respondents with pronounced psychopathic characteristics according to Hare's criteria can be identified within the population with these diagnoses. An additional criterion for inclusion in the sample was that the respondents completed a minimum sixth grade of elementary school, in order to have sufficient reading skills to complete the questionnaires. The age of the respondents in the younger group varied in the range of 13 to17 years (AS = 16.27; SD = .985), and in the older group from 18 to 25 years (AS = 22.17; SD = 1,780).

Instruments

Psychopathy Assessment Questionnaire (PAQ; Novović et al., 2006)

PAQ questionnaire (Biro et al., 2008) is based on Hare's model of psychopathy (PCL-R, Hare, 1991). It comprises 4 subscales that correspond to the facets of Hare's model of psychopathy (Interpersonal Relationships, Psychopathic Affect, Lifestyle and Antisocial Behavior). It contains 40 items with a binary response form (Yes/No), and it is intended for use with an adult population. According to the authors of the instrument, the questionnaire show ssatisfactory metric characteristics (Biro et al., 2008). In order to check the latent structure of the PAQ subscale measurement space, the questionnaire is modified and shortened (consisting of 24 items) for the purpose of this study, based on

the principal component analysis with Oblimin-Kaiser rotation, because it has not been used in adolescents so far. In the modified version, the subscale Antisocial Behavior (4 items) includes items that indicated tendency for criminal behavior, problems at school or work, and breaking the rules. Subscale Lifestyle (6 items) includes items indicating increased need for stimulation, irresponsibility, proneness to abuse of psychoactive drugs, and promiscuous behavior. Subscale Interpersonal Relationships (8 items) includes items corresponding with impulsivity, lack of scruples, callous belief in personal charm, and being manipulative, while subscale Psychopathic Affect (6 items) includes items of superficial affect and lack of empathy, remorse, and guilt. The reliability of the modified scale is presented by Cronbach's alpha coefficient in the study sample ranged from .534 for Psychopathic Affect to .739 for Antisocial Behavior. The less satisfactory reliability of the Psychopathic Affect subscale results from the lower reliability of this subscale in the initial version of the questionnaire and possible limitations in terms of the construct validity measurement (modification of the questionnaire improved the reliability of the subscale). Also, the modified subscale contains 4 items that have a socially desirable connotation (reverse scoring), which may have influenced the way respondents chose the answer to this subscale.

Temperament and Character Inventory (TCI-5) (Cloninger, 1999) (Serbian version by Knežević & Džamonja-Ignjatović, 2005)

TCI-5 consists of 7 scales describing the 4 dimensions of temperament (Novelty Seeking, Harm Avoidance, Reward Dependence, and Persistence) and 3 dimensions of character (Self-Directedness, Cooperativeness, and Self-Transcendence), intended for ages 18 and older. The questionnaire contains a total of 240 items, which are assessed on a five-point Likert scale (from 1-Strongly disagree to 5-Strongly agree). Studies confirmed construct validity, reliability and the cross-cultural applicability of the TCI-5 in Serbia (Džamonja-Ignjatović & Knežević, 2005; Dzamonja-Ignjatovic et al., 2010). The reliability of the TCI-5 questionnaire scales in the study sample is relatively satisfactory and ranges from Cronbach's alpha .57 for the Novelty Seeking scale to .86 for the Persistence and Self-Directedness scales. The slightly lower reliability of the

Novelty Seeking scale possibly results from sample selection (antisocial adolescents male), since TCI-5 was validated on a representative sample from the normal population.

Adolescent Temperament and Character Inventory (ATCI-84) (Dukanac & Džamonja-Ignjatović, 2008)

ATCI-84 is intended to assess adolescents aged 14-18 years. It contains 84 items grouped into four temperament scales (Novelty Seeking, Harm Avoidance, Reward Dependence, and Persistence) and three-character scales (Self-Directedness, Cooperativeness, and Self-Transcendence), which correspond to Cloninger's personality dimensions. All scales have 12 items that are assessed on a five-point Likert-type scale (1-Strongly disagree to 5-Strongly agree). There are no published data on the metric characteristics of this questionnaire, while the reliability of the scales for the ATCI-80 version of the questionnaire indicates moderate reliability, ranges from .69 to .79, estimated by the alpha coefficient of internal consistency. The scales show acceptable validity (Dukanac et al., 2011). ATCI-84 reliability expressed by Cronbach's alpha coefficient in this study ranges from .62 for Cooperativeness to .74 for Self-Transcendence scale and .76 for Harm Avoidance.

The MMPI-202 Psychopathic Deviation (Pd) subscale (Biro, 2001)

Pd subscale (MMPI-202) which was used to assess the clinically significant severity of psychopathic deviation, has a binary response form (Yes/No) and satisfactory metric characteristics.

Procedure

The sample was collected within youth offender correctional and clinic facilities (Juvenile Penitentiary-Correctional Facility Valjevo, Juvenile Detention Facility Kruševac, District Prison in Novi Sad, and Clinic for Psychiatry, Department for Child and Adolescent Psychiatry, Novi Sad). Objective assessment of subjects for selection in the sample was performed over a period of six months, by two authors of this study (clinicians who specialized in mental health). The assessment was based on insight in to patients' medical records

(medical history) in clinical settings, and into personal criminal records for those respondents residing in youth offender correctional facilities. After selection, the respondents filled out self-assessment questionnaires, and the examination was conducted in small groups within correctional institutions, and individually in a clinical setting. Participants in the 13- to 17-year-old age group filled out PAQ and ATCI-84, while participants in the 18- to 25-year-old age group filled out PAQ, TCI-5 and MMPI-202 Pd subscale.

The research was conducted voluntarily, in the presence of a one or two authors, and in a presence of prison officers in correctional settings in accordance with the rules of those institutions. All participants and parent/guardian of a minor signed the informed consent, including the anonymity and confidentiality of the data agreement.

Data analysis

A model-based clustering (MBC) (Banfield & Raftery, 1993) was used from the R (R Core Team) Mclust software package (Sccruca et al., 2016) in order to isolate clusters based on the configuration and severity of scores on psychopathic factors. The MBC goes beyond the limitations of traditional explorative cluster analysis related to cluster number selection and grouping procedures. The likelihood-based Bayesian Information Criterion (BIC) were used to determine the best fitting model to the data, which allows models to be compared with different cluster numbers and sizes. If the BIC value is higher, the support for a given model is greater. A multivariate analysis of variance (MANOVA) was conducted in order to compare the clusters on the four variables used for their derivation. Wilks Lambda test statistics and post hoc tests of inter-subject effects were used. Differences in temperament and character dimensions for participants belonging to different clusters, and different age groups within the cluster were examined by linear discriminant analysis with bootstrap procedures in order to calculate parameters and confidence intervals. Basic assumption testing was conducted for homogeneity of covariance matrices. Since the younger and older respondents filled out a parallel form of questionnaire (ATCI and TCI-5) the scores on the scales were converted to

standardized values based on the norms, and then expressed on the T scale (AS = 50, SD = 10). Self-Transcedence scale was not used in the analysis, because in ATCI form was modified and shortened, and could not be compared with normative data.

Results

Subtypes of antisocial adolescents

Based on the scores of the total sample of antisocial adolescents, a model-based cluster analysis on four factors of psychopathy assessed on the PAQ questionnaire (Antisocial Behavior, Lifestyle, Psychopathic Affect, and Interpersonal Relationships), singled out the best fit model representing the solution with 2 clusters and with the highest *BIC* value = - 15551.843. This model was chosen among the four best models, all with 2 cluster solutions, because it has the best suitability index and it is more stable across data subsamples and variable sets. The selected clusters are diagonal, with equal volume and shape.

The first cluster is called non-psychopathic, due to the low expression of Antisocial Behavior and Lifestyle factors, relatively low pronounced Interpersonal Relationships factor, and the more moderately pronounced Psychopathic Affect factor. The second cluster has highly pronounced scores on the Antisocial Behavior, Lifestyle and Interpersonal Relationships scales and more moderate score on the Psychopathic Affect scale of the PAQ questionnaire and it is called the psychopathic type. In the first cluster there were 29 (28.71%), and in the second 72 (71.29%) respondents. All respondents from the older group (except one) were classified in the psychopathic cluster, while respondents from the younger group were classified in both clusters (28 respondents in the first cluster and 43 in the second cluster). Figure 1 shows the means of the isolated subtypes on psychopathy factors. The subsequent multivariate analysis of variance (MANOVA) to compare one subtype with another on psychopathy factors, found a significant multivariate effect, $F = 66.083$, $p = .001$, *Wilks' Lambda* = .266. There was a significant effect of cluster affiliation on PAQ subscales, except on the Psychopathic Affect scale (Interpersonal Relationships, ($F(1)$ =

130.250, p = .000, Antisocial Behavior, (F(1) = 124.791, p = .000, Lifestyle, (F(1) = 60.131, p = .000, and Psychopathic Affect, (F(1) = .495, p = .483).

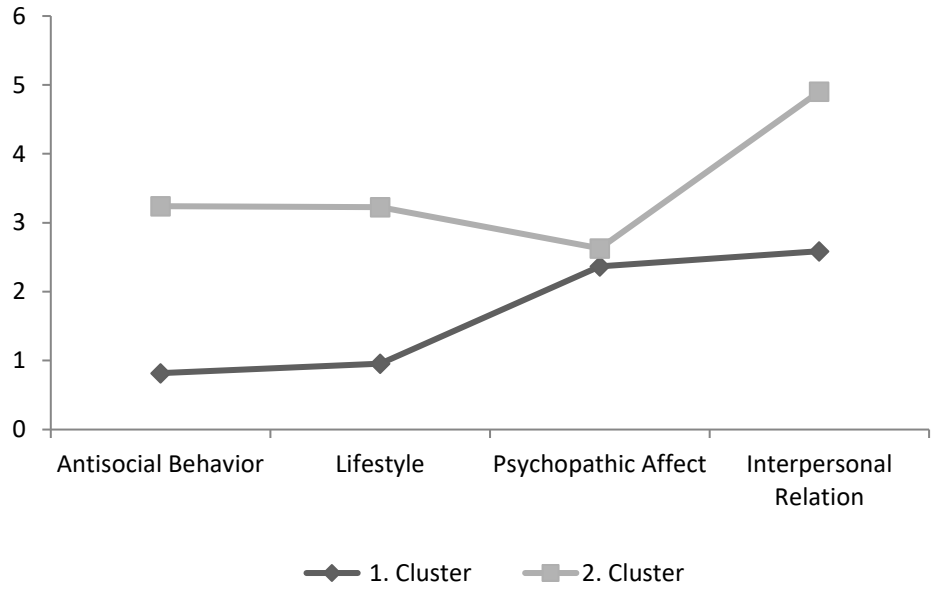

Figure 1. Means of clusters on psychopathy factors

Difference between older and younger psychopathic types by dimensions of character and temperament

We were interested in learning whether within the isolated psychopathic type we could differentiate between older (18-25) and younger (13-17) offenders who belong to this type regarding the dimensions of temperament and character.

The discriminant analysis highlights one significant discriminant function (*Wilks' Lambda* = .093, $\chi 2$ = 154.499, *df* = 6, p = .000). The structure of the discriminant function of temperament and character dimensions are given in Table 1. The discriminant function is predominantly determined by the Cooperativeness, Self-Directedness and Persistence dimensions. According to

the bootstrapping procedure, only the character dimensions of Cooperativeness and Self-Directedness are important for the discrimination of younger and older psychopaths, because the 95% confidence interval of the standardized coefficient does not include 0 (Table 1). Younger psychopaths have higher scores on the discriminatory function, which means that they are more cooperative and self-directed compared to older adolescent psychopaths.

Table 1

Matrix structure of discriminant function of temperament and character dimensions for younger and older psychopaths

Personality dimensions (Cloninger)*	Standardized canonical discriminant coefficients	Bootstrapping				Structure of discriminantfunction
		Bias	Standard error	95% confidence interval		
				lower	upper	
Cooperativeness	.594	.083	.186	.340	1.102	.749
Self-Directedness	.682	-.014	.301	.042	1.221	.738
Persistence	.064	-.034	.317	-.615	.617	.675
Harm Avoidance	.257	-.003	.164	-.069	.578	.048
Reward Depedance	-.171	-.028	.203	-.629	.175	.027
Novelty Seeking	-.069	.012	.219	-.493	.381	.001

Note. Self-Transcedence scale was not used in the analysis

Distinguishing between members of the psychopathic and non-psychopathic type within the younger age group by dimensions of character and temperament

We conducted a discriminatory analysis of "bootstrapping" to determine whether juvenile offenders (13-17 years) belonging to the psychopathic and non-psychopathic subtypes differ based on personality dimensions (ATCI). The results

show that there were no significant differences between younger psychopaths and non-psychopaths in the degree of expression of temperament and character dimensions, i.e., that no significant discriminant function was singled out (*Wilks' Lambda* = .908, $\chi 2$ = 6.215, *df* = 7, *p* = .515). Table 2 shows the descriptive characteristics of the selected types of younger adolescents on the dimensions of temperament and character.

Table 2
Descriptive values on temperament and character dimensions for psychopathic and non-psychopathic younger adolescents

Cluster	Personality dimensions	*M*	*SD*
Non-psychopathic	Novelty Seeking	39.85	9.48
	Harm Avoidance	38.93	7.76
	Reward Dependence	39.07	6.37
	Persistence	44.26	7.14
	Self-Directedness	40.67	5.86
	Cooperativeness	42.07	7.50
	Self-Transcendence	18.48	5.55
Psychopathic	Novelty Seeking	43.14	7.65
	Harm Avoidance	36.25	9.44
	Reward Dependence	37.93	7.94
	Persistence	45.65	7.55
	Self-Directedness	42.05	7.99
	Cooperativeness	40.93	6.17
	Self-Transcendence	19.30	6.01

Note. M- mean; *SD* - standard deviation.

Discussion

This study singled out the psychopathic type in the group of juveniles (under 18), which was grouped together with the older psychopathic group of adolescents (18 years and older), which suggests that the concept of psychopathic traits can be extended to juvenile delinquents. This is in line with empirical evidence from numerous studies (Andershed at al., 2018; Byrd et al., 2018; González Moraga et al., 2019; Frick, 2009; Frick et al., 2014; Luo et al., 2021; Ronchety et al., 2014).

The isolated psychopathic type was characterized by a significantly higher expression of scores on the three facets: Antisocial Behavior (disrespect of rules and norms, and diverse and chronic crime) and Lifestyle (impulsivity, irresponsibility, seeking excitement, substance abuse, promiscuous behavior), as well as on the personal facet of Interpersonal Relationships (grandiosity, superficial charm, manipulativeness, tendencies to lie and exploit other people), while there are no significantly more pronounced scores on the Psychopathic Affect facet (superficial affect, decreased empathy, lack of remorse and guilt, callousness). The first hypothesis was partially confirmed. It was confirmed that the psychopathic subgroup compared to the non-psychopathic group of adolescents showed significantly higher scores on Antisocial Behavior, Lifestyle and Interpersonal Relationships factors, while the hypothesis was not confirmed in part that the psychopathic subtype had significantly higher scores on Psychopathic Affect factor. The isolated psychopathic subtype of adolescents corresponds to the secondary type of psychopathy, with pronounced features of impulsivity and reactive aggression, but without highly pronounced callous-unemotional (CU) traits, i.e., affective features of psychopathy (Dochery et al., 2016; Yildirim et al., 2015). CU traits are considered a key factor in psychopathy in youth and were constructed as "primary" psychopathy (Baskin-Somers et al., 2015; Dochery et al., 2016; Squillaci & Benoit, 2021). The prevalence of primary psychopathy is relatively low compared to secondary psychopathy (Hare & Neuman, 2010), which is probably why there is no distinction between the subtypes in psychopathic affect found in this study.

In relation to the Cloninger's personality model, it was found that older adolescents (18-25 years) with more pronounced psychopathic scores compared to younger psychopaths (13-17 years) show a significantly lower expression of two-character dimensions, Self-Directedness and Cooperativeness, with Self-Directedness having the highest contribution to the distinction between younger and older psychopaths, while there are no significant differences in temperament dimensions. The second hypothesis (H2a) was partially confirmed. The hypothesis was confirmed in the part that younger and older members of the psychopathic subtype did not differ significantly in temperament dimensions, while it was not confirmed that they did not differ significantly in character dimensions. The Self-Directedness dimension is the most important in determining all PDs (Cloninger, 2005; Snowden & Grey, 2010). Although there were no significant differences in temperament dimensions, older adolescents with psychopathic scores had less pronounced Harm Avoidance dimensions than younger psychopaths, which is associated with a lack of fear and inhibition in responding to aversive stimuli and is consistent with Cloninger's APD. Compared to younger ones, older psychopaths were also characterized by lower Persistence expression, i.e., less ambition, perseverance, and tolerance to frustration, and these differences show a trend towards statistical significance. Persistence was not related to a specific neurotransmitter system, which has led some authors to question its temperamental basis (Gillespie et al., 2003) and link it to character dimensions (Dukanac & Džamonja-Ignjatović, 2008).

It is interesting that younger psychopaths show higher levels of Novelty Seeking and Reward Dependence dimensions compared to older ones, which indicates that they are characterized by greater impulsiveness, curiosity, risk-taking, search for rewards and approval, and weaker self-control of behavior. This is in line with the results of the previous studies (Asch et al., 2009; Chang et al., 2007; Ha & Kwon, 2016; Hemphälä et al., 2012; Kim et al., 2006; Lee et al., 2018; Lenox & Dolan, 2014; Schmeck et al., 2006). It is possible that the typical developmental features of adolescence in the form of emotional and cognitive immaturity and reduced self-control (Icengole et al., 2019) have a greater impact on scores on these two dimensions than the psychopathic features themselves.

This is supported by the findings that adolescents with CD did not differ from the non-clinical population of adolescents in Novelty Seeking (Atarhouch et al., 2004) and Harm Avoidance (Schmeck & Poustka, 2001). The described developmental features have a biological basis in the incomplete development of the prefrontal lobe, which is responsible for executive functions, and the dominance of the amygdala, responsible for processing emotional information, especially up to 18 years of age (Popma & Raine, 2006; Romer et al., 2017; Rudolph et al., 2017). With the psychobiological maturation of adolescents, it is possible to achieve better levels of self-control at a later age and to alleviate these temperament traits.

The comparison of members of psychopathic and non-psychopathic subtypes within the group of younger adolescents, by dimensions of temperament and character, showed that there were no significant differences between the two types of young adolescents. The second hypothesis (2b) was not confirmed. This can be explained by the fact that the entire sample of younger respondents consisted of adolescents with CD, or juvenile offenders with diverse and severe antisocial behavior, so it was expected that they would all show a similar antisocial temperament configuration. It is also possible that character dimensions were not completely formed at a younger age, as in older respondents, which could have had an impact on the registered absence of differences in the expression of character dimensions between juvenile offenders' subtypes. Character is based on individual differences in self-concept and higher cognitive processes which are not fully developed in adolescence (Icengole et al., 2019; Popma & Raine, 2006). Personality and cognitive functions are considered the most important in the occurrence and maintenance of aggressive antisocial behaviors, and character maturity could be an important protective factor against these behaviors (Crescentini et al., 2018; Dukanac et al., 2016; Nilson et al., 2016; Seidl et al., 2020).

Older adolescents with pronounced psychopathic traits show temperament and character traits that correspond to Cloninger's theoretical model for antisocial and/or psychopathic personality disorder. The configuration of personality dimensions shown by adolescent psychopaths from the younger

age group does not fit into the existing Cloninger's theoretical model, except for the pronounced Novelty Seeking dimension.

The inability to distinguish between younger psychopaths and non-psychopaths by character and temperament dimensions in this study suggests that juvenile offenders are in the process of developing personality traits, especially character dimensions. Among adolescents with high psychopathic scores, the final outcomes of personality development, i.e., the formation of psychopathy and/or APD, cannot be predicted with certainty. Incomplete formation of personality and character traits suggests greater susceptibility of young people to treatment and interventions, and the possibility of a more positive outcome in young people with high psychopathic scores. According to Cloninger's model, character develops under the influence of social environment and learning. Temperament and character are in constant interaction during a person's life, so temperament affects character and vice versa. The results of this research on the incomplete formation of character traits in younger antisocial adolescents indicate the possibility of developing treatments that would be aimed at encouraging the development of character and prosocial characteristics in these adolescents. These treatments could include promoting prosocial goals and values, developing self-esteem and self-acceptance, fostering personal responsibility, developing problem-solving and decision-making skills, improving connection with others and self-efficacy in the social environment (Lee et al., 2018). Character strengths interventions, described in the literature, should be conducted from childhood and in different contexts (school, home, peer group, local community) in order to prevent behavioral problems in children and adolescents (Coppley & Niemiec, 2021; Lee et al., 2018). Assessment instruments and interventions which focus on psychopathic traits in adolescents are of special importance, as adolescence represents a period of hopeful positive changes (Pauli et al., 2020; Ray et al., 2018; Ronchetti et al, 2014; Waller et al., 2016). High psychopathic scores on psychopathy assessment questionnaires can give a false positive picture of the existence of psychopathy in young people, because inflation of psychopathic scores may occur due to impulsiveness, irresponsibility, risky behavior in adolescents that can be developmentally expected and

transient (Simões & Conçalves, 2017). Studies show that increases in psychosocial maturity over time predicted decreases in psychopathic scores for adolescents (Cauffman et al., 2016), and a decline in criminal activity of youths with psychopathic traits as they approach early adulthood (Dick et al., 2013; McCuish & Lussier, 2018). These results call into question the reliability of reliance on psychopathy measures in making decisions about youthful offenders that will have long-term consequences (Cauffman et al., 2016). These data indicate the need to be careful in assessing antisocial youth only based on psychopathic measures and need to include assessment based on basic personality models. Treatment in adolescent offender populations could be more effective if it was individualized and if it considered personality dimensions (Seidl et al., 2020, Snowden & Gray, 2010).

Conclusion

We can conclude that younger adolescent psychopaths do not show complete age continuity and homogeneity with older adolescent psychopaths. It cannot be argued that adolescent psychopathy exists as a stabilized PD and assumes the same or sufficiently similar development to adult psychopathy (Simões & Conçalves, 2017). The results of the present study indicate that caution is needed in assessing and predicting the outcome of psychopathic traits in adolescents, especially juvenile delinquents, given the possible false-positive recognition rate, greater susceptibility to change and treatment in adolescents, and a greater possibility of a more positive outcome.

The limitations of this research concern the characteristics of the sample, the method of self-assessment, the metric characteristics of measuring instruments and the transverse method of testing. The study lacked a comparison with a group of non-delinquent adolescents, and it is possible that the same types would stand out in that population, so that these types are not specific to delinquents. Guidelines for further research include the need to replicate the study on a larger sample, and on the general adolescent population. Longitudinal follow-up research and studies of psychopathic

adolescents are important in order to gain more reliable knowledge about the course and outcomes of antisocial behavior of these adolescents.

Conflict of Interest

We have no conflicts of interest to disclose.

Data availability statement

For further details on data, contact the corresponding author of the manuscript.

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Razlike u temperamentu i karakteru kod psihopatskih i nepsihopatskih adolescentnih delinkvenata

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REZIME

U ovoj studiji ispitivana je mogućnost izdvajanja tipova antisocijalnih adolescenata na osnovu psihopatskih obeležja, i međusobne razlike antisocijalnih adolescenata različitog uzrasta i suptipova u odnosu na Klonindžerove dimenzije ličnosti. Uzorak je obuhvatao 101-og antisocijalnog adolescenta muškog pola, podeljenih u dve uzrasne grupe (71 ispitanika u grupi od 13-17 godina i 30 u grupi od 18-25 godina). Na celokupnom uzorku, na osnovu klaster analize zasnovane na modelu, izdvojeni su nepsihopatski tip, bez izraženih obeležja psihopatije i psihopatski tip, sa izraženom antisocijalnom, interpersonalnom i facetom životnog stila (Herov model), u koji su se svrstali i mlađi i stariji adolescenti. U okviru psihopatskog tipa, stariji adolescenti u odnosu na maloletne adolescente pokazuju značajno nižu izraženost dimenzija karaktera, Samousmerenost i Kooperativnost, ključnih u određenju svih poremećaja ličnosti. U okviru grupe maloletnih adolescenata, pripadnici psihopatskog suptipa u odnosu na nepsihopate se nisu značajno razlikovali po temperamentu i karakteru, što ukazuje da se adolescenti mlađi od 18 godina nalaze u procesu razvoja ličnosti, posebno karaktera, pa su podložniji tretmanu i kod njih su krajnji ishodi neizvesni. Rezultati sugerišu da kod mlađih od 18 godina moguće dolazi do inflacije psihopatskih skorova usled identifikovanja razvojnih obeležja adolescencije (impulsivnost, nezrelost) kao psihopatskih, što

implicira nužnost primene bazičnih modela ličnosti u proceni adolescentnih delinkvenata.

Ključne reči: antisocijalno ponašanje, crte ličnosti, adolescentna psihopatija, maloletni delinkventi, procena psihopatije