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Green Economy Versus Dark Health: Risk Tolerance Boosts Adaptation to Soot-Contaminated Environment

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Abstract: There are growing mental health concerns over soot contamination of Niger-delta communities as a result of oil exploration activities. Our study sought to understand soot risk tolerance (SRT) as a pathway through which the association between exposure to soot (ES) and perceived soot risk concerns (SRCs) could be explained among residents of oil-producing communities in the coastal region of Nigeria. Data were obtained through a survey research design with the aid of The Authors suggest that Self-report measures is allowed as it is of ES, SRC, and SRT. PROCESS macro moderation results revealed that the positive association between ES and SRC ($B = 1.22$, $t = 2.07$, $p = 0.027$) was weakened by SRT (negative moderated) ($B = -2.38$, $t = -4.16$, $p = 0.000$) such that the association was weak for residents with high SRT scores and strong for residents with low SRT sores. The key finding implies that risk tolerance is crucial to survival in oil-producing communities with physical soot pollution. We recommend that risk tolerance should be included in measures designed to boost individual's capacity to adapt and function in a soot-contaminated environment.

Keywords: adaptation to soot environment, soot risk tolerance, oil-producing communities, moderation model, physical and health concerns

The oil and gas sector has continued to be the main source of the Nigerian economy as it contributes over 85% of the country's annual earnings for the past 4 decades. These economic gains are however without human capital and mental health costs as the oil production activities have resulted in established water, air, and land pollution in the oil-producing regions of Nigeria. The mental health status of the residents of the oil-producing communities has been majorly affected by soot emissions from gas and production plants. Thus, adaptation to these environments requires more psychological energy than financial strengths.

1. Introduction

Empirical evidence abounds on the negative impacts of oil exploration on the mental health statuses of residents of oil-producing communities (Akpan, 2016; Nriagu et al., 2016). Research has established a link between oil and gas activities and adverse environment in the Niger-delta in the form of oil spillage (Ite & Ibok, 2013; Nwaogazie et al., 2016), water and land contamination (Akinfolarin et al., 2018), environmental degradation, and recently, emission of soot particles (particulate matter (PM)) (Awo et al., 2019a) which Charlson and Heintzenberg (1995) described as particles formed during the quenching of gases at the outer edge of flames of organic vapors. PM consists predominantly of carbon, with lesser amounts of oxygen and hydrogen present as carboxyl and phenolic groups and exhibiting an imperfect graphitic structure. Specifically, studies (Perron et al., 2010; Adewal & Mustapha, 2015; Gehrig et al., 2007) show that a PM is made up of elements such as Pb, Zn, Cu, Ni, Fe, Mn, Cr, Ca, K, Mg, P, S, Mg, and Na. In the oil and gas firms, PM is a collection of impure carbon particles produced as a result of incomplete combustion at the gas phase of the combustion process (Bagi et al., 2016; Bond et al., 2013).

In most instances, PM exists in a powder-like form of amorphous carbon that contains polycyclic aromatic hydrocarbons known as mutagens that have been classified as carcinogens (International Agency for Research on International Agency for Research on Cancer, 1985; Bagi et al., 2020). Common PMs include PM10 which is a 10-micrometer particle that could be inhaled, and PM2.5 which is a fine inhalable 2.5-micrometer particle (Fu et al., 2015; Lin et al., 2018). The PM size is associated with its potential for causing health problems. PM2.5 poses the greatest health risks as it has the capacity to get deep into human lungs, and sometimes the bloodstream (Xing et al., 2016), and it could be carried over long distances by wind and then settle on surfaces or water where they contaminate such surfaces and water bodies, deplete the soil nutrients, and damage sensitive forests and farm crops (Mangia et al., 2015).

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2. Literature Review

Continued exposure to PM could have an adverse impact on the general well-being of plants, animals, and humans, as well as the esthetic configuration of the ecosystem (Akinfolarin et al., 2018). Extant research (Nwachukwu et al., 2012; Aregbe, 2017) shows that protracted exposure to PM was associated with an increased risk of air-related morbidities such as coronary artery disease, lung infections, cerebrospinal meningitis, bronchitis, pulmonary tuberculosis, upper respiratory tract infection, child deformities, and eye and skin disorders. However, these studies focused on medical health implications of soot contamination established through a prevalence study among residents of non-coastal cities in Nigeria. The need, thus, arose to explore the psychological and mental health impacts of soot in the coastal communities in Nigeria.

One study (Awo et al., 2019a) reported that exposure to soot (ES) was associated with the depletion of the functional capacity of academic of polytechnic staff in a community where soot pollution was common. Awo et al.'s (2019a) study is limited by its involvement of only staff and students of an academic institution and cannot compare with the present study that involves rural dwellers who are directly exposed to PM particles in their daily activities in the farm market places. Similarly, Nriagu et al. (2016) found evidence of the negative impacts of pollution on psychological indices of worry, annoyance, and capacity limitation. However, Nriagu et al.'s (2016) finding is limited and differs from the present study by its focus on oil pollution as the predictor variable. Li et al. (2021) established a bidirectional relationship between global per capita carbon emissions, economic, and social changes such that increased carbon emissions social changes affect each other negatively. This negativity could impact the mental wellness of the residents' high carbon-contaminated cities.

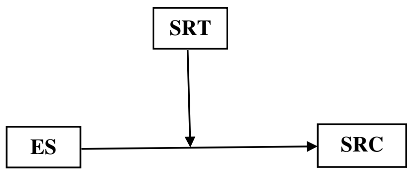
Other studies (Alola & Ozturk, 2021; Wang et al., 2022) reported a positive association between the economy and carbon emission between the economy and carbon emissions as well as ecological footprint. However, the positive effect of economic growth on the ecological footprint is greater than that of carbon emissions suggesting the need for psychological energy such as tolerance in adaptation to challenging physical environment. The interaction effects found in this study emphasize suitability of the moderation model. Alola and Ozturk (2021) held that environmental sustainability is achievable at the maximum level of income and ability to adapt to contaminated and risk-prone environment.

One of the more valuable contributions of personality-type constructs such as risk tolerance is the ability to withstand pressures and adapt to harsh environmental conditions (Gaube et al., 2019). According to Chen (2018) and Jun and Jin (2021), risks, mostly from a health perspective, are generally viewed as the threat potential for harm, injury, disease, and even death under certain circumstances. Risk is defined as the common belief of the perception of the possibility of a negative event (Venette, 2008). Tolerance is characterized as a tendency to develop "thick skin" against unfavorable conditions (Slovic, 2016). Irwin defined risk tolerance as the willingness to accept behaviors and conditions that are laden with a possible negative outcome, and it differs considerably from risk acceptance (Tchiehe & Gauthier, 2017) which implies fully taking a risk(s) into consideration after due analysis. According to Eastin et al. (2015), risk tolerance acts as a gauge of how at-risk individuals, groups, or public cope with risks as evidenced by how willing they are to live with it since they seem unable to overcome them. In the domain of environmental health and hazards, empirical evidence suggests that a lower level of risk tolerance was associated with higher perceived risk such that individuals with low-risk tolerance are more likely to perceive the source of risk as more harmful than those with high tolerance for risk. Less risk-tolerant individuals tend to manifest elevated symptoms of anxiety and apprehension in the presence of risky incidences in their environment compared to more risk-tolerant others (Jun & Jin, 2021). Thus, risk tolerance could act as a pathway to understanding the mental health statuses of at-risk individuals and populations.

3. The Present Study

To our understanding, there is paucity of research on the associations between ES, soot risk concerns (SRCs), and soot risk tolerance (SRT) among communities exposed to oil exploration in Nigeria. Specifically, there is a lack of data on the potential of risk tolerance to act as a pathway through which the impact of ES on the SRCs (feeling unsafe as a result of exposure to environmental soot) could be explained. In the present study, we aim to (a) examine the general associations among ES, SRT, and SRC among the population of two host communities of gas-producing firms, and (b) through the use of a moderator model, we aim to demonstrate the conditional influence of ES via the different levels of SRT. This hypothetical relationship is depicted in Figure 1 showing the direct and indirect relationships among the factors under investigation.

Figure 1
Moderation effect of risk tolerance on the ES–SRCs association



Note: ES = exposure to soot; SRT = soot risk tolerance; SRC = soot risk concern.

4. Research Methodology

4.1. Research design

The present study adopted a cross-sectional study design to examine risk tolerance as a moderator of the link between ES and SRCs of Nigerians in oil-producing communities. The idea behind this was to involve maximum number of participant that could account for a reliable and valid finding.

4.2. Participants

A cross-sectional survey was conducted with a total of 1480 male ($n = 912$, 61.62%) and female ($n = 568$, 38.38%) healthy individuals aged between 20 and 53 years ($M = 31.07$, $SD = 4.22$) who had lived in either Finima or Bonny communities in Bonny

Island for 5 years and above. Twenty participants were excluded from the analyses due to missing responses at least two items in the predictor and/or outcome variables. Among the participants, 211% were fish farmers, 529% were market traders, 56 % were hospital/medical staff, 124% were students, 203% were oil workers, 242% worked in an employee position, 62% worked in a middle-level management position, and 53% worked as academics. The majority (74.73) had certificates equal to or less than O'Level.

4.3. Instruments

The instruments of the present study consist of two parts: part one contains questions on respondents' age, gender, community, and occupation, while part two contains the English versions of the different measures of the study variables: exposure to soot scale, soot risk tolerance scale (SRTS), and soot risk concern scale.

4.3.1. Exposure to soot

Individual's ES was measured with Awo et al.'s (2019a) 7-item soot exposure checklist (SEC) which assesses participants' exposure to and experience of soot pollution in their residential, business, offices, and worship areas owing to their proximity facilities that flare gases and emit soot to the environment in the past 4 weeks. Each item (e.g., How much of the time do you experience soot particles in your home, business/workplace, office, market, school, or worship centers in the past 1 week?) is anchored on a 7-point scale with anchors ranging from "Never" (scored 1) to "Every time" (scored 7). A total SEC score was calculated by averaging the scores on the seven items. Awo et al. (2019a) reported a good internal consistency coefficient for the SEC (α = 0.82) and content validity index (α = 0.83) among a sample of polytechnic staff. The SEC demonstrated a high internal consistency index (α = 0.84 for males and α = 0.79 for females) and a content validity coefficient (α = 0.87 for males and α = 0.81 for females).

4.3.2. Soot risk concern

Respondents' SRC was measured with a 4-item scale adapted from Lerner et al. (2003). This measure was adopted following the close link and similarities between oil pollution (as studied by Lerner et al. (2003)) and soot pollution as a focus of the present study, as these are common occurrences in oil-producing communities. The participant was asked to rate their level of concern over the risks that are associated with soot pollution. Participants responded to each item (e.g., "Original version: I am concerned over getting sick from oil spillage; Modified version: I am concerned over getting sick from soot pollution"; Original version; I am worried over being a victim of contaminated food or water due to oil spillage; Modified version: I am worried over being a victim of contaminated food or water due to soot pollution; "Original version; I am worried that my farm or business might be ruined by oil spillage; Modified version: I am worried that my farm or business might be ruined by soot pollution", and "Original version; livelihood might be ruined by oil spillage; Modified version: livelihood might be ruined by soot pollution") on a 5-point rating scale with anchors ranging from "Not concerned" (1) to "Very concerned" (5). A total SRC score was obtained by averaging the item scores with higher scores indicating higher level of risk felt by the respondent. Lermer et al. reported a high internal consistency coefficient for the original version of the risk measure (α = 0.77) and good content validity (α = 0.80). In the context of the present study, the SRC measure demonstrated a high internal consistency coefficient (α = 0.88) and a high content validity index (α = 0.84).

4.3.3. Soot risk tolerance

SRT was measured with a 7-item soot risk questionnaire developed by the researchers. Items on the questionnaire include "I tolerate the risks that are associated with soot pollution in Bonny," "I did not really care that much about the effects of risks associated with soot," "If I read the effects of soot pollution, I would feel disinterested, because I know I will not avoid soot," and "I will continue to stay in Bonny regardless of soot pollution." Participants responded to each item on a 5-point rating scale with anchors ranging from "Strongly disagree" (rated 1) to "Strongly agree" (rated 5). A total SRT score was calculated by averaging the scores on the seven items. The SRT measure demonstrated high internal consistency (α = 0.81), inter-item reliability (α = 0.80), test–retest reliability (α = 0.81), and a construct validity coefficient (α = 0.86).

4.4. Procedure

Ethical approval for the present study was secured from the Dean, School of General Studies, Federal Polytechnic of Oil and Gas (FPOG), Bonny, community heads, and the participants by means of oral and written consent due to the absence of an institutional-based research ethics committee in the FPOG at the time of this research. Participants were recruited using the availability sampling technique. They were visited in their homesteads/settlements, offices, and business premises. Participation was voluntary and anonymous. Participants were offered no compensation at the end of the study. After providing informed consent (orally), participants completed measures of the exposure to environmental soot, followed by the SRC measure, soot risk tolerance measures, and demographic questions. At the completion of the measures, the purpose of the study was made known to each respondent with a view to giving them a feedback at the completion of the study. The study was conducted between November 2020 and February 2021.

4.5. Design and data analytical procedure

The generalized extreme studentized deviate (Rosner, 1983) model was employed to screen the ES, SRT, and SRC scores for outliers and skewness by dividing the mean score of each construct by its standard deviation. The result showed that the scales had no outliers, and their skews were within acceptable limits (ES = 0.21, soot risk = 0.29, and SRT = 0.43). Soot risk and ES scores displayed positive skews (2.16 and 3.00, respectively), while SRCs scores displayed a negative skew (−2.53). These indices indicate that the test provides fit for the study assumptions. Thus, bootstrapped standard errors (BSEs) and associated confidence intervals (CIs) were used to test their associations as shown in Table 1, while the HAYES macro moderation model was used to test the moderating role of SRT on the association between ES and SRCs as presented in Table 2 (age and years lived in Bonny Island were treated as control variables). The HAYES model was employed because it has some advantages over other analytical models such as the structural equation modeling as it provides not just the estimates but also the direct and indirect effects of the moderation model (BSE), as well as the CIs (Hayes, 2017). The CIs reported for the BSEs are bias-corrected bootstrapped CIs based on 5000 samples. Thus, if a product term (i.e., interaction of predictor and moderator) was

Table 1
Descriptive statistics, correlations, and scales' alpha

Variables		Mean	*SD*	1	2	3	4	5
1	Age	27.51	3.07	–				
2	Y_Bonny	6.18	4.83	0.10*	–			
3	ES	15.09	2.64	0.03	0.09*	0.83		
4	SRT	22.70	4.10	0.08*	0.11*	−0.24**	0.79	
5	SRC	25.01	2.71	0.02	−0.10*	0.18**	−0.21**	0.86

Note: Y_Bonny = years lived in Bonny Island; ES = exposure to soot; SRT = soot risk tolerance; SRC = soot risk concerns; *** = $p < 0.001$; ** = $p < 0.01$; * = $p < 0.05$.

Table 2
Hayes PROCESS moderation analysis for soot risk tolerance on the association between exposure to soot and soot risk concerns

Variables	*B*	*t*	*p*	95% CI
ESP	1.22	2.07	0.027	[−2.19, 3.53]
SRT	−3.31	−2.11	0.001	[−1.42, −0.27]
ESP * SRT	−2.38	−4.16	0.000	[1.55, 2.11]
Age	0.06	0.16	0.703	[0.01, 1.05]
Y_Bonny	0.09	0.11	0.531	[0.50, 1.22]
$R^2 = 0.394$				
$\Delta R^2 = 0.394$				
$\eta^2 = 0.520$				

Note: Y_Bonny = years lived in bonny; ESP = exposure to soot pollution; SRT = soot risk tolerance.

significant, it would mean that the association between the predictor (i.e., ES) and the outcome (SRCs) was either stronger or weaker in the presence of the moderator (SRT). The HAYES macro moderation analysis model is the most widely used statistical tool in the analysis of moderation effect in psychological research (Chukwuorji et al., 2020).

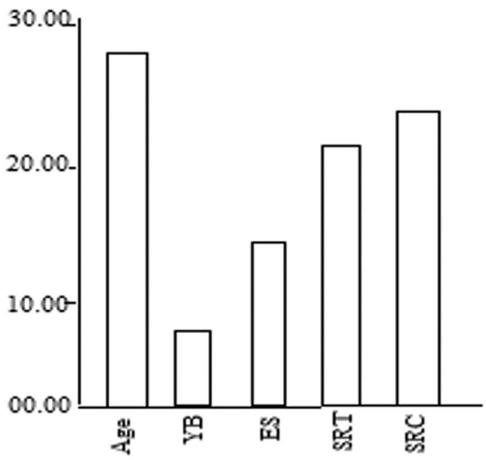
5. Results

The result of the analysis plan is presented in Tables 1 and 2, and Figure 2.

Table 1 reveals that there was a significant positive correlation between ES and SRC scores, ES and SRT scores were negatively correlated, and SRT and SRC scores were negatively correlated. The relationship between age and years lived in Bonny, and age and SRT scores was positive and significant. Years lived in Bonny Island were positively correlated with ES and SRT scores but negatively correlated with SRC scores.

The moderation effect of SRT was tested, and the standardized beta weights (*B*) and 95% CIs results for the model are shown in Table 2. The table reveals that ES was positively associated with SRCs ($B = 1.22$, $t = 2.07$, $p = 0.027$). SRT was, however, negatively associated with SRCs ($B = -3.31$, $t = -2.11$, $p = 0.001$). SRT negatively moderated the association between ES and SRCs ($B = -2.38$, $t = -4.16$, $p = 000$). The SRT moderator model explained 14% of the variance in SRCs scores, $F(3, 274) = 21.05$, $p = 0.004$. The conditional effect for SRT was tested at 1 SD below the mean (low tolerance), at the mean (moderate tolerance), and 1 SD above the mean (high tolerance). The association between ES and SRCs was weakest when tolerance was high ($B = 1.07$, $t = 2.13$, $p = 0.031$), weaker when tolerance was moderate ($B = 2.35$, $t = 2.75$, $p = 0.018$), and strongest ($B = 3.21$, $t = 2.97$, $p = 0.003$) when tolerance was low. The link between ES and SRCs for each level of the conditional effects tested for the ES × SRT is depicted in Figure 3.

Figure 2
Bar chart of mean scores of the demographic and main study variables

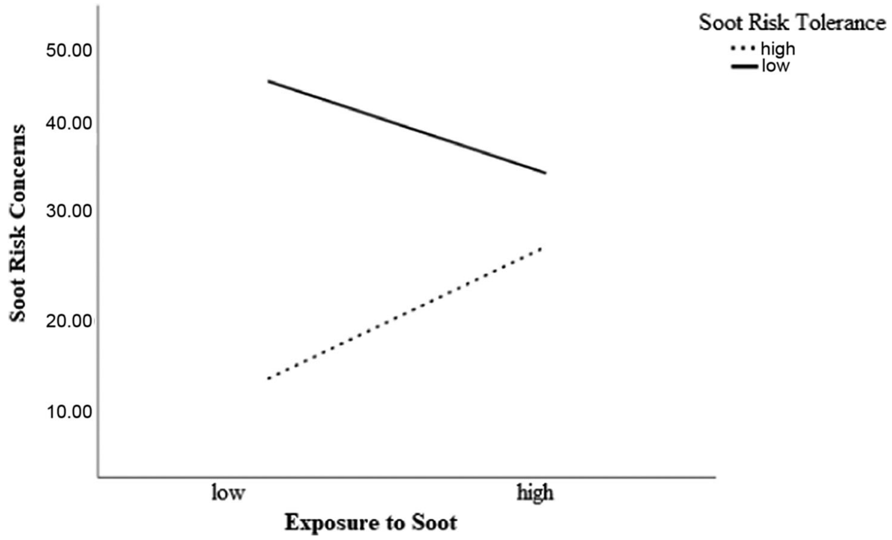


Note: YB = years lived in Bonny Island; ES = exposure to soot; SRT = soot risk tolerance; SRC = soot risk concerns.

6. Discussion and Implication

Research has extensively found evidences of the positive relationship between environmental soot and soot risk worries (Awo et al., 2019a; Nriagu et al., 2016). However, the extent to which ES and personality variables such as risk tolerance jointly determine SRCs among residents of Bonny Island, Nigeria, where gas flaring contributes significantly to the presence of soot in the environment has largely remained unknown. The present study

Figure 3
Conditional effects of levels of soot risk tolerance on the relationship between exposure to soot and soot risk concerns



found that persistent ES was associated with an increased feeling of concern over risks associated with soot. This finding corroborates past documentations that environmental soot as stress attenuates the mental well-being and health of residents of oil-producing communities (Akinbobola & Njor, 2014), functional capacity (Awo et al., 2019b), and quality of life (Kponee et al., 2015).

The addition of SRT in the model allowed for further exploration of the association between ES and SRCs. Our suspicion that increase in SRT will associate significantly with a decrease in perceived soot risk was confirmed. Our finding portrayed SRT as a negative correlate of SRCs such that increases in SRT scores were associated with diminished SRCs despite continued ES. This finding presents a variation from existing literature (Yakubu, 2018; Nwaogazie & Zagha, 2015) that risk tolerance was associated with heightened feeling of anxiety and asthma. However, this difference may be traced to differences in predictor and outcome variables of interest. Whereas available evidence (Nriagu et al., 2016) focused on oil spillage, the present finding on soot as a sort of environmental pollution is a fresh insight into environmental pollution studies. The current finding presents SRT as a pointer to understanding adaptation to high-risk soot environments by residents and visitors.

An interesting finding of the current study was the conditional effect of SRT on the association between ES and concerns over soot risk. Specifically, ES was associated with less feeling of soot risk among respondents with high SRT scores and felt that they have "thick skin" for risks associated with soot. In contrast, the association between ES and the feeling of being at risk of soot strengthened as SRT waned, that is, the ES–SRCs link was a function of respondents' level of tolerance for soot risks. Respondents who had high SRT scores showed reduced feeling of being at soot risk, which tends to quicken adaptation to the adverse environment and, therefore, showed less worry and anxiety over soot presence in the environment. The ability to develop SRT influences reactions to environmental soot as those who reported high tolerance, felt less concern for soot risk, while those who reported little or no SRT tended to be overwhelmed by risks associated with environmental soot.

Our findings provide support for the position that persistent exposure to environmental soot increases the feeling of being at risk of the hazards associated with soot (Awo et al., 2019b; Nriagu et al., 2016); however, the interaction of ES and SRT suggests that the development of tolerance for environmental soot may act as a cushion against the heightened feeling of risk of soot hazards among residents of gas oil-producing communities with high degree ES. In particular, the association of ES pollution and SRC attenuated when community residents reported high soot tolerance, whereas the association amplified when the residents reported low tolerance for soot risk.

6.1. Implications

This findings imply that developing and improving tolerance for soot and its associated risks could quicken adaptation to soot-polluted environments. The key strength of our study was its provision of empirical data on the ability of risk tolerance to extinguish feelings of soot risk by residents of soot-contaminated environments, thus bringing clarity to the quest for the psychological explanation of why residents of the oil-producing community tend to be less concerned/worried over the menace of soot in the environment (Awo et al., 2019a). This finding is crucial for boosting of mental wellness and adaption to soot contaminations. It encourages policies and strategies to boost risk awareness and tolerance of residents of oil-producing communities.

6.2. Recommendations

We recommend that oil-producing firms adopt global-best practices in controlling soot particles and pollution by re-injecting the gases for secondary oil recovery, liquefying the gas that emit PM and storing them in vessels as liquid gas, compressing natural gas into methane stored at high pressure, and other established measures as recommended by studies (Aregbe, 2017; Adewale & Mustapha, 2015; Orimoogunje et al., 2010). We also recommend strategies that increase risk tolerance among residents of oil-producing communities as this could boost their ability to adapt to adverse impacts of oil exploration and exploitation on the physical and mental health of the residents.

However, the present results should be interpreted with caution due to some design limitations. For example, the sample included only non-clinical respondents recruited from local communities, the extent to which the present finding can apply to clinical samples, at-risk populations, or the general oil-producing communities of Nigeria remains to be ascertained. Furthermore, the cross-sectional nature of the study prevents causation inferences. Although exposure to environmental soot may be considered a precursor to mental and physical health risks, testing this assertion was, however, not possible in the present study. We opine that this limitation which should be addressed by considering clinical samples, a larger sample size, adopt an experimental and/or longitudinal research design in testing the relationships among the present study variables.

7. Conclusion

Our study explores the moderating effects of SRT on the association between ES and SRCs among residents of two oil-producing communities in Nigeria. The findings show that the positive association between ES and SRCs was weakened by high SRT. We, thus, conclude that SRT is included as part of test batteries and treatment plans for individuals who struggle to adapt to soot-contaminated environments. This is based on the revelation that SRT was a critical pathway for understanding the relationship between ES and SRCs, that is, the negative moderation effect of SRT in the association between ES and SRC showed that ES was weakly associated with SRC among respondents with a high tolerance for soot risk, while the association was strong for respondents with a low tolerance for soot risk.

Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

Data available on request from the corresponding author upon reasonable request.

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