

Autistic traits and gender modulate emotion changes before and during the COVID-19 outbreak: a preliminary evidence based on quasi-experimental design

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Abstract

Individuals with autism spectrum disorder (ASD) show an enhanced response to stressors, and gender plays an important role in stress response. Thus, autistic traits (ATs) in the general population and gender may regulate the emotion changes before and during the outbreak of COVID-19. The present study addressed this issue through a participants between quasi-experimental design, in which the epidemic status (before, during), gender (male, female), and AT groups (high ATs, low ATs) were independent variables, and positive and negative emotions were dependent variables. We used generalized linear models to estimate the effects of the independent variables and their interactions on emotions. The results showed that the COVID-19 outbreak reduced positive emotions and increased fear and anger. Furthermore, compared with before the COVID-19 outbreak, individuals with high ATs and females experienced stronger anger and fear than individuals with low ATs and males during the epidemic. The present study revealed the emotional impacts of COVID-19 and greater emotional susceptibility to COVID-19 pandemic among individuals with high ATs and females. Our findings provide prospective evidence for understanding the ASD/ATs-related enhanced response to pathogen threat-related stressors and have implications for COVID-19 crisis interventions.

Introduction

Autism spectrum disorder (ASD) is a set of neurodevelopmental conditions, characterized by impaired social functions and unusually restricted behaviours and interests ([Baron-Cohen et al. 2001](#)). Autistic traits (ATs) are considered the primary symptoms of ASD and are assumed to be distributed continuously amongst the general population ([Zhao et al. 2019](#)). Quantifying the differences in cognitive-emotional function associated with ATs can provide an indispensable alternative for the understanding of ASD symptoms ([Haruvi-Lamdan et al. 2019](#)).

Some endogenous characteristics associated with ASD, such as executive dysfunction, sensory hypersensitivity, poor emotional regulation, and difficulties in socialization and communication, are likely to predispose individuals with ASD to be especially vulnerable to stressors ([Bishop-Fitzpatrick et al. 2015](#)). For instance, individuals diagnosed with ASD report significantly higher subjective stress regarding general life and experimental stressors ([Bishop-Fitzpatrick et al. 2015](#); [Bishop-Fitzpatrick et al. 2017](#)), as well as exhibit increased peripheral physiological responses to stressors, marked with enhanced cortisol release and increased heart rate, compared with those in the typical development (TD) controls ([Spratt et al. 2012](#); [Taylor and Corbett 2014](#); [van Oort et al. 2020](#)). Furthermore, these individuals do not show decreased default mode network connectivity nor increased frontoparietal network connectivity in response to stressors compared with TD controls ([van Oort et al. 2020](#)), which might indicate that individuals with ASD fail to transfer effectively attention resources from their internal emotional state to the external world, and that they fully invoke emotional regulation and executive functions to support adaptive coping when facing stressors ([van Oort et al. 2020](#)). Evidence on relation between ASD/ATs and increased posttraumatic stress disorder symptoms (PTSS), especially in the hyper-arousal and negative emotion clusters ([Haruvi-Lamdan et al. 2020](#); [Haruvi-Lamdan et al. 2019](#); [Nirit et al. 2018](#)), has further consolidated the atypical stress mechanism associated with ASD. In sum, all these findings suggest that individuals with ASD or high ATs may have an enhanced response (e.g. emotion-related) to or are more susceptible to the negative consequences of stressors.

Nevertheless, previous studies have assessed self-perceived stress in individuals with ASD as a general sense of stress, such as stress measured by the Perceived Stress Scale ([Bishop-Fitzpatrick et al. 2017](#); [Hirvikoski and Blomqvist 2015](#)), rather than based on specific stressful events. The stress response of individuals with ASD or high ATs is likely to be regulated by the category of stressors ([Taylor and Corbett 2014](#)), and as such, the response characteristics of these

individuals in different stress situations need to be further elucidated. In the study of the relation between ASD/ATs and PTSS, although the measured PTSS is based on a specific stressor, type of stressor has a great deal of within-group variation, because participants' responses are based on the most traumatic events they have individually chosen from the list of stressful and traumatic life events (Haruvi-Lamdan et al. 2020; Haruvi-Lamdan et al. 2019), which means that the stressor types are almost different for each participant. Furthermore, in contrast to TD controls, individuals with ASD tend to perceive social stressors as their most traumatic event (Haruvi-Lamdan et al. 2020; Haruvi-Lamdan et al. 2019). This overall bias in event types between groups is likely to limit the inter-group comparability of the measured PTSS. Therefore, comparing the differences of the negative output of the same or similar stressors among groups (e.g. ASD vs. TD or high ATs vs. low ATs) is helpful to shed light on the atypical stress mechanism of autism spectrum.

The public has been exposed to a considerable stressor that is the COVID-19 pandemic (Wang et al. 2021). The pandemic has significantly reduced positive emotions and increased negative emotions, especially fear and anger (Huang et al. 2020; Li et al. 2020; Moron and Biolik-Moron 2021; Wang et al. 2021). Meanwhile, ASD is associated with an increased risk of pathogen infection or disease related to immune system malfunctions (Masi et al. 2015; Saresella et al. 2009). According to the risk-as-feelings model (Tanu and Kakkar 2019), these cognitive and emotional experiences associated with pathogen infection may lead to individuals with ASD or high ATs having an increased awareness of pathogen threat to avoid the recurrence of similar disease experiences. However, the association between ASD and the possible enhanced response to pathogen threat has not been identified. In addition, life stressors rarely impact an entire population at the same time (Valenti et al. 2012). Thus, the COVID-19 pandemic has provided an opportunity for research, from the perspective of stressor related to pathogen threat: the risk of infection serves as the same stressor among all participants for exploring how ATs regulate emotion-related stress response.

Gender has also been suggested to play an important role in stress response. Females are more susceptible to experience PTSS than males owing to genetic and biological risk factors (Farhood et al. 2018; Haruvi-Lamdan et al. 2020), and tend to show more negative emotions, such as anger and fear after natural disasters (Shavit et al. 2013) and during the current COVID-19 pandemic (Huang et al. 2020; Isabelle and Kleinberg 2020). The association between ASD/ATs and trauma exposure and PTSS mainly brought by social stressors may be stronger in females than in males (Haruvi-Lamdan et al. 2020; Haruvi-Lamdan et al. 2019). However, owing to the significant imbalance in the proportion of male and female in clinical studies, whether this gender inequality association can also be applied in the response to stressors associated with pathogen threat (e.g. COVID-19 pandemic) needs to be further verified based on large-sample studies with a relatively balanced gender ratio.

Taken together, autism spectrum is likely to be endogenously associated with impaired stress mechanism. However, there is a lack of description of whether individuals with high ATs exhibit distinct responses to COVID-19 and of the role of gender. Based on a quasi-experimental between-participants design, which has been used to examine the changes in dreams and self-concept before and during COVID-19/COVID-19 lockdown (Barrett 2020; González-Valero et al. 2020), the present study first compared the changes in positive and negative emotions measured by the Positive and Negative Affect Schedule (PANAS) (Watson et al. 1988), as well as anger (Irritable) and fear (Scared and Afraid) in the negative emotions subscale that seem to be particularly sensitive to the emotional impact of COVID-19 (Li et al. 2020; Moron and Biolik-Moron 2021), before and during the COVID-19 outbreak. Moreover, we further explored the moderating effect of ATs and gender on the emotional impacts of COVID-19. We hypothesized that the COVID-19 outbreak reduced positive

emotions but increased negative emotions, especially fear and anger. We further assumed that females and individuals with high ATs, especially females with high ATs, were more susceptible to the emotional effects of COVID-19.

Methods

2.1 Participants

Convenience sampling was used to select participants (college students) before and during the COVID-19 pandemic. All of the participants before the outbreak were recruited offline in Shanghai, whereas the participants during the COVID-19 pandemic were recruited online from universities located in various regions of China (see Table 2 for details). A total of 1,374 university students were recruited before ($n = 580$) and during ($n = 794$) the COVID-19 outbreak. We eliminated questionnaires with incomplete answers or that showed items being consistently selected for the highest or lowest score; 558 (304 females) pre-COVID and 721 (385 females) during-COVID valid participants were included for preliminary analysis.

We explained the nature of the study to all the participants, who then gave written or electronic informed consent form. All of them self-reported having no psychiatric, neurological, or other serious medical illness, and no direct relatives with an ASD diagnosis.

To investigate the regulatory effect of ATs and gender on the emotional impacts of COVID-19, we used the quartile (Q3 and Q1) scores in the Autism Spectrum Quotient (AQ) to compose the AT groups: participants who scored higher than Q3 and lower than Q1 were divided into the high and low AT groups, respectively. The Q1 and Q3 scores before the COVID-19 pandemic were 110 and 122, and those during were 112 and 124, respectively. In total, 157 (average age = 22.56 years, $SD = 2.38$) and 139 individuals (average age = 22.39 years, $SD = 2.55$) were categorized into the high and low ATs groups, respectively, before the COVID-19 pandemic; during the pandemic, 169 (average age = 22.47 years, $SD = 3.40$) and 165 individuals (average age = 22.30 years, $SD = 3.00$) were categorized into the high and low ATs groups, respectively. Detailed demographic information is listed in Tables 1 and 2.

Table 1. Background characteristics of the pre-COVID-19 outbreak sample.

High ATs group ($n = 157$)	% (n)	Low ATs group ($n = 139$)	% (n)
Gender		Gender	
Male	52.23 (82)	Male	40.46 (57)
Female	47.78 (75)	Female	59.54 (82)
Major		Major	
Business administration	19.11 (30)	Business administration	10.07 (14)
pedagogy	29.94 (47)	pedagogy	22.30 (31)
psychology	19.75 (31)	psychology	26.62 (37)
engineering	16.56 (26)	engineering	18.71 (26)
biology	14.65 (23)	biology	22.30 (31)

Table 2. Background characteristics of the during-COVID-19 outbreak sample.

High ATs group (n= 169)	% (n)	Low ATs group (n= 165)	% (n)
Gender		Gender	
Male	46.75 (79)	Male	46.67 (77)
Female	53.25 (90)	Female	53.33 (88)
Major		Major	
Business administration	20.12 (34)	Business administration	21.82 (36)
pedagogy	23.67 (40)	pedagogy	19.39 (32)
psychology	21.30 (36)	psychology	25.45 (42)
engineering	21.89 (37)	engineering	18.18 (30)
biology	13.02 (22)	biology	15.15 (25)
RL before outbreak		RL before outbreak	
Eastern China	68.05 (115)	Eastern China	78.18 (129)
Central China	13.61 (23)	Central China	11.52 (19)
Western China	18.34 (31)	Western China	10.30 (17)
RL during outbreak		RL during outbreak	
Eastern China	51.48 (87)	Eastern China	53.94 (89)
Central China	19.53 (33)	Central China	16.36 (27)
Western China	28.99 (49)	Western China	29.70 (49)
RA during outbreak		RA during outbreak	
Rural areas	70.41 (119)	Rural areas	74.55 (123)
Urban areas	29.59 (50)	Urban areas	25.45 (42)
Only child or not		Only child or not	
Yes	36.09 (61)	Yes	51.52 (85)
Not	63.91 (108)	Not	48.48 (80)

Note: RL = Region of location; RA= Residence area

2.2 Measurements

2.2.1 Autism Spectrum Quotient (AQ)

The Chinese version of AQ is a reliable instrument for quantifying ATs in both clinical and non-clinical samples in mainland China (Zhao et al. 2020). The continuous (four-point Likert) scale was used. In our study, the alpha for internal reliability (henceforth, α) were 0.72 and 0.73 for the overall AQ collected before and during COVID-19, respectively.

2.2.2 Emotional experiences

The PANAS is a 20-item self-report measure of positive and negative emotions developed by Watson et al. (1988). The scale, as well as individual items or emotional words selected from the scale, has been used to measure the emotional impact of the COVID-19 pandemic and dynamic emotional changes during COVID-19 lockdown (Canet-Juric et al. 2020; Huang et al. 2020; Moron and Biolik-Moron 2021). The scale ranges from 1 (*very slightly or not at all*) to 5 (*very much*). In the present study, the time frame for responses regarding emotional experience was 'during the past two weeks'. The reliability of the positive emotions subscale obtained before and during COVID-19 were $\alpha = 0.85$ and $\alpha = 0.88$, respectively; the reliability of the negative emotions subscale obtained before and during COVID-19 were $\alpha = 0.81$ and $\alpha = 0.90$, respectively.

We also used a demographic (Table 1 and 2) and health survey. Participants' health was examined using the following questions:

1. Do you have a diagnosis of any mental health condition? (e.g. anxiety, depression, and schizophrenia)
2. Do you have a diagnosis of any neurological disease? (e.g. epilepsy and meningitis)
3. Do you have a diagnosis of any serious medical illness? (e.g. head injury and heart disease)
4. Do you or your relatives have a diagnosis of ASD?
5. Were you or your relatives confirmed as a COVID-19 case? (This question was only asked during the outbreak.)

2.3 Procedures

2.3.1 Before COVID-19

The data were collected from September 17 to 27, 2019 during the freshmen's entrance education or class interval. Participants were informed about the voluntary nature of the study, guaranteed the anonymity and confidentiality of their data, and given a small gift (a ballpoint pen worth RMB 2.5) for participating. After the students gave their consent, we distributed the questionnaire. During data collection, the participants were asked to place the questionnaires in the corner of the table after they had completed the survey. Subsequently, the questionnaires were collected on the spot, and students were appreciated for their participation.

2.3.2 During COVID-19

On January 20, 2020, the National Health Commission in China officially listed COVID-19 as a type B infectious disease, marking the actual beginning of the comprehensive upgrade of epidemic prevention and public concern. The data collection period was from February 6 to 16, 2020. Because the COVID-19 outbreak coincided with the Spring Festival, the students were on vacation, and the state called on everyone to be isolated at home; as such, offline data collection was rendered almost impossible. Therefore, the participants were asked to complete an online questionnaire hosted by Wenjuanxing (<https://www.wjx.cn/>). Previous studies have shown that there are differences in the level of autistic traits

among students of different majors (Baron-Cohen et al., 2001), to reduce the heterogeneity between participants before and during COVID-19, we only investigated college students with the same major before the outbreak. On the front page of the online questionnaire, we explained the purpose of this study in detail, and clarified the number of items in and the approximate time needed to complete the questionnaire. The participants were given RMB 2 for their participation.

2.4 Statistical analysis

To exclude the false differences caused by possible measurement non-equivalence between the data before and during the pandemic, we conducted a multi-group confirmatory factor analysis (MCFA) in AMOS 20.0 to test the measurement invariance (Putnick and Bornstein 2016). Given that the AQ contains more items and dimensions, item parcelling strategy was used for MCFA to improve the index fit of the model (Rocha and Chelladurai 2012).

To confirm the suitability of analysis of variance (ANOVA) as the method for estimating the effect of categorical variables on emotions, we tested whether the dependent variables followed the normal distribution. The normal distribution test in SPSS showed all dependent variables following a non-normal distribution (negative emotions: K-S = 0.085, $df = 630$, $p < 0.05$, skewness = 0.53, kurtosis = -0.27; fear: K-S = 0.171, $df = 630$, $p < 0.05$, skewness = 0.732, kurtosis = -0.316; anger: K-S = 0.241, $df = 630$, $p < 0.05$, skewness = 0.899, kurtosis = -0.127; positive emotions: K-S = 0.059, $df = 630$, $p < 0.05$, skewness = -0.11, kurtosis = -0.023). Therefore, we used a generalized linear model using maximum likelihood estimation to estimate the effect of independent variables (i.e. epidemic situation [before, during], gender [male, female], and ATs group [high ATs group, low ATs group]) on emotions.

Results

3.1 Measurement invariance test

The results of the MCFA are shown in Table 3. The fit indexes of these two unconstrained models were good and met the preconditions for subsequent equivalence testing. If the chi-squared difference test of model comparison is not significant, then the comparison models can be considered equivalent in the corresponding test level (Meade et al. 2008). In the case of large samples, small chi-squared differences also indicate significant differences; when the chi-squared is indicated as significant, the difference of the fit index (ΔCFI and ΔTLI) is further used to detect equivalence—that is, when ΔCFI and ΔTLI are both less than 0.01 (Meade et al. 2008)—then the comparison models do not have a significant difference. The results of the model comparison showed no significant difference between the fit indexes of the baseline model and the model with equal defining factor loading (Model A vs. Model B), and between the fit indexes of Model B and the model with equal defining factor loading and covariances (Model B vs. Model C) for both AQ and PANAS. Thus, the null hypothesis of invariance should not be rejected under moderate loose criterion (Wasti et al. 2007). In other words, the understanding of the same construct and the true score of potential factors among the two groups measured at different time points were consistent, thereby meeting the conditions for the subsequent comparison between the time points of before and during the COVID-19 pandemic.

Table 3. Fit indexes of model equivalence and results of the nested model comparison

Model	χ^2	<i>df</i>	CFI	TLI	RMSEA	Model-C	$\Delta\chi^2$	Δdf	<i>p</i>	ΔCFI	ΔTLI
PANAS											
A	1189.686	324	.918	.904	.047						
B	1246.594	342	.914	.905	.047	(1)	56.908	18	<.01	-.002	.001
C	1250.646	345	.914	.906	.047	(2)	4.052	3	>.05	.000	.001
D	1443.983	372	.899	.896	.049	(3)	193.336	27	<.01	-.015	.009
AQ											
A	36.607	8	.962	.904	.054						
B	39.531	12	.963	.939	.044	(1)	2.924	4	>.05	0.001	0.035
C	40.321	13	.963	.944	.042	(2)	.790	1	>.05	0.000	0.005
D	74.182	18	.925	.916	.051	(3)	33.861	5	<.01	-0.038	-0.028

Note: A = unconstrained baseline model, B = measurement weights, C = structural covariances, D = measurement residuals; the grey shaded part shows the comparison results, Model C = model comparison, (1) = Model A vs. Model B, (2) = Model B vs. Model C, (3) = Model C vs. Model D.

3.2 Effects of COVID-19, gender, and autistic traits on emotions

The detailed descriptive statistics are shown in Table 4.

Table 4. Descriptive statistics on variables of interest

		Male				Female			
		L-ATs		H-ATs		L-ATs		H-ATs	
		Before (n=57)	During (n=77)	Before (n=82)	During (n=79)	Before (n=82)	During (n=88)	Before (n=75)	During (n=90)
AQ	M	102.44	104.74	127.57	129.85	101.63	105.26	126.76	129.56
	SD	(7.26)	(6.20)	(4.30)	(5.47)	(6.20)	(5.40)	(3.87)	(4.48)
	Range	[76-109]	[81-111]	[123-143]	[125-147]	[84-109]	[85-111]	[123-143]	[125-152]
Positive emotions	M	32.07	29.75	28.79	26.18	32.83	27.70	27.85	25.54
	SD	(6.56)	(7.65)	(6.44)	(7.18)	(6.30)	(6.41)	(5.47)	(5.19)
	Range	[19-46]	[12-48]	[11-41]	[10-46]	[14-47]	[12-38]	[14-38]	[11-37]
Negative emotions	M	20.16	16.29	25.62	22.36	18.90	19.25	23.11	24.76
	SD	(6.39)	(5.68)	(6.76)	(7.18)	(5.70)	(6.78)	(6.54)	(6.55)
	Range	[11-41]	[10-32]	[12-45]	[10-42]	[10-46]	[10-39]	[10-39]	[11-39]
Scared and Afraid	M	3.32	3.11	4.65	4.44	3.24	4.15	4.61	5.26
	SD	(1.57)	(1.56)	(1.94)	(2.09)	(1.59)	(1.79)	(2.16)	(1.75)
	Range	[2-8]	[2-8]	[2-10]	[2-10]	[2-10]	[2-9]	[2-9]	[2-9]
Irritable	M	1.79	1.65	2.09	2.37	1.77	1.81	1.88	2.61
	SD	(0.99)	(0.86)	(0.98)	(1.14)	(0.93)	(0.97)	(0.96)	(1.02)
	Range	[1-5]	[1-4]	[1-5]	[1-5]	[1-5]	[1-5]	[1-4]	[1-5]

The results of the statistical test are shown in Table 5.

Table 5. Statistical test results on the effect of independent variables on emotions

source	dependent variable- emotions							
	Anger		Fear		positive emotions		negative emotions	
	Wald c ²	Sig.(p)	Wald c ²	Sig.(p)	Wald c ²	Sig.(p)	Wald c ²	Sig.(p)
Gender	0.308	.579	8.864	.003	1.972	.160	.585	.444
ATs group	37.479	.000	77.306	.000	47.136	.000	105.558	.000
COVID-19	8.358	.004	3.837	.050	36.830	.000	6.150	.013
Interaction 1	12.501	.000	.208	.649	1.526	.217	.860	.354
Interaction 2	3.97	.046	11.133	.001	1.507	.220	19.448	.000
Interaction 3	0.096	.757	.094	.759	.019	.890	.787	.375
Interaction 4	0.738	.390	.194	.660	2.336	.126	.109	.741

Note: Interaction 1 = ATs group * COVID-19; Interaction 2 = gender * COVID-19; Interaction 3 = gender * ATs group; Interaction 4 = gender * ATs group* COVID-19; df = 1 for all models.

In the analysis of positive emotions, we found that the high ATs group experienced significantly fewer positive emotions compared with the low ATs group (95% Wald CI for difference: -4.496, -2.500). The level of positive emotions during COVID-19 was significantly lower than that before COVID-19 (95% Wald CI for difference: -4.090, -2.093).

Regarding negative emotions, the level of negative emotions during COVID-19 was significantly lower than that before COVID-19 (95% Wald CI for difference: -4.090, -2.093). The level of negative emotions experienced by the high ATs group was significantly higher compared with the low ATs group (95% Wald CI for difference: 4.300, 6.328). We also observed a significant interaction effect between epidemic situation and gender. Further analysis indicated that the level of negative emotions during COVID-19 was lower than that before COVID-19 in males (95% Wald CI for difference: -5.047, -2.080; $p < 0.05$), but this difference was not present among females (95% Wald CI for difference: -.383, 2.380).

The level of anger experienced by the high ATs group was significantly higher than that of the low ATs group (95% Wald CI for difference: .328, .636), whereas the level of anger during the COVID-19 pandemic was significantly higher than that before (95% Wald CI for difference: .073, .382). We found a significant interaction effect between ATs group and epidemic situation. Further analysis indicated that anger during the pandemic was of a higher level than that before in the high ATs group (95% Wald CI for difference: .293, .720; $p < 0.05$); this difference was not present in the low ATs group (95% Wald CI for difference: -.274, .173). We also found a significant interaction effect between epidemic situation and gender. Further analysis indicated that anger level during the pandemic was higher than that before in females (95% Wald CI for difference: .174, .595; $p < 0.05$), but not among males (95% Wald CI for difference: -.155, .297).

The level of fear experienced by females was significantly higher than that of males (95% Wald CI for difference: .149, .721). The level of fear during the COVID-19 pandemic was marginally significantly higher than that before (95% Wald CI for Difference: .000, .572). The level of fear experienced by the high ATs group was significantly higher compared with the low ATs group (95% Wald CI for difference: .997, 1.570). The results also indicated a significant interaction effect between epidemic situation and gender: fear during the COVID-19 pandemic was higher than that before in females (95% Wald CI for difference: .383, 1.163; $p < 0.05$) but not in men (95% Wald CI for difference: -.620, .218).

Discussion

The present study aimed to examine the emotional impact of the COVID-19 pandemic as well as the moderating effects of gender and ATs on the former. Our analysis revealed that the COVID-19 outbreak reduced positive emotions and increased fear and anger. More importantly, individuals with high ATs and females were found more susceptible to the emotional changes before and during the COVID-19 pandemic. The strengths of this research include the comparison of emotions before and during the COVID-19 pandemic, large sample with a relatively balanced gender ratio, and use of ATs as a moderator. The core contribution to the body of knowledge is the extension of the association between ASD and enhanced stress response to stress situations related to pathogen threats.

Consistent with the results of a recent psycholinguistic analysis (Li et al. 2020), our findings showed that people's positive emotions significantly decreased during the COVID-19 pandemic, suggesting that the levels of enthusiasm, vitality, and immense interest during the pandemic was lower than those before. In the face of a potential disease threat like COVID-19, a set of adaptive psychological mechanisms, namely, the behavioural immune system (BIS), is activated to trigger avoidance behaviour or motivation for self-protection, leading people to act in a more reticent and conservative manner (Li et al. 2020; Olivera-La Rosa et al. 2020). Meanwhile, as the main dimension of human emotional experiences, as measured by the PANAS, positive emotions reflect the activation of the behavioural activation system (BAS), which contributes to approach-related behaviour and motivation (Schiltz et al. 2018; Zhao et al. 2020). Thus, BAS and BIS have a certain degree of functional compatibility. Therefore, we suggested that the decreased positive emotions during the COVID-19 pandemic may partly reflect the adaptive decrease of BAS that is caused by BIS.

Contrary to our research hypothesis, our results showed that the overall negative emotion during COVID-19 was lower than that before. However, this effect was only found in males. Gender differences in attitudes and behaviours to the ongoing COVID-19 situation may contribute to this seemingly counterintuitive phenomenon. The COVID-19 pandemic has not always had negative consequences. The extensive and effective anti-epidemic action in China, such as the sending of aid in terms of materials and medical personnel from provinces across the country to Wuhan, had a broad and positive social impact, such as increased collective cohesion and patriotism (Li et al. 2020). Males have tended to be more concerned with the social impact of COVID-19 than females (Isabelle and Kleinberg 2020). Therefore, we suggested that men would be more likely to be permeated by these positive effects, diluting their overall negative emotions, compared with women. In addition, males are reported to take fewer family and care responsibilities than females during the epidemic (Etheridge and Spantig 2020). Meanwhile, the data collection for the during-COVID-19 variables was only during the Spring Festival. Men are more likely than women to enjoy leisure time on holidays (Moron and Biolik-Moron 2021), which may explain their lower overall negative emotions in our study. However, these are speculations, and the role of other variables in this gender difference, such as coping strategies and emotional regulation during the COVID-19 pandemic, needs to be further examined.

The discrete negative emotions approach is more informative for describing the emotional impacts of the COVID-19 pandemic compared with the overall measurement of negative emotions (Moron and Biolik-Moron 2021). Consistent with recent studies (Li et al. 2020; Moron and Biolik-Moron 2021; Wang et al. 2021), our results showed that the levels of fear and anger during the COVID-19 pandemic were significantly higher than those before. However, it should be noted that the enhanced fear and anger during the epidemic are likely derived from different sources. Specifically, fear is the core emotional response to an impending risk of viral infection (Moron and Biolik-Moron 2021; Schimmenti et al. 2020). Although fear is an undesirable emotional experience, as indicated by the theories of BIS and perceived risk (Li et al. 2020; Makhanova and Shepherd 2020), fear-related emotions can prompt individuals faced with a potential pathogen threat to discover potential infection sources in time and take action to avoid infection. The increased anger during the outbreak seems to be a response to inaction and reflects the negative effects associated with anti-epidemic measures, such as lockdown and self-isolation at home (Brooks et al. 2020; Li et al. 2020; Moron and Biolik-Moron 2021). Therefore, the authorities must also seek to minimize the collateral negative effects of public health initiatives.

Our results further revealed that the changes in anger and fear before and during the COVID-19 pandemic were more prominent among females, which is in line with recent findings on females reporting high levels of fear and anger than males during the COVID-19 pandemic (Huang et al. 2020; van der Vegt and Kleinberg 2020). Females more concerned with disease infection risk than males (Knez et al. 2018). This enhanced risk assessment of pathogen threats in females is undoubtedly also applicable to the current COVID-19 pandemic, as recent studies have shown, for example, that females perceive COVID-19 as more prevalent and lethal than males do (Galasso et al. 2020; Isabelle and Kleinberg 2020; Oreffice and Quintana-Domeque 2020). Based on the robust association between perceived risk and increased fear (Zheng et al. 2019), we held that the enhanced risk perception of being infected in females would likely increase their fear. Studies measuring fear and risk perception are needed to validate this hypothesis. In terms of the increased anger among females, their lower tolerance for the inconsistent dissemination of information on the transmission of COVID-19 from person to person (Li et al. 2020) as well as the increased burden of family care and job risk caused by the COVID-19 outbreak among females (Barrett 2020; Etheridge and Spantig 2020) are likely to increase their anger.

Independent of the epidemic condition, our results showed that individuals with high ATs reported fewer positive emotions and more negative emotions compared with individuals with low ATs. These findings are consistent with previous ones: emotional experiences as measured by the PANAS in individuals with ASD are more negative and less positive compared with TD controls (Zhao et al. 2020), supporting the similarity hypothesis of ATs in the general and clinical ASD population (Baron-Cohen et al. 2001).

Scholars have hypothesized on an intrinsic relation between impaired stress mechanisms and autism spectrum (Haruvi-Lamdan et al. 2020; Haruvi-Lamdan et al. 2019; van Oort et al. 2020). However, the evidence is scarce on whether individuals with ASD also show increased stress response to COVID-19, which affects the entire population at the same time. Through an analogy-ASD approach that grouped the general population into high and low ATs segments, our study showed that individuals with high ATs were more susceptible to emotional changes before and during the outbreak than those with low ATs, as reflected in the significantly higher levels of fear and anger experienced during COVID-19 than those before. To some extent, this result is consistent with a previous study that compared adaptive function after an earthquake between TD controls and individuals with ASD, who were shown to have lower adaptive function (Valenti et al. 2012).

Individuals diagnosed with ASD are frequently affected by pathogen-related illness owing to the dysfunction of their biological immune system (Masi et al. 2015; Saresella et al. 2009). According to the risk-as-feelings model (Tanu and Kakkar 2019), the unpleasant experiences associated with pathogen infection may lead to individuals with ASD or high ATs having an increased awareness of pathogen threats, and thereby experiencing greater levels of fear during the COVID-19 pandemic. Our results and their explanations are supported by a recent finding showing that the activation of BIS and risk perception mediate the association between ATs and enhanced fear during the COVID-19 pandemic (Zhao et al. 2020). We proposed the following two aspects to explain the higher level of anger experienced by individuals with high ATs during the COVID-19 pandemic. Firstly, the inconsistent dissemination of information by the relevant responsible units in Hubei Province on whether COVID-19 was transmitted from person to person led to moral outrage (Li et al. 2020). Previous studies have shown that moral judgment in individuals with ASD is more rigorous (Margoni and Surian 2016). Therefore, individuals with high ATs may have judged the spread of misinformation as morally more impermissible compared with those with low ATs, resulting in an increased indignation in the former. Secondly, the anti-epidemic measures have tended to force the public to make rapid changes to their daily habits, established plans, and even social contacts (Brooks et al. 2020; Moron and Biolik-Moron 2021). ASDs or ATs are associated with a lower tolerance for uncertainty and unexpected change (Cassidy et al. 2020; Hirvikoski and Blomqvist 2015) and with impaired executive function (Zhao et al. 2019), which may make it difficult for individuals with high ATs to manage effectively the series of changes caused by the COVID-19 pandemic and lead to them becoming more irritable. Finally, atypical emotional regulation and poor social support as a result of difficulties in social communication (Cassidy et al. 2020; Zhao et al. 2020) may further increase the levels of anger and fear experienced by individuals with high ATs.

Our findings suggested improving the emotions of females and individuals with high ATs during the COVID-19 pandemic should be given priority. The development of consistent policies and procedures to ensure the timely update of information related to COVID-19 would help reduce the perceived lack of control and certainty, which would mitigate the fear experienced by individuals with high ATs and females. Improving the scientific bases and effectiveness of anti-epidemic actions, as well as supporting individuals with high ATs, when creating new action plans would help reduce the anger felt by these groups. Finally, improving psychological anti-epidemic capability, such as emotion regulation skills, is also helpful to ameliorate the negative emotions that are caused by COVID-19.

The present study had the following limitations. Firstly, different samples were evaluated before and during the COVID-19 pandemic, although the use of the same major categories and large sample size could effectively eliminate the heterogeneity between the groups. Nonetheless, the extent of the homogeneity of the two groups and of the reliability of the pre-epidemic measurements as a baseline in highlighting the emotional impact of the COVID-19 pandemic remain unclear. In addition, the data collection was only during the Spring Festival, which could have potentially interfered with the emotional impact of the COVID-19 pandemic. These inherent limitations did not allow for causal association to be established (test-retest) (González-Valero et al. 2020), and as such, the findings obtained ought to be interpreted with caution. Secondly, the sample in this study was only composed of college students. The moderating effect of ATs on the emotional impacts of the COVID-19 pandemic could differ in autistic populations, which warrant further investigation. Thirdly, the self-report method may not be effective in ensuring health screening, and individuals with pre-existing mental disorders may be at higher risk of relapse or new episodes of their disorder during the COVID-19 pandemic (Rajkumar 2020). Therefore, our results may be potentially affected by the data of the participants missed by the health screening. Lastly, the emotional experience during the epidemic changes dynamically over time (Lorena Canet-Juric et al. 2020),

and our findings only reflected the early stage of the epidemic development. Emotional impact and its regulatory factors in the later stage of the epidemic development need to be further explored.

Conclusions

The present study revealed that the COVID-19 outbreak reduced the public's positive emotions and increased fear and anger. More importantly, females and individuals with high ATs showed increased susceptibility to pre- and during-epidemic emotion changes. These findings have implications for epidemic crisis interventions. Meanwhile, our preliminary results provide interesting bases for further examination in future studies.

Declarations

Conflict of interests

The authors declare that they have no conflicts of interests.

Ethics approval

All participants were informed about the study and provided written or electronic informed consent before the study.

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