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Psychological Effects and Behavioral Impact of Smog on High School Youths

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Abstract

This study intends to investigate the psychological consequences and behavioral impact of smog on high school students, focusing on four major factors. First, how students evaluate or react emotionally to increased air pollution. Secondly, how the smog affects day-to-day behavior such as outdoor activities. Thirdly, how the smog affects social behavior such as interpersonal behaviors. Finally, how the smog affects study behavior and academic performance. Data were collected in a survey conducted on senior high school students in a heavy polluted region in North China (n=214) and a non-polluted region in South China (n=214). The results of this study indicate that there is a significant association between smog and behavior of high school students, and that air quality affects many facets of student life such as their health, social behavior, mood, attitude, outdoor activities and academic performance.

Keywords: Smog; Psychology; Behavior; High school youth; Academic performance

Introduction

Air pollution is one of the most serious environmental problems confronting our civilization. Smog is a kind of air pollution, originally named after the mixture of smoke and fog in the air. Modern smog is formed when industrial emissions from power plants, factories, cars, and other sources react with heat and sunlight in the atmosphere. The World Health Organization (WHO) has reported that this air pollution has severe negative short-term and long-term impacts on human health, and can cause acute diseases such as asthma and chronic respiratory diseases. The WHO has also reported that an estimated 3.7 million premature deaths were caused by air pollution worldwide in 2012 [1].

As the world's largest and fastest developing country in economy, China faces greater environmental challenges. Epidemiologic studies showed that exposures to outdoor air pollution especially PM10 and PM2.5 caused an increase of mortality in China [2]. Zhou investigated the acute health impacts of the smog episodes and PM2.5 on mortality in 2013 [3] and found that the mortality of rural people living close to large polluted cities in northern China were statistically significantly affected by the smog episodes.

Mental health is impacted by air pollution. The preponderance of the existing literature on human behavioral responses to air pollution has focused on how people evaluate air pollution in their local or national communities and the relation between perceived air quality and measured, atmospheric pollutants or physical properties related to visibility [4]. Interviews with a large representative sample of Los Angeles residents suggested significant relationships between ambient photochemical oxidants and individual measures of anxiety, hostility and stress [5].

The effects of air pollution on human behavior have been conceptualized and modeled from a psychological stress perspective [6,7]. Per these concepts, the resultant strain on individuals exposed to acute levels of ambient air pollution over time constitutes a continuous overload condition, often characterized by heightened levels of anxiety, tension, anger, and stress. Thus, the stress of living or working in a toxic environment may gradually reduce and deplete one's coping capacity and push an individual toward their limits. Moreover, one of the potential costs of living with air pollution stress is the decreased capacity to respond to subsequent demands of the environment. This will often result in fatigue, helplessness, anxiety, and reduced ability to respond to environmental demands [8]. Several constitutional factors have been claimed to increase an individual's actual or perceived vulnerability to air pollution, including personality dimensions (e.g., anxiety, intellectual ability, etc.), old age, stressful life events, chronic ill-health, and limited socioeconomic resources [8,9]. Anxiety has been reported to be significantly greater among individuals exposed to greater levels of ozone [9]. Affective concern about air pollution has been reported to be positively correlated with cognitive awareness of air pollution [4,10]. Furthermore, concern with air pollution has been found to be directly related to socioeconomic status [11], ethnicity, degree of urbaneness; and respiratory impairments [4]. Berlinger [12] also found evidence of neuropsychological impairments caused by pollutant levels in a single case time-series approach.

Air pollution not only influences physical health and mental health but also negatively affects human performance. Nunes et al. observed impaired task performance among office workers in the air pollution area. Pastor [13] reported a series of research efforts focused on Los Angeles to look at the intersection of ambient air quality and school performance in the state of California. Results indicate a correlation of the respiratory hazards from air toxins with lower academic performance. Mohai [14] also reported that the highest proportions of students who failed to meet state educational testing standards in schools located in areas with the highest air pollution levels in Michigan.

Compared to the research activity devoted to health effects of smog, studies on psychological consequences of smog are underrepresented. There have been no reports on psychological reactions from adolescents to smog in China. Youths are known to be more vulnerable than adults to the effects of pollution, and exposure to environmental pollutants during critical stages of physiological development can lead to long-lasting physical and mental health problems. This study aims to investigate psychological consequences and behavioral impact of smog on high school students. The research revolves around four main questions: how students evaluate or react emotionally to smog; how the smog affects day-to-day behavior such as outdoor activities; how the smog affects social behavior; and how the elevated pollution levels impacts learning productivity.

Research Methodology

Study population

The students were recruited from two high schools. The selected study schools were chosen based on Air Quality Index (AQI) data, obtained from [15]. Langfang High School (LHS) is in Beijing, a heavy polluted area. Hongling High School (HHS) is in Shenzhen, a non-polluted area. AQI data for the two weeks before the survey for both areas are shown in **Figure 1.** The AQI in Shenzhen always fell below 50, while the AQI in Beijing ranged from 53 to 199.

To recruit a representative study population, both school administrations assisted in asking a sample of 280 senior high school students from each school to participate. A total of 214 volunteers from each school agreed to participate and were included in the study.

Procedures

The investigation was conducted from June 19, 2017 to July 2, 2017. An initial survey and discussions were carried out prior to the actual survey. Evaluation of environmental conditions, sociodemographic data, health status information and personality variables were also obtained via interview. The data were collected after lunch on July 2, 2017. The AQI's were 181 (an unhealthy level) and 30 (a good level) in Beijing and Shenzhen, respectively. Self-reporting questionnaires with informed consent were handed out to all student volunteers by their head teachers and filled out by the volunteers.

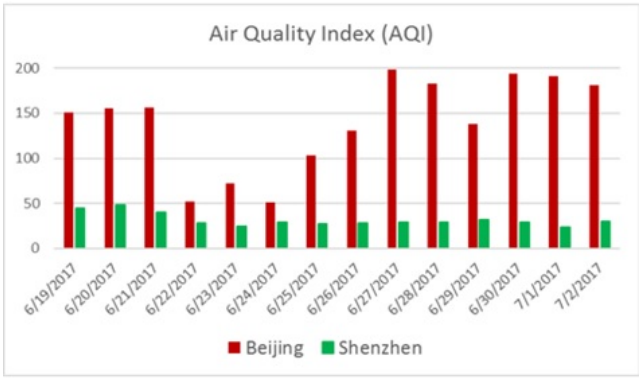

Figure 1 Air Quality Index (AQI) of Beijing and Shenzhen from 6/19/2017 to 7/2/2017.

An introductory letter was included with the questionnaires that informed them the main goals and activities of the project.

The survey consisted of the following questions:

- Perceived smog levels in one's own city. The perceived smog scales and AQI index are tabulated below in **Table 1.**
- Degree of stress aroused by smog (0=Low, 4=High)
- Degree of anxiety aroused by smog (0=Low, 4=High)
- Degree of anger aroused by smog (0=Low, 4=High)
- Number of times complained about smog in past two weeks
- Smog has negative effect on health (0=Low, 2=High)
- Decrease in time of outdoor activities (0=Low, 2=High)
- Increase in time on internet (0=Low, 2=High)
- Smog has positive effect on interpersonal affection (0=Low, 2=High)
- Smog has positive effect on learning productivity (0=Low, 2=High)

Table 1 The perceived smog scales and AQI index.

Perceived Smog Levels	AQI Levels of Health Concern	AQI Numerical Value
0	Good	0 - 50
1	Moderate	51 - 100
2	Unhealthy for Sensitive Groups	101 - 150
3	Unhealthy	151 - 200
4	Very Unhealthy	201 - 300
5	Hazardous	301 - 500

Statistical analysis

The one-way analysis of variance (ANOVA) was used to analyze differences between high school students of polluted

and non-polluted areas in terms of perceived smog levels, degree of stress aroused by smog, degree of anxiety aroused by smog, the number of times complained about smog, effect on health, time of outdoor activities, time on internet, interpersonal affection and learning productivity.

Results

Summary of Students' responses to smog

Table 2 presents the percentage for the dependent variables in this study by area (polluted vs. non-polluted) in the form of the students' responses to the survey.

Table 2 Summary of students' response to smog.

Variables	Scale alternative and percentages (%)											
	LHS (Polluted)						HHS (Non-polluted)					
	0	1	2	3	4	5	0	1	2	3	4	5
Perceived Level	0	14	30	50	6	0	68	28	5	0	0	0
Number of times complained in two weeks	72	6.3	7	7	5	3	95	3	1	0	0	0
Anxiety	3.3	25	40	30	1		74	16	6	3	1	
Stress	4.7	22	44	33	1		82	14	2	2	1	
Anger	66	16	11	7	1		72	15	8	6	1	
Negative effect on health	18	45	37				92	8	2			
Decrease in outdoor activity	22	31	47				92	8	2			
Increase in time on the Internet	31	45	24				87	12	1			
Decrease in social interaction	24	40	33				79	18	4			
Increase in productivity	21	52	27				86	9	6			
Interpersonal affection	24	39	37				83	15	2			

Environmental evaluations

Table 3 displays the mean and standard deviation (SD) of a survey taken by consenting high school students from LHS, Beijing and HHS, Shenzhen. The survey prompted the students to rate on a scale of 0-5, where 0 is good and 5 is hazardous, how serious of a threat to their health they believed the smog to be. The mean rating for the air pollution severity scale by students from LHS was 2.49 with a SD of 0.55, and the actual scale in Beijing was 3.0.

Table 3 Perceived smog severity.

Variables	LHS (Polluted)		HHS (Non-polluted)		ANOVA Analysis	
	Mean	SD	Mean	SD	F Value	Pr>F
Perceived Level	2.49	0.55	0.4	0.1	985	<0.0001

The students from HHS responded with a mean of 0.40 with a SD of 0.10, and the actual scale in Shenzhen was 0.0. Perceived severity of air pollution was strongly correlated (F value=985.31, p<0.0001) with actual neighborhood pollution per ANOVA analysis.

This supports our hypothesis that there is a direct relationship between high school students' perceptions of the seriousness of air pollution and the actual severity of air pollution. The mean severity rating of 2.49 is significantly less than the actual pollution of 3.0, indicating that the students in polluted area who are accustomed to higher levels of pollution underestimate the amount of pollution.

Psychological and physical health

The effects of smog on psychological and physical health were also evaluated. **Table 4** displays the responses when the students prompted to estimate to the negative effect and what degree they felt certain emotions because of the air pollution, from a scale of 0-4, where 0 is very little and 4 is a strong feeling. Students of polluted neighborhoods are observed to show higher levels of anxiety (Mean=2.10) and stress (Mean=2.14) than students of non-polluted neighborhoods with anxiety (Mean=0.42) and stress (Mean=0.26). ANOVA analysis shows that the neighborhood

pollution has a significant effect on anxiety (F=383.28, Pr<0.0001) and stress (F=606.20, Pr<0.0001).

Students of polluted neighborhoods are observed to have slightly higher levels of anger relative to those living in non-polluted neighborhoods.

Table 4 Psychological and physical reactions towards smog.

Variables	LHS (Polluted)		HHS (Non-polluted)		ANOVA Analysis	
	Mean	SD	Mean	SD	F Value	Pr>F
Negative effect on health	1.19	0.37	0.12	0.04	400.49	<0.0001
Anxiety	2.01	0.42	0.42	0.06	383.28	<0.0001
Stress	2.14	0.48	0.26	0.05	606.26	<0.0001
Anger	0.59	0.1	0.5	0.08	2.1	0.1483

Because of these results, our previous hypothesis that the perceived high levels of pollution directly correlate with anger in adolescents was rejected (F=2.10, Pr=0.1483), as there is no observable effect that indicates such.

The students were also asked to rate the degree to which they felt the air pollution had a negative impact on their overall health on a scale from 0-2, where 0 is the lowest and 2 is the highest. The students from LHS, on average, responded with 1.19, while the students from HHS responded with an average of 0.12. These results indicate that the higher levels of air pollution led to a perceived higher negative impact on the students' health (F=400.49, Pr<0.0001).

Coping behaviors

Coping behaviors and reactions are demonstrated in **Table 5.** The students were asked to estimate a variety of behaviors on a scale of 0-2, with 0 being the lowest and 2 the highest. Students from LHS responded with a 1.25 decrease in outdoor activity, a 0.93 increase in time spent online, and a 1.09 decrease in social interaction.

On the other hand, students from HHS responded with a 0.14 decrease in outdoor activity, a 0.20 increase in time spent online, and a 0.25 decrease in social interaction. Comparing with Shenzhen as the control, we can thus conclude that the higher levels of air pollution in Beijing caused the students to spend more time online (F=149.87, Pr<0.0001), reducing outdoor activity (F=343.24, Pr<0.0001) and social interaction (F=178.66, Pr<0.0001). The proportion of people in the previous two weeks who complained about smog (28% as per **Table 2**) are moderate. ANOVA analysis shows that the neighborhood pollution has a significant effect on the number of times complained in two weeks (F=400.49, Pr<0.0001).

Interpersonal Affection

When asked to rate their affection of other peers on a scale of 0-2, with 0 being the lowest and 2 the highest, there were unanticipated results on the effects of air pollution. The mean and SD for Interpersonal affection is shown in **Table 6**.

ANOVA analysis shows that smog has a significant effect on interpersonal affection (F=237.27, Pr<0.0001). The students of LHS responded with an average of 1.13, much higher than the HHS students' average of 0.19.

Table 5 Behavioral responses towards smog.

Variables	LHS (Polluted)		HHS (Non-polluted)		ANOVA Analysis	
	Mean	SD	Mean	SD	F Value	Pr>F
Number of times complained in two weeks	0.76	0.1	0.1	0	400	<0.0001
Decrease in outdoor activity	1.25	0.4	0.1	0.1	343	<0.0001
Increase in time on the Internet	0.93	0.3	0.2	0.1	150	<0.0001
Decrease in social interaction	1.09	0.3	0.3	0.1	179	<0.0001

This demonstrates an increase in fondness between students experiencing high levels of pollution in contrast to students in low polluted areas. This contrasted with our original hypothesis that more air pollution would have led to more enmity due to the other negative psychological effects.

Productivity

When looking at all the negative psychological and physical effects of a perceived increase in pollution on students, combined with conventional wisdom, one might assume that higher levels of pollution would lead to less productivity due to

an unhealthier mind and body. However, our research suggests that this is not the case.

Table 6 Smog and interpersonal affection.

Variables	LHS (Polluted)		HHS (Non-polluted)		ANOVA Analysis	
	Mean	SD	Mean	SD	F Value	Pr>F
Interpersonal affection	1.13	0.37	0.19	0.07	237.27	<0.0001

The same students were asked to estimate their learning productivity on the same scale of 0-2, where 0 is the lowest and 2 the highest. The mean and SD for productivity are shown in **Table 7.** Students from the polluted LHS responded with an average of 1.06, while students from the non-polluted HHS responded with an average of 0.20, demonstrating an increase in productivity when students perceived a larger amount of air pollution, in contrary to popular belief (F=210.90, Pr<0.0001).

Table 7 Smog and productivity.

Variables	LHS (Polluted)		HHS (Non-polluted)		ANOVA Analysis	
	Mean	SD	Mean	SD	F Value	Pr>F
Increase in productivity	1.06	0.3	0.2	0.06	210.9	<0.0001

Discussion

This is the first study of adolescents' coping strategies, assessment of, as well as psychological and physical response to air pollution. The present study found effects of smog on well-being and cognitive performance.

This study shows that higher levels of air pollution directly and negatively affect adolescents in China both psychologically and physically. These very youths are the generation of the future, and will grow up to replace and contribute to society. Their perceptions of air pollution and their reactions to it will also carry with them into the future, and similar attitudes and behavior will likely be passed onto future generations through learned familial behavior. Therefore, we must view the dire issue of air pollution in China with a sense of urgency as it is damaging the youth that have yet to fully mature.

Findings on decreasing outdoor activity in response to the smog corroborate with the study conducted by Evans [5]. This study is the first to find a correlation between the decrease in social interaction and increase in online activity because of increased levels of air pollution. In a world where technology is already infiltrating the lives of youths and abating social interaction in favor of online interaction, higher levels of air pollution would further this anti-social trend. Adolescents would stay indoors even more, receiving less social interaction and becoming further incapable of communication as their relationship with technology only becomes more dependent.

We referenced a study conducted by Evans [5] that examined the effects of varying ambient air quality on citizens in Los Angeles, California. Although the PPB (concentration) of ozone in Los Angeles was only 45 as opposed to Beijing's 246, similar results were displayed in terms of anxiety and anger, but with differences in stress. In both our and their study, anxiety levels were proven to rise significantly as the result of increased air pollution. Additionally, both studies indicated that air pollution levels had no observable impact on anger in subjects. However, Evans found that the air pollution in Los Angeles did not have a statistically significant impact on stress in its citizens, but our study indicated a rise in stress because of a rise in air pollution [5]. This discrepancy can be attributed to the large disparity of pollution severity between Los Angeles and Beijing (a 201 PPB gap). This suggests that while low levels of concentration will still lead to increased stress, it takes higher concentration to see observable effects on stress in subjects.

The original hypothesis was that the negative psychological effects of smog would lead to more hostility, but the study indicates that classmates elicited greatest liking in the polluted atmosphere. It is likely that smog had increased attraction for another who experiences the same smog. The "shared stress" presented by smog intensified liking for people whom they knew were experiencing the same unpleasant conditions. This coincides with the "shared stress" hypothesis that was proven by Rotton [16-18] in his study.

Despite the widespread belief that air pollution conditions are related to low productivity, we found evidence that people are more productive on air polluted days. We propose that smog increases students' learning productivity by eliminating potential cognitive distractions resulting from good air conditions. Good air conditions might cause students to be distracted by outdoor activity when faced with a learning task, making it difficult for them to focus. Another possibility is that when faced with poor air quality, youths begin to spend more time inside, further supported by our study which suggests that more air pollution leads to less time spent outside. This is further corroborated by two other studies. It was found that

avoiding outdoor settings and activities appears to be the most common and frequently used strategy for coping with air pollution [19,20]. Lercher [21] also reported that children in the traffic air pollution area spend less time outdoors. When they are inside and less likely to go outside recreationally, students are faced with little other choice but to focus and do their work properly without the distractions and temptations of the outdoors.

Despite these proven negative effects from air pollution, the Chinese students from Beijing admitted to increased levels of productivity, contrasting with previous studies such as Mohai [14] and Pastor [13] that suggested that increased air toxicity and pollution levels correlates to decline in academic performance. The disagreeing data can be explained by the cultural differences, as Mohai and Pastor conducted their studies in the United States of America while our study was conducted in China. Chinese culture typically promotes perseverance and endurance and places a heavier emphasis on education and academic achievement than American culture [22,23]. Chinese students are more likely to work harder on academics without the distractions of outdoor activity.

Conclusion

In conclusion, our study provides us with more data supporting the harmful effects of air pollution, but more specifically provides new data on how it specifically impacts Chinese youth. We can observe that it leads to harmful psychological and physical effects, and the adolescents also began to spend less time outdoors and focus more time on the internet, worsening a modern epidemic. We are the first study to confirm that the higher amounts of air pollution surprisingly lead to higher levels of learning productivity. Moreover, the adolescents have been proven to feel shared stress, and become more amicable with others whom they knew were enduring the same conditions and pollution. Ultimately however, the negative effects outweigh the positive, as the future Chinese generations plagued by smog cannot continue to be damaged and put at risk, no matter the minor benefits.

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