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Original Research

A Configurational Analysis of Factors Affecting Low-Carbon Behavior of College Students Based on the Motivation-Opportunity-Ability Framework

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Abstract

Individual low-carbon behavior (LCB) plays an important role in reducing carbon emissions and achieving climate mitigation goals to build a low-carbon society. Based on data collected from college students in Xi'an City, this study proposes a Motivation-Opportunity-Ability (MOA) integrated framework that simultaneously considers eight elements and analyzes their combinatorial effects on the LCB of college students through the fuzzy-set qualitative comparative analysis (*fs*QCA) method. The analysis results show that: (1) low-carbon knowledge (LK) is a necessary condition for the implementation of LCB among college students and, along with behavioral intention (BI), plays universal and important roles in LCB implementation. (2) the combination of MOA conditions can be summarized into four different paths affecting LCB implementation among college students: 1) publicity and education (PE)-driven under the motivation-dominant mode; 2) the opportunity-pull mode; 3) enjoyment perception (EP)-driven under the motivation-dominant mode; and 4) the ability-push mode. (3) Each mode represents different characteristics and coupling paths to achieve LCB implementation among college students. This study enriches the literature on LCB and provides potential implications for guiding college students' LCB and improving low-carbon management.

Keywords: low-carbon behavior, MOA, configurational analysis, *fs*QCA, college students

Introduction

The climate is facing increasingly serious challenges, including increasing carbon dioxide emissions, ozone layer destruction, growing water scarcity, and declining biodiversity [1-3]. Therefore, many countries are committed to taking measures to effectively control environmental pollution through low-carbon actions. For example, the Chinese government launched the Action Plan for Carbon Dioxide Peaking before 2030 in 2021 [4]. In December 2019, the EU introduced the Green Deal, with the overall goal of achieving "carbon neutrality" in the EU by 2050. The plan also includes the EU's carbon border adjustment mechanism (CBAM),

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a tax on the carbon emissions of some imported goods, covering most EU countries [5].

To achieve carbon neutrality, many governments have implemented numerous policies targeting the supply-side sectors. However, increasing evidence indicates that demand-side measures in climate change mitigation are critical and require more attention [6]. For example, the results of the 2020 Emissions Gap Report showed that household consumption accounts for approximately two-thirds of global greenhouse gas emissions on average. Relevant statistical data show that household consumption in China accounts for 52% of total national emissions [7]. As the micro-object of carbon emission policy implementation, there is a substantial need to investigate the factors influencing residents' low-carbon behavior (LCB) to effectively stimulate their willingness to engage in carbon emissions and shape low-carbon life skills. However, as Liu et al. [8] point out, owing to China's special population structure and wide distribution, it is exceedingly difficult and unrealistic to conduct a complete, complicated, and vast project simultaneously. Thus, college students were considered a good sample for this study. In addition to Liu et al.'s reasoning [8], we should recognize that college students will serve as the backbone of our future society, are the most active groups in society, and are a new force in low-carbon environmental protection. Indeed, as future decision-makers, builders, and creators, college students' attitudes and behaviors play a crucial role in reducing CO2 emissions. Therefore, it is essential to explore ways to enhance college students' low-carbon consumption behaviors. Certainly, some existing studies have focused on college students and delved into the factors influencing low-carbon consumption behavior. For example, Qi et al. [7] discussed the impact of the gain-loss frame on college students' intention to participate in an individual LCB reward system, and Liu et al. [8] explored the role of situational factors in low-carbon consumption behaviors among college students.

The existing literature provides rich and profound insights for the current study. However, the variables influencing college students' LCB are relatively fragmented and scattered. Furthermore, no integrated analytical theoretical framework has been built for the factors influencing LCB. In addition, almost all of the literature discusses the net effects of individual elements on LCB and ignores the interdependent holistic effects of multiple factors. There is no doubt that, as a complex decision, the adoption of LCB is the result of multiple factors, including psychological and non-psychological factors and social situations. This causal complexity problem cannot be fully explained by a traditional regression analysis, which explores the net effect of each aspect in isolation or the moderating effect of up to three variables. Therefore, revealing the combined effects and interactive relationships among various factors can not only help to fully understand the complexity of the adoption of LCB (e.g., many combinations of factors can lead to the same outcome) but also provide complementary or alternative solutions for policy practitioners to effectively mitigate climate change and support a low-carbon lifestyle.

This study addresses this gap by developing a configurational (rather than correlational) theory. The marginal contributions of this study are as follows:

(1) Based on an individual and configurational perspective, we are the first study to introduce the Motivation, Opportunity, and Ability (MOA) theoretical framework into the study of college students' LCB and comprehensively explain the reasons for the multiple LCB paths among college students. Through referencing MOA theory, we provide a more theoretical perspective for understanding the multiple causal pathways in college students' LCB and its influencing factors and broaden the scope of application of the MOA theoretical framework.

(2) From the perspective of research content, this study changes the driving mode of LCB from the influence of fragmented antecedents to the combined holistic effects of multiple antecedents (e.g., personal MOA), which enriches the research content on the influencing factors of individual LCB. Thus, the overall knowledge of the influencing factors of LCB can be enhanced by organizing the MOA elements simultaneously so that they are no longer fragmented and incomplete.

(3) Unlike other related studies, we first introduce the fuzzy-set qualitative comparative analysis (fsQCA) method to explore the influencing factors of college students' LCB, thus not only making up for a drawback of traditional studies (i.e., the outcome is better explained by individual elements in isolation) but also enriching the existing toolbox of research methods in the field of LCB.

(4) Through a configurational effects analysis of multiple antecedent conditions, we reveal the novelty and complexity of the relationship between the configurational elements (i.e., the eight conditions discussed in this paper) and the outcome of college students' LCB in terms of their set-subset relations, thus providing a theoretical analysis.

Literature Review and Research Framework

Literature Review

Previous studies have shown that individual behavior significantly impacts CO_2 emissions [9]. Therefore, focusing on the individual-micro level, many studies have explored which and how different factors affect individual LCB, or low-carbon consumption. When exploring the causes of individual LCB, the academic community mainly uses the following several classic behavior theories and conceptual models, including the theory of planned behavior, the norm-activation model, the value-belief-norm, and the attitude-behavior-external conditions model [10, 11]. Academic circles have contributed abundant research results on low-carbon consumption, concentrating mainly on the following two aspects:

Cognition of LCB

Individual CO_2 emissions are derived from daily human activities [11]. Therefore, individual daily activities that are directly or indirectly related to CO_2 emissions significantly contribute to reducing carbon emissions. According to Wang et al. [11], household energy consumption, personal transportation, and the consumption of green merchandise are the three most important areas for individual LCB. Mi et al. [12] divided LCB into two dimensions: purchasing low-carbon consumption behavior (PLCB) and habitual low-carbon consumption behavior (HLCB). The former occurs when an individual purchases energy-efficient or low-carbon products and is usually a one-off behavior that is economically rational. The latter refers to a direct reduction in fossil energy consumption by improving the way energy-consuming products are used. This behavior is characterized by repeatability and bounded rationality. In addition, some scholars have proposed the concept of sustainable LCB, that is, the replication and sublimation of LCB, which includes purchase, daily use, waste disposal, and public participation behaviors that support sustainability [1]. Barr et al. [13] categorized individual energy-saving behaviors into three types: habitual behavior, consumer behavior, and resource recycling.

Factors that Influence Low-Carbon Behavior

The current study focuses on exploring the main factors that affect individuals' LCB. The main literature divides the influencing factors into three categories: demographic characteristics, individual internal characteristics, and external environmental factors [11]. Most studies discuss the influence of the latter two factors and compare the different results in the context of individual demographic characteristics (e.g., gender, age, education level, and income). Paco and Lavrador [14] investigated students' general environmental knowledge, attitudes, and behaviors and found that although males have higher levels of environmental knowledge, females seem to display more awareness of attitudes and behaviors. Du and Pan [15] examined gender differences in university students' reasoning regarding energy-saving behaviors. Ji et al. [16] and Wang et al. [11] provided a detailed description of the influence of demographic characteristics on LCB. In general, individual internal characteristics refer to personal characteristics, abilities, and subjective willingness related to LCB. Bai and Liu [17] confirmed that individual LK positively affects both private and public LCB, whereas low-carbon attitudes do not significantly impact private LCB. Yang et al. [18] verified that low-carbon cognition and intention positively impacted residents' LCB. Regarding external environmental factors, Wei et al. [1] showed that information incentives and social influence are two important predictors of low-carbon consumption behavior. Mi et. al. [12] demonstrated that reference groups have a more significant influence on HLCB than on PLCB. Jiang et al. [19] explored the effects of Chinese cultural values (man-to-nature orientation and collectivist values) on low-carbon consumption behavioral intention. For the individual low-carbon behavior reward system (ILBRS), a pilot initiative in China, Ji et al. [20] compared the effects of monetary and non-monetary incentives on LCBs and discussed high-willingness and low-willingness behaviors. Many researchers have integrated internal and external factors to explore their degree of influence and influence paths. Chen and Li [9] assessed the impact of five influencing factors (low-carbon awareness, LK, personal norms, social norms, and situational factors) on private and public LCBs.

Although the above studies provide theoretical and methodological support to clarify the influence mechanisms of individual LCBs, some shortcomings remain. First, although existing studies have provided rich explanations for individual LCBs, they do not offer sufficient theoretical support for differentiated path selection to improve individual LCBs. Second, traditional econometric models and correlation analyses are used to explore the net effect of a single variable. These methods have limitations in exploring the concurrent influence of the combined interaction and mutual configuration of conditions on the results. LCB adoption relies on the interdependence of conditions rather than independent influence; thus, the assumption of a uniform symmetric relationship between the independent and dependent variables in the existing literature limits path selection for individual LCB. Third, in a realistic situation, individual LCB reflects the logical relationship between the matching modes of different conditions and the results. Adherence to LCB, or behavioral changes, are complex processes that are influenced by the combination and synergistic interaction of multiple factors. This interaction of conditions leading to LCB implementation among college students has not been explored in previous studies. Most notably, in the research field of LCB, the complexity of causality leading to LCB implementation among college students has received little attention.

Research Framework

In summary, although scholars agree that LCB adoption is an outcome of multiple factors, the extant literature is generally limited to exploring the net effect of individual or partial elements, thus ignoring their combined complementary effects on LCB adoption. To address this gap, we explored the mechanisms influencing college students' LCB from a configurational perspective. Owing to the complicated combinations of antecedents, multiple pathways through which college students can take low-carbon actions are often available but are difficult to investigate using traditional methods [21, 22]. To address these limitations, we introduced the *fs*QCA method to explore the combined and complementary effects of different elements concerning LCB implementation among college students. Based on the following framework (see Fig. 1), we considered eight main elements simultaneously and analyzed their combined effects.

In 1989, Macinnis et al. [23] first proposed the MOA framework, which states that individuals engage in decision-making behaviors under the combined effect of internal motivation (i.e., whether they want to), external opportunities (i.e., whether they are allowed to), and personal abilities (i.e., whether they can). Motivation is usually regarded as a driving force that directs individuals to exert effort toward achieving a target [24, 25]. Opportunity refers to situational factors that facilitate or hinder a particular behavior [26]. Ability refers to the knowledge and skills required to implement a certain behavior [26]. This framework has been widely used in marketing [23], online bidding strategies [24], knowledge-sharing [27], travelers' social media involvement [28], and local community participation[29, 30].

MOA theory holds that motivation, opportunity, and ability significantly impact individual behavioral decision-making. Given its broad utility, we believe that MOA can also be applied to LCB studies, particularly because the behavior of taking low-carbon actions is essentially a decision-making behavior. A mature theoretical model can help to uncover the underlying relationships between LCB and its influencing factors. In deciding whether or not to adopt LCB, university students' behavioral norms are affected by subjective and objective factors to a certain extent (i.e., adoption MOA). Thus, the MOA framework has good applicability and explanatory power. Based on this theory, this study combines the context of college students with the practice of taking low-carbon actions to build a theoretical model framework that analyzes the influencing factors that drive LCB.

Motivation

Motivation is the driving force behind an action. In this study, we divided motivation into three aspects: perceived risk (PR), enjoyment perception (EP), and low-carbon behavioral intention (BI). Individuals' PR for the environment greatly influences their environmental behavior. Previous studies have found that people who perceive the risks and threats that environmental pollution may bring pay more attention to environmental issues and regulations and are more willing to contribute to a direct reduction in energy consumption and cyclic utilization. EP captures a positive emotional response; that is, participation in LCB enables individuals to obtain enjoyment, pleasure, work achievement, and other hedonic values. Finally, BI refers to one's willingness and degree to make an effort to adopt a certain behavior prior to taking action. Low-carbon behavioral intention positively affects LCB.

Opportunity

Opportunity reflects situational influence, wherein the probability of obtaining a particular result differs under different situational factors. Hence, a difference in circumstances represents a difference in opportunities. In the case of LCBs, some situations are conducive to participation opportunities; for example, the higher the level of situational support (SS), such as accessible recycling facilities and monetary and non-monetary incentives for LCBs, the more consumers are willing to take low-carbon actions. Social norms (SN) can be regarded as external pressures that stimulate individuals to engage (or not engage) in particular actions. These norms can effectively limit or restrict their values and behaviors. In this study, the greater the external pressure one person feels, the stronger their intention to take low-carbon actions. The core of publicity and education (PE) is to create an atmosphere in which society promotes active and effective LCB implementation. Instrumental support for PE positively impacts knowledge dissemination and experience exchange. Media, campuses, and communities can establish close and stable social relations with individuals through long-term, frequent contact, which is conducive to improving their cognition and abilities and establishing more unified values and behaviors.

Ability

Ability generally refers to whether people have sufficient resources (e.g., knowledge, technical, and physical) to direct them toward a set goal. This study defines ability as the low-carbon knowledge (LK) and low-carbon skills (LS) that an individual possesses that can be used to promote willingness to adopt LCBs. Ability relates to "whether I can do it," not "whether I want to do it." People who lack sufficient ability, despite having a strong motivation to engage in LCB, will be limited in the LCB they adopt in the areas of household energy consumption, low-carbon transportation, and green merchandise consumption. When people see themselves as incapable of doing something, they do not commit themselves to that action or even consider it as an alternative.

In conclusion, we extracted eight key MOA elements related to the adoption of college students' LCB to analyze how different configurations of these elements impact LCB implementation among college students. Embedded in the MOA theory noted above, these core mechanisms have led scholars to focus on these elements to investigate ways to achieve the goal of reducing carbon dioxide emissions. Accordingly, we attempt to bridge the aforementioned knowledge gaps by

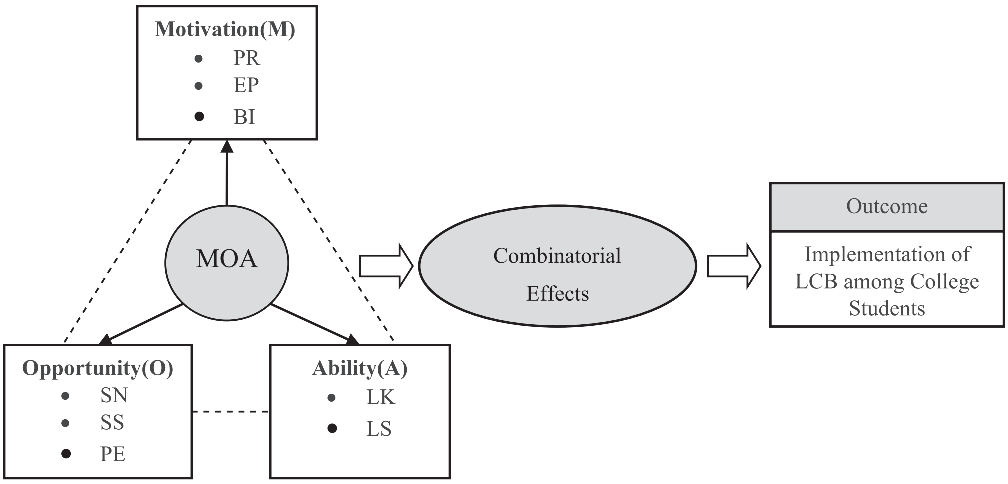

Fig. 1. A configurational theory with MOA framework.

developing an MOA framework based on configuration analyses, which enables us to integrate antecedent variables.

Research Design

Research Method

Based on the MOA framework, this study adopted the *fs*QCA method to achieve its theoretical objectives. As a set-theoretic configurational method, QCA integrates set theory, Boolean algebra, and counterfactual analysis to handle the complex interdependencies among the multiple factors [21, 31, 32]. We selected *fs*QCA instead of conventional regression analysis techniques mainly because it offers a series of analytical advantages relevant to this study.

First, it can identify the antecedent condition configurations that affect the occurrence of individuals' LCB. Existing studies have shown that a single condition rarely adequately explains one resident's LCB. For example, according to the theory of planned behavior, a person's LCB is influenced by multiple factors, including behavioral intention, behavioral attitude, subjective norms, and perceived behavioral control. However, conventional statistical analysis cannot determine which of the many elements that cause LCB to occur are core and peripheral and how they collectively affect the behavior. QCA holds that the outcome is better explained by different combinations of causes and not by any single input factor in isolation (the so-called "multiple conjunctural causation") [33]. Thus, this method is more conducive to a deeper understanding of the differentiated mechanisms that drive college students' LCB implementation.

Second, based on the assumption that multiple configurations of the causal conditions can result in the same outcomes, this method explores the equality between different antecedent configurations. The diversity of low-carbon behavioral choice paths indicates that there may be multiple "equivalent" causal chains for the same behavior path. For example, our study shows that SN (one person with a high degree of conformity to social norms) and SS (one person with a high degree of dependence on social support), along with ~SN (one person with a low degree of conformity to social norms) and ~SN (one person with a low degree of dependence on social support), can all lead to college students' LCB. Equifinality implies multiple pathways to the implementation of LCB among college students, meaning that one student has multiple ways of configuring their MOA factors. However, the traditional statistical analysis method suggests that the variation in the dependent variable is explained only by the substitution or accumulation relation of the independent variable rather than the complete equifinal relation. Therefore, given the characteristic of "all paths lead to the same destination", the QCA method is more suitable to explore the problem of factors affecting LCB among college students compared to traditional statistical analysis.

Third, in this study, we expect the causal factors included in the MOA framework to be combined into complex patterns to achieve LCB implementation among college students. The fsQCA method is well suited to accommodate such complexity because it allows for causal asymmetry between outcomes. Causal asymmetry implies that the absence or presence of an input condition can lead to the same outcome [33]. Regression analysis assumes a linear correlation between variables; therefore, the results of the regression analysis are symmetric. For example, regression analysis has shown that SN positively impacts LCB [9]. Hence, it can be inferred that higher (lower) social norm compliance can lead to a higher (lower) likelihood of LCB implementation. However, under the asymmetric assumption of QCA, even if it can be concluded that the emergence of social norm conditions leads to a higher likelihood of LCB implementation, it cannot be inferred that the absence of social norm conditions leads to a lower likelihood of LCB implementation. In contrast, the assumption of causal asymmetry can better explain the differences between cases and the configuration effects of the interdependence between conditions.

Questionnaire Design

Based on the MOA framework, we designed a questionnaire to collect empirical data and conducted a first-hand investigation. This questionnaire included nine perspectives: perceived risk (PR), enjoyment perception (EP), low-carbon behavioral intention (BI), situational support (SS), social norms (SN), publicity and education (PE), low-carbon knowledge (LK), low-carbon skills (LS), and low-carbon behavioral intention (LCB). A 5-point Likert scale ranging from 1 = "strongly disagree" to 5 = "strongly agree" was used to measure items. While constructing the variables affecting college students' LCB, we ensured that all measurement items referred to the existing study as much as possible. The reliability and validity of the scales must be guaranteed if an existing study is modified according to the actual situation to improve the accuracy and validity of this study.

Sample and Data Collection

The data collection procedure focuses on sampling and data collection techniques. The sampling process comprises several stages: target population, sampling frame, and sample [34]. In the first stage, we defined the target population. Based on the current study's objectives, we chose college students as the target population for several reasons. First, owing to China's special population structure and wide distribution, it is difficult and unrealistic to conduct a complete, complicated, and large project simultaneously. College students come from all over the country, and the sample is representative of the general population. Second, Chinese universities regularly conduct environmental conservation activities every year around World Environment Day and National Energy Saving Publicity Week. College students play a key role in advocating green consumption and promoting green or low-carbon production methods and lifestyles. Third, college students are the most active group in society and a new force for low-carbon environmental protection.

The second step is to select a sampling frame, that is, an accessible section of the target population from which a sample can be drawn. For this study, we selected college students from Xi'an, China. The city was selected as the study area for two reasons. First, as the capital of Shaanxi Province, Xi'an is a hub for Chinese universities and research institutes. The city ranks third for the most college students in China and is one of the three major education and research centers in China. Second, as Xi'an has a high density of universities and the largest number of people receiving higher education in China, it attracts and enrolls college students from all over the country.

In the final stage, we selected a sample from the sampling frame using a well-defined sampling technique – snowball sampling – to ensure the representativeness and generalizability of the sample. We began by identifying several respondents who matched the inclusion criteria, namely, 1) enrolled in universities in Xi'an, 2) had different disciplinary backgrounds, and 3) had different grades. For example, respondents attended Xi'an Jiaotong University, Chang'an University, and Shaanxi University of Science and Technology. Students' subject backgrounds were in different disciplines, such as science and engineering, humanities, social sciences, and others. We then asked them to recommend the survey to others they knew who also met our selection criteria.

After selecting an appropriate sample, we collected data from the population using a questionnaire. Questionnaires were distributed and collected using a professional online survey platform (Wenjuanxing). College students from Xi'an City were invited to complete the survey and forward it to their social circles. To improve the efficiency of questionnaire collection and ensure the authenticity and effectiveness of the data, we confirmed the respondents' grades, whether they were college students studying in Xi'an, the university names, their majors, and other information in the questionnaire. In this way, we screened survey subjects to ensure they met the requirements.

Further, to assess the questionnaire quality, we conducted a pre-survey with 45 college students before the formal investigation in February 2023. While completing the questionnaire, the research team communicated with the college students and obtained effective suggestions. One week after completing the questionnaire, the research team discussed the results, shared suggestions, and revised and improved the items based on respondent feedback and the pre-survey data results. Table 1 lists the variables, items, and references. From March to April 2023, the revised and improved questionnaires were officially distributed through WeChat Moments and WeChat groups. A total of 320 questionnaires were sent to respondents, and 241 valid questionnaires with detailed content were received, with an effective rate of 75.3%. Table 2 shows the descriptive statistics of respondents' characteristics.

Reliability and Validity Analysis

Before applying the *fs*QCA method, we assess the reliability and validity of the questionnaire. Table 3 shows that the Cronbach's alpha values for each variable were greater than 0.7, indicating that the internal consistency and reliability of the questionnaire were satisfactory. In terms of composite reliability (CR), the CR values of each factor were higher than the threshold of 0.7 [19, 45], indicating that the internal consistency

Table 1. Sample characteristics analysis (N = 241).

Characteristics	Category	Frequency	Proportion (%)
Sex	Male	112	46.47%
	Female	129	53.53%
Grade	First Grade	70	29.05%
	Second Grade	64	26.56%
	Third Grade	56	23.24%
	Fourth Grade	45	18.67%
	Other grades	6	2.49%
Discipline	Science and engineering	88	36.51%
	Humanities and social sciences	43	17.84%
	Economic and management	65	26.97%
	Medical science	24	9.96%
	Other disciplines	21	8.71%
Education background	Junior college students	24	9.96%
	Undergraduates	156	64.73%
	Postgraduates	49	20.33%
	Doctoral students	12	4.98%

Table 2. Variables, items, and references in the questionnaire.

Variables	Items number	Items	Sources
Perceived Risk (PR)	PR1	I think environmental problems are becoming more and more serious now.	Qi et al. [7]; Bai and Liu [17]; Sarri et al. [35]; Marquart-Pyatt [36]
	PR2	I think everyone needs to pay attention to environmental issues, and implementing low-carbon behaviors is the social responsibility of everyone.	
	PR3	I am concerned about low-carbon issues mainly to protect the natural environment and ecosystem, and even the survival and development of human beings.	
Enjoyment Perception (EP)	EP1	I am willing to spend some time and energy paying attention to and understanding low-carbon knowledge.	Bai and Liu [17]; Han et al.[37]; Kasilingam [38]
	EP2	The low-carbon behavior I implement will play a role in reducing carbon emissions and protecting the environment and will bring me a high sense of accomplishment.	
	EP3	If I do not implement low-carbon behavior, I will feel guilty.	
Behavior Intention (BI)	BI1	To reduce energy consumption, I prefer to buy products that can be recycled.	Mi et al. [12]; Yang et al. [18]; Jiang et al. [19]; Sarri et al. [35]; Min et al. [39]
	BI2	I am willing to become a low-carbon and energy-saving volunteer at the university or in the community.	
	BI3	I am willing to pay much higher prices and even accept cuts in my standard of living to protect the environment.	
Social Norms (SN)	SN1	Most people around me believe that we should adopt low-carbon and energy-saving measures in our lives.	Wei et al. [1]; Du and Pan [15]; Jiang et al. [19]; Han et al.[37]; Yin and Shi [40]
	SN2	If I litter or do not save water and electricity, I will be condemned by the people around me.	
	SN3	Most college students around me choose low-carbon behaviors in their daily lives and studies.	
Situational Support (SS)	SS1	I can clearly identify which are low-carbon products.	Chen and Li [9]; Sun et al. [41]; Wang et al. [42]
	SS2	I can easily find ways to save water and electricity and travel green.	
	SS3	The facilities around me provide convenient channels for waste recycling.	
	SS4	If there are policy incentives, I will consider implementing low-carbon behaviors.	

Table 2. Continued.

Publicity & Education (PE)	PE1	The media and school have taught me a lot of knowledge and skills about low-carbon methods.	Liu et al. [8]; Yin and Shi [40]; Wang et al. [42]
	PE2	I realized that the environmental problems caused by consumption are becoming more and more prominent, mainly through the media and school publicity.	
	PE3	Understanding the methods and channels of low-carbon behavior is very important for my practice.	
Low-carbon Knowledge (LK)	LK1	I am well aware of the importance of implementing low-carbon practices.	Yang et al, [18]; Min et al, [39]; Frick et al.[43]
	LK2	Here's what I know: opening and closing the refrigerator door frequently increases its power consumption; appliances in standby mode still consume power.	
	LK3	I am very familiar with using low-carbon transportation.	
Low-carbon Skills (LS)	LS1	With my new knowledge of low-carbon, I will soon know how to apply it.	Du and Pan [15]; Kasilingam [38]; Min et al. [39]; Si et al. [44]
	LS2	I can apply the low-carbon or energy-saving tips introduced to others in my own life.	
	LS3	I can develop some life tips that can save energy and reduce emissions.	
Low-carbon behaviors (LCB)	LCB1	If the time is not urgent, I usually take public green transportation rather than private transportation	Wei et al, [1]; Mi et al, [12]; Du and Pan [15]; Bai and Liu [17]; Yang et al. [18]
	LCB2	I often turn off electrical appliances that are not in use, such as dormitory and classroom lights, computer equipment, etc.	
	LCB3	I usually pay more attention to saving water.	
	LCB4	I usually buy energy-saving, green, and environmentally friendly products.	

Table 3. Construct reliability and validity analyses.

Variables	Items number	Factor loading	Cronbach's alpha	CR	AVE
Perceived Risk (PR)	PR1	0.874	0.805	0.813	0.632
	PR2	0.872			
	PR3	0.939			
Enjoyment Perception (EP)	EP1	0.764	0.757	0.786	0.626
	EP2	0.767			
	EP3	0.802			
Behavior Intention (BI)	BI1	0.742	0.812	0.836	0.678
	BI2	0.846			
	BI3	0.903			
Social Norms (SN)	SN1	0.815	0.724	0.798	0.629
	SN2	0.714			
	SN3	0.703			
Situational Support (SS)	SS1	0.954	0.823	0.867	0.702
	SS2	0.803			
	SS3	0.833			
	SS4	0.732			
Publicity & Education (PE)	PE1	0.803	0.732	0.784	0.619
	PE2	0.729			
	PE3	0.748			
Low-carbon Knowledge (LK)	LK1	0.857	0.923	0.901	0.752
	LK2	0.845			
	LK3	0.983			

Table 3. Constinued.

Low-carbon Skills (LS)	LS1	0.788	0.823	0.828	0.696
	LS2	0.837			
	LS3	0.876			
Low-carbon behaviors (LCB)	LCB1	0.845	0.903	0.912	0.784
	LCB2	0.991			
	LCB3	0.861			
	LCB4	0.973			

of the measurement model is high. The factor loadings of all items were not less than the recommended value of 0.5 [12], illustrating that the measurements of the constructs had good indicator reliability. The average variance extracted (AVE) value was larger than 0.5, and the CR value was higher than 0.7, indicating good convergent validity of the constructs.

Variable Calibration

In the *fs*QCA method, each case (including both the conditions and outcomes) was treated as an independent set and had a membership score within these sets. Thus, the initial step before using the fsQCA analysis was to convert each variable into a fuzzy set, also known as "calibration." As mentioned previously, we employed a 5-point Likert scale to calibrate the continuous variables as fuzzy sets. Calibration can be done using two approaches: directly (by identifying three points of membership into a set: "fully in," crossover," and "fully out") or indirectly (classified qualitatively based on theoretical and substantive knowledge) [46, 47]. Based on existing research and considering our measures, we used a direct calibration method to convert the interval scale values into fuzzy sets according to the survey results. The selection of the anchors followed the principles of rationality and transparency. Researchers can refer to existing theories that provide a theoretical basis, to external samples for empirical demonstration, or to choose anchors based on the frequency distribution of the sample data. Based on the above analysis and data distribution characteristics and following the advice proposed by Fiss [21] and Douglas et al. [48], we finally set "5" as a full membership, "4.1" as the crossover point, and "1" as a full non-membership. By setting three thresholds, we converted these values into fuzzy scores ranging from 0 to 1. However, it is worth noting that if a membership score of 0.5 appears in the fuzzy set, we need to add 0.001 to avoid dropping ambiguous cases when calculating the fuzzy set [49].

Table 4. Results of necessary conditions analysis.

Conditions	Consistency	Coverage
PR	0.856	0.829
~PR	0.499	0.836
EP	0.716	0.929
~EP	0.673	0.783
BI	0.869	0.930
~BI	0.546	0.783
SN	0.787	0.911
~SN	0.622	0.811
SS	0.784	0.944
~SS	0.639	0.799
PE	0.798	0.925
~PE	0.617	0.803
LK	0.907	0.874
~LK	0.484	0.815
LS	0.798	0.929
~LS	0.604	0.782

Note: the ~ sign indicates the absence of the condition

Results and Discussion

Results of the Necessary Condition Analysis

The first step in the QCA method involves an analysis of necessity to determine whether any of the conditions are necessary to produce an outcome [50]. Following previous QCA research criteria, we verified whether all individual conditions were necessary to constitute LCB among college students. In QCA, when a certain condition always exists when the result is obtained, it becomes a necessary condition for the result. As an important test standard for necessary condition analysis, consistency measures the extent to which an outcome depends on the presence of one or more conditions [51]. If the consistency value is greater than 0.9, the condition is necessary for the outcome [46, 51]. Table 4 shows the results of the necessary conditions (both in their presence and absence) leading to college students' LCB using *fs*QCA 3.0 software. Only the consistency value of LK was above the threshold level of 0.9; thus, it can be considered necessary for college students to implement LCB. Moreover, the consistency scores of all the other conditions were not higher than 0.9, indicating that no condition was necessary on its own to determine the outcome, which also indirectly indicates that college students' LCB implementation is the result of multiple conditions in the three aspects of MOA. Therefore, it is necessary to further analyze the sufficient conditions for exploring paths for college students' LCBs.

Results of the Sufficiency Analysis

Unlike the above analysis of necessary conditions, causal configuration analysis attempts to reveal the combinations of inputs (as opposed to single sets) that lead to the college students' implementation of LCB. Hence, to reveal the influence mechanism of LCB implementation among college students, the effective configuration of conditions leading to LCB in college students must be further analyzed. In the process of constructing the truth table (i.e., a table that lists all possible combinations of explanatory conditions), we need to define the following criteria to carry out the relevant work: First, configuration consistency captures the degree to which a configuration of conditions is reliable in line with the outcome. However, the acceptable minimum criterion for the configuration consistency threshold may differ. Schneider and Wagemann [52] suggested that the configuration consistency threshold should not be less than 0.75. In addition, the proportional reduction in inconsistency (PRI) is a surrogate measure of consistency in subset relations that can be used to avoid simultaneous subset relations of a given causal configuration in the occurrence and non-occurrence of the outcome. The commonly recommended PRI threshold value is 0.75 [53]. Furthermore, the frequency threshold for the number of cases supporting a given causal configuration associated with an outcome should be determined according to the sample size. For small and medium-sized samples, the frequency threshold is 1, whereas for large samples, the frequency threshold should be greater than 1 [49]. Regarding the sample size of this study and referencing previous research [49], we used a consistency threshold of 0.80, a PRI of 0.9, and a frequency threshold of 3 to collapse the number of sets and create a final solution. The *fs*QCA software provides three sets of solutions: complex, parsimonious, and intermediate. In line with previous studies, we reported intermediate and parsimonious solutions [51].

Table 5 presents eight configurations that lead to the implementation of LCB among college students. Each column represents a distinct configuration for

Table 5. The results of sufficiency analysis.

	Path 1	Path 2		Path 3		Path 4		
Conditions \ Configurations	S1	S2a	S2b	S3a	S3b	S4a	S4b	S4c
PR	•	•	•	•	•	•		•
EP	•	•	⊗	●	●			⊗
BI	•	•	⊗	•	•	●	●	●
SN	⨂	•	•	•	⊗		•	⊗
SS	⊗	●	●	•		•	•	⊗
PE	●	●	●		•	•	•	
LK	•	•	•	•	•	•	•	•
LS	⊗			•	⊗	●	●	●
Raw coverage	0.387	0.572	0.445	0.569	0.567	0.620	0.624	0.428
Unique coverage	0.002	0.004	0.004	0.006	0.005	0.017	0.033	0.014
Consistency	0.993	0.992	0.987	0.989	0.992	0.989	0.981	0.987
Solution coverage	0.711							
Solution consistency	0.973							

Note: The large symbol ● denotes that the core condition (contained in the intermediate and parsimonious solutions) is present; the symbol ⨂ denotes that the core condition is absent; the small symbol • denotes that the peripheral condition (contained in the intermediate solution but not the parsimonious solution) is present; the symbol ⊗ denotes that the peripheral condition is absent. "Blank" suggests that the presence or absence of the condition is not consequential to a particular configuration the outcome. This table illustrates that the consistency level of every single solution (configuration) and overall solution is higher than 0.75, where the overall solution consistency and overall solution coverage are 0.973 and 0.711, respectively. Therefore, the results can be considered informative and worth analyzing. The eight different configurations in Table 5 can be regarded as a combination of sufficient conditions for college students' LCB. In the following sections, we explain below how each of these configurations can lead to the implementation of LCB among college students.

The three conditions in MOA theory were fully reflected in the configuration results. The conditions under the MOA framework interacted to guide college students in participating in low-carbon activities. Among the eight configuration results, seven came from the combination of motivation, opportunity, and ability (S1-S4b), and one came from the combination of motivation and ability (S4c), indicating that none of the three conditions in the MOA can guide high participation behavior alone and that they need to be combined with other conditions. For all configurations, BI and LK were key to LCB implementation among college students. Based on the core and peripheral conditions contained in the eight configurations, we categorized them into four distinct paths to the outcome.

(1) Path 1: PE-driven under motivation-dominant mode. This configuration corresponds to Configuration S1. In this configuration, PE plays a central role, while the three motivational conditions and LK play peripheral roles in producing the outcome. The first configuration for the implementation of LCB among college students is broadly consistent with previous literature in that it shows that PE is one way in which relevant departments mobilize the necessary resources to achieve a high level of LCB implementation.

Although this path is broadly consistent with the results of prior studies that find a positive relationship between PE and BI, our work shows that this relationship is more bounded than is typically acknowledged in the previous research. For example, Path 1 suggests that except for the core condition (PE), all three motivational conditions play a peripheral role, implying that college students engaged in LCB only when it was sufficiently cultivated. To illustrate, one student said, "Publicity activities can help me realize the importance of a low-carbon life on the one hand and inspire me to take the initiative to adopt LCB on the other."

Therefore, even when they do not care about what other people think or favorable external conditions, college students with a high level of motivation and LK supported by PE can quickly adjust their decision-making plans and take effective measures to implement LCB. Accordingly, we label this configuration as "PE-driven under motivation-dominant mode." This configuration emphasizes the importance of PE. On the one hand, PE can be seen as the main channel for college students to obtain information resources such as knowledge and experience. On the other, as a typical social learning method, PE can equip college students with sufficient low-carbon motivation to follow their thoughts and feelings without being concerned about SN or SS, and indirectly promote individual low-carbon practices.

(2) Path 2: Opportunity-pull mode. Configurations S2a and S2b have the same core conditions; that is, SS and PE play a core role in LCB implementation among college students, but there are differences in the peripheral conditions. Compared with other paths, this path emphasizes the core role of opportunity conditions, so we name it the "opportunity-pull mode."

On this path, college students showed a high degree of environmental dependence. Among the three elements of the opportunity dimension, two exist as core variables and one as a peripheral variable, highlighting the importance of external opportunity support. Therefore, opportunities can be regarded as drivers of an individual's motivation and ability, which is an important contribution to the MOA literature. One interviewee said, "Most of us were exposed to the education of low-carbon publicity activities, which affected our behaviors, and our college also provided us with convenient facilities for LCB. These initiatives motivate us to develop the ability and help us learn how to adopt LCB." Our results confirm that these opportunities drive LCB implementation among college students. SS and PE were important antecedents, and both stimulated college students' tendencies to adopt LCB. However, this path had two different configurations.

Configuration S2a presents a completely mutually beneficial feature, that is, college students' MOAs are in an overlapping ecological niche. For this reason, the simultaneous existence of MOA conditions could result in the synergistic and enhanced effects of internal incentives and the external environment. Configuration S2b has slightly different conditions. Although these opportunities motivate students to develop low-carbon abilities, it should be recognized that some college students do not possess sufficient BI or EP. With SS and PE, they are forced to react to controlled motivations and participate in low-carbon practices. Thus, unlike Configuration S2a, the students in Configuration S2b participate in LCB because they are trapped by external environmental pressure and forced to produce the motivation for action.

(3) Path 3: EP-driven under motivation-dominant mode. This mode includes configurations S3a and S3b, which are basically the same. In this mode, college students' perceptions of EP play a core role. Other motivational conditions, including PR and BI, were peripheral conditions. Thus, we label this configuration as "EP-driven under motivation-dominant mode."

In contrast to Configuration S2b, this mode highlights the importance of students' autonomous motivation, which is embodied in the sense of satisfaction, achievement, and pleasure individuals obtain during the process of participating in LCB by their own will [54]. The motivational logic of these students was reflected in one participant's statement, as follows: "I have an obvious perception of risks and threats caused by environmental pollution, which strengthens my intention to participate in LCB. More importantly, such behaviors can bring enjoyment, pleasure, work achievement, and other hedonic values, thus strengthening motivation." This result is consistent with that of earlier research showing that increased autonomous motivation is associated with increased energy-saving behaviors. However, this mode triggers two pathways under different peripheral conditions.

Some college students have a more obvious perception of the risks and threats caused by environmental pollution, which strengthens their intention to participate in LCB. More importantly, such behaviors can bring enjoyment, pleasure, work achievement, and other hedonic values, thus strengthening motivation. This triggered two pathways. One pathway (Configuration S3a) is that some college students can fully understand and make use of the external opportunity conditions and actively master the necessary knowledge and skills to enhance their low-carbon ability, which leads to a greater possibility of implementing LCB. The other pathway (Configuration S3b) is that some college students do not care about SN or SS but rely on specific action knowledge (i.e., knowledge related to individual behavior choices and specific practices or "knowing how to do things") to directly drive their LCB. This result is consistent with the conclusions of Min et al. [39].

(4) Path 4: Ability-push mode. The model consists of three configurations (S4a, S4b, and S4c) in which college students' behavioral intention (a core condition) and LS (a core condition) play a core role, and LK (a peripheral condition) plays a peripheral role. Thus, we label this configuration "ability-push mode."

Path 4 substantially differs from the above three paths, mainly because it emphasizes the important role of LS. In addition to including LK, low-carbon ability emphasizes having the skills to implement LCB. If a person has the will but no ability to engage in LCB, the possibility of successfully carrying out the behavior is very low. Indeed, "wanting to do well" and "being able to do well" work together to actually "do well." Our results are broadly consistent with those of prior studies showing that behavior is driven by both behavioral intention and behavioral ability. Thus, stimulating low-carbon intention alone is insufficient, explaining the discrepancy between intention and actual behavior. Improving college students' low-carbon abilities can help bridge the gap between intention and behavior.

Configurations S4a and S4b are essentially the same, showing that the ultimate likelihood of an individual implementing LCB is closely related to the three elements of MOA, although some conditions may be irrelevant (e.g., perceived enjoyment). Even though LK does not necessarily stimulate low-carbon intentions, it remains an important driving factor in cultivating college students' low-carbon abilities. PE is required in this area. It is worth noting that, in the process of PE, we need to popularize not only the action knowledge (i.e., knowledge related to individual behavior choices and specific practices, or "knowing how to do things"), but also effective knowledge (i.e., knowledge related to the results and benefits of specific actions, or "knowing which method is more effective") [39].

In addition, Configuration S4c shows that in the case of inadequate external infrastructure, even if college students' sense of achievement generated by participating in low-carbon activities is poor and if they do not pay attention to SN, high BI, high LK, and high LS serve as the basis for driving high LCB implementation among college students. These college students do not care about the impact of the external environment when implementing LCBs and do not even derive emotional enjoyment from it. They may be more concerned about the perceived risk of environmental deterioration, which stimulates their willingness to act, complemented by higher LCB ability, thus promoting the adoption of LCB.

Additionally, we analyzed the antecedent conditions affecting college students' LCB using a horizontal comparison involving three dimensions (motivational, opportunity, and ability).

(1) Motivation dimension. PR appeared in all the configurations except for Configuration S4b as a peripheral condition, showing that perceived risk can affect most college students' LCB but not independently. BI existed in Paths 1, 2, 3, and 4, particularly as a core condition in Path 4, indicating that behavior intention can significantly affect college students' LCB and is strongly correlated with college students' LCB. EP was not present in Configurations S2b and S4c, suggesting that the correlation between EP and LCB is poor and needs to be combined with other factors to affect LCB.

(2) Opportunity dimension. SN appeared in Configurations S2a, S3a, and S4b as a peripheral condition not in other configurations, indicating that SN can affect college students' LCB but does not have a strong correlation with it. This situation was similar to that of SS, in which PE appeared as a core condition in configurations S1, S2a, and S2b and a peripheral condition in configurations S3b, S4a, and S4b. This element may or may not be present under other conditions. These findings highlight the importance of PE.

(3) Ability dimension. LK appeared in all configurations as either a core or peripheral condition. LK can significantly affect and be correlated with college students' LCB. While the LS condition appeared in Path 4 as a core condition, the states presented in the other paths did not indicate the importance of a single element. The results show that although mastering LS can affect college students' LCB, even if individuals follow traditional and habitual behavior patterns, LS alone does not affect college students' LCB, and the obstacle effect on LCB is small under the combined effect of other factors.

Furthermore, we identified conditional interactions using configuration analysis. BI and LK existed in the eight configurations simultaneously, and there was a clear complementary relationship between them. BI is based on an individual's beliefs about the potential outcomes of behavior, normative beliefs about others' expectations, and beliefs about the potential constraints of behavior. BI is also the result of attitude, subjective norms, and perceived behavioral control, so it can be seen as an internal driving force for college students' LCB. In addition, LK appeared in eight configurations, acting as a powerful driving factor for college students' LCB. LK provides students with basic theoretical information on LCB. For students familiar with LK, engaging in LCB can be viewed as an exploration based on the solid cognition of low-carbon. College students with a basic understanding of low-carbon issues are more likely to be inspired by curiosity than students who know nothing about them. Therefore, knowledge can change college students' perceptions of how a low-carbon lifestyle meets their psychological or social needs, which, in turn, may lead to changes in individual BI and ultimately affect LCB. Therefore, as motivation and ability factors, BI and LK jointly affect college students' LCB through internal and external interactions.

Robustness Tests

In this study, we conducted a robustness test by adjusting the consistency threshold to ensure the stability of the results [31]. We changed the consistency threshold from 0.80 to 0.9; the other processing methods remained unchanged, and the resulting configuration was consistent. The test showed that the results remain robust.

Conclusions

Research Conclusions

Based on the MOA theoretical framework and equifinal configurations, this study used the *fs*QCA method to identify combinations of college students' motivation, opportunity, and ability linked to LCB implementation among college students. The conclusions of this study are as follows:

(1) The necessity analysis of the influencing factors shows that LK is a necessary condition for college students to implement LCB. However, aside from this, none of the single MOA conditions were necessary for LCB implementation among college students. Variations in MOA conditions can lead to distinct outcome configurations. BI and LK play universal and important roles in LCB implementation among college students.

(2) The combination of MOA conditions resulted in eight configurations affecting the LCB implementation among college students, which can be summarized into four different paths: PE-driven under motivation-dominant, opportunity-pull, EP-driven, and ability-push. Each mode represents different characteristics and coupling paths for implementing LCB among college students.

(3) Among the four modes that achieved LCB implementation among college students, the PE-driven motivation-dominant mode emphasized the linkage and matching of PE as well as motivation conditions. In the opportunity-pull mode, SS and PE played a core role in LCB implementation among college students. College students' EP played a core role in the EP-driven motivation-dominant mode, whereas other motivation conditions, including both PR and BI, were peripheral conditions. In the ability-push mode, college students' BI and LS played a core role, whereas LK played a peripheral role.

Implications for Management

Based on the above research conclusions, we offer the following three recommendations:

(1) The impact of LK on the implementation of LCB among college students was most prominent in the eight configurations. This condition is also necessary to implement LCB among college students. Therefore, popularizing LK should be prioritized. Specifically, universities should strengthen the popularization of general education for LK education. They can open courses, such as introductions to green and low-carbon development and skills, to popularize the basic theory and knowledge of green development for college students of all majors. In addition, universities can mobilize professional teachers and students to establish college associations related to low-carbon or green development and regularly conduct universal education on LK. Simultaneously, the focus of popularizing activities should be on practical knowledge, if possible, rather than only theoretical knowledge.

(2) According to the results, in addition to LK, behavioral intention plays a universal and important role in LCB implementation among college students. Policymakers need to conduct vivid and effective knowledge education activities to enhance college students' internal motivation. For example, colleges can hold knowledge competitions to attract students attention to low-carbon lifestyles. In addition, to more effectively shape a low-carbon lifestyle on campuses, universities can post advertisements or put up posters about low-carbon lifestyles in public places, while ensuring that the content includes practical tips and attractive benefits of low-carbon living. Furthermore, knowledge can be integrated into social scenarios for different groups (e.g., college students and community residents). For example, for printing work, it is necessary to use the "double-sided printing" function to use both sides to save paper. We can also use slogans to send messages about the environmental pollution caused by paper waste. In addition, given the linkage effect with BE, we should reduce the time and effort required to participate in LCB.

(3) Given the significant role of PE and PR in LCB implementation among college students, the idea of low-carbon consumption should be publicized to promote the public's awareness of the need for environmental protection. In addition to strengthening propaganda on low-carbon through new or traditional media, universities should provide more intuitive education and increase publicity to draw attention to the benefits generated by being involved in low-carbon consumption. For example, one respondent explained that his university proposed the concept of green consumption, which combines the benefits of consumption with the benefits of protecting the human living environment when individual consumption is carried out. On the one hand, this PE activity used posters to demonstrate the benefits of low-carbon consumption. On the other, it continuously strengthened the dissemination of effective knowledge of "methods that lower carbon emissions," and achieved the expected effect. Furthermore, enhancing college students' environmental risk perception can be incorporated into PE activities. For example, pictures or videos can be used to convey problems such as environmental pollution and rising temperatures triggered by non-green consumption behavior. It is essential to convey information that helps a person perceive the risks and threats of environmental pollution and enhances their positive emotional feelings when engaging in LCB.

(4) This study found that different paths are linked to LCB implementation among college students. However, in addition to the abovementioned factors, we need to consider other factors in different contexts. For example, for college students whose focus is not on emotional enjoyment, colleges and other institutions should pay more attention to the construction of convenient measures or the promotion of LS. For college students who focus on emotional enjoyment, improving their PR or BI is an effective way to promote LCB implementation.

Research Limitations and Future Prospects

It must be noted that this study has several limitations that require further improvement in future research. Although the MOA theoretical analysis framework covers a variety of influencing factors, it may not be sufficiently comprehensive. The framework does not include social institutions, culture, institutional changes, governance structures, or other influencing conditions [55]. Thus, the role and influence of these conditions on the implementation of LCB should be discussed in the future. In addition, owing to the availability of data, more than 200 students from a dozen universities in Xi'an City were used as samples in this study, which may have affected the external validity of the conclusions. In the future, more data from college students at other universities or from residents across the country should be collected to analyze multiple equifinal pathways to outcomes.

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Conflict of Interest

The authors declare no conflict of interest.

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