Research article

Emotional design for pro-environmental life: Visual appeal and user interactivity influence sustainable consumption intention with moderating effect of positive emotion

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ABSTRACT

As the public pursues sustainable consumption patterns, pro-environmental mobile applications are being developed to promote green lifestyles. Ant Forest has attracted a large number of users to participate due to its gamified interactive design. The objectives of this study are to understand the process by which visual appeal and user interactivity in pro-environmental mobile applications influence the user's sustainable consumption intention and to analyse the moderating effect of the user's positive emotion on this process. The researchers constructed a theoretical framework based on the Stimulus-Organism-Response (S-O-R) theory in this study and used the Partial Least Squares Structural Equation Modelling (PLS-SEM) for quantitative analysis with an online questionnaire survey of 586 Ant Forest users. Findings for this study include: 1) Visual appeal shows a large positive effect on the perceived usefulness of Ant Forest; 2) Ant Forest's perceived usefulness shows a significant positive effect on the user's sustainable consumption intention; 3) Ant Forest's perceived usefulness fully mediates the relationship between visual appeal and the user's sustainable consumption intention; 4) Positive emotion moderates the relationship between perceived usefulness and sustainable consumption intention. This study improves the application of the S-O-R theory in emotional design research, while emphasising the importance of optimising the visual appeal of design elements and guiding users' positive emotions in the development of pro-environmental mobile applications. The findings of this study highlight the importance of incorporating positive emotions into visual design for designers and developers of pro-environmental applications, further clarifying the focus of emotional design.

1. Introduction

At the end of the twentieth century, consumers began to seek more ways to maintain sustainable consumption as the impact of consumption patterns on sustainable development gradually attracted public attention [1]. Only 9 % of sustainability experts agree with the current state of sustainable consumption, while 59 % disagree, making sustainable consumption the second most pressing Sustainable Development Goal (SDG) (after climate action) [2]. In order to achieve sustainable consumption, the application of renewable energy and energy storage is very important, along with reducing transportation emissions and resource waste, collecting, sorting and reusing waste [2].

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Research on sustainable consumption is gradually shifting from an environmental impact-centred approach to a consumer-centred approach, which views consumers' overall sustainable behaviour and its impact from the perspective of the earth, humanity, and profit [3]. Meanwhile, the popularity of mobile technologies has attracted a large number of visionary developers to turn to them, helping to eliminate knowledge gaps, alleviate poverty and improve the environment with gratifying results [4].

To this end, Ant Forest has established China's most influential Internet pro-environmental project to promote sustainable consumption and green lifestyles [5]. As a social media mobile application operated by a fintech company, Ant Forest has built a pro-environmental-themed online community and has attracted more than 550 million users to participate in the interaction as of 2020 [6].

Ant Forest sets up carbon accounts for users in the mobile application, and transforms the process of users practising pro-environmental behaviours into the process of planting a virtual tree in a gamified scene [7]. Most of the sustainable consumption in users' daily lives is included in these pro-environmental behaviours, including renting shared bicycles, using electronic invoices, paying for public transportation, purchasing green products, etc. [8]. Such an intuitive design allows users to instantly understand their contribution to environmental protection after completing their daily sustainable consumption, thereby encouraging them to try more low-carbon lifestyles [8]. After gaining public recognition, Ant Forest continued to add advanced functions such as Ant Manor, Protected Areas, and Ocean Cleaning to improve users' interactive experience [10].

Cognitive and emotional experiences proved to be important factors in users' continued interaction with Ant Forest [11]. The combination of digital interactive applications and social innovation marketing models embeds sustainability into individuals' daily decisions and consumption behaviours [12]. In Ant Forest, the environmental goals that users need to achieve are designed as a cartoon tree, and the rewards for completing pro-environmental behaviours are designed as green energy balls, which attract users to continue to participate as gamified design elements [6] (Fig. 1). Interaction with virtual objects and interaction with other users stimulates users' positive emotions towards nature in such an interactive environment full of cartoon appeal [13]. Users' environmental enthusiasm and perceived usefulness indirectly promote sustainable consumption through their perceived value and usage stickiness [14].

Although developers and designers have used techniques such as gamification to increase user engagement in mobile applications, the mechanisms and consequences of these techniques need to be further studied [15]. In such mechanisms, how visual appeal stimulates users' aesthetics and is associated with their pleasure and arousal deserves researchers' attention [16]. Visual graphic design and navigation interactivity together constitute the usability of Internet applications, but a unified evaluation model has rarely been mentioned by previous researchers [17]. In addition, past studies have overemphasised the functions of mobile applications and ignored the role of emotional factors [18].

Therefore, the researchers clearly stated the objectives of this study.

(1) To examine the effects of visual appeal and user interactivity on users' sustainable consumption intentions in Ant Forest.
(2) To test the role of Ant Forest's perceived usefulness in the above influence process.
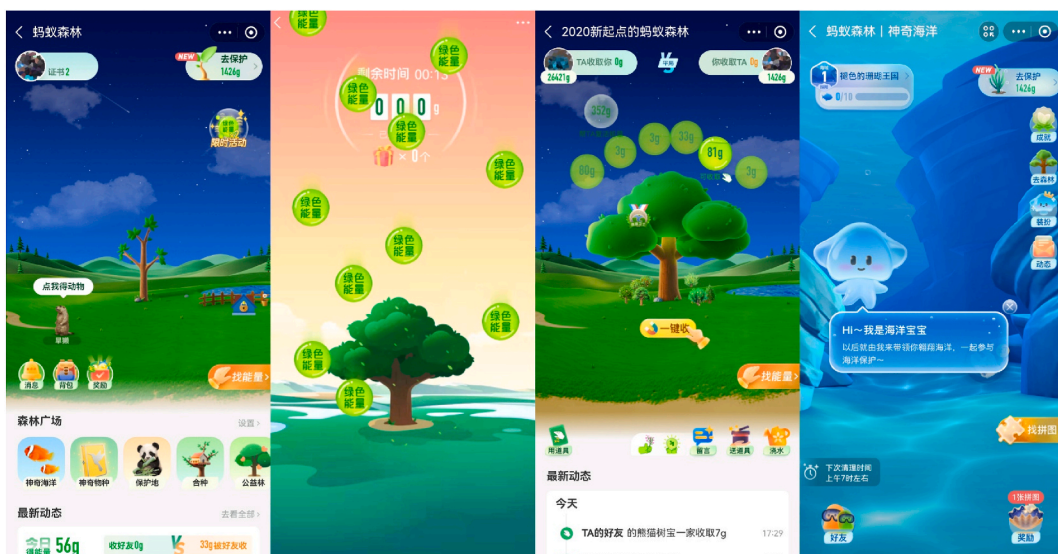(3) To understand the moderating effect of positive emotion on Ant Forest interaction design.

Fig. 1. Ant Forest's user interface (Screenshots from researchers' mobile devices).

2. Literature review

2.1. Emotional design in pro-environmental mobile application

Mobile applications in the form of new media make it easier to change the attitudes, behaviours, and habits of modern consumers, making them more receptive to pro-environmental behaviours [19]. Intuitive design and ease of use combined with smart data-driven mobile applications inspire and promote large-scale public participation in sustainable actions in local urban communities [20]. Meanwhile, these mobile applications provide ecological feedback as reminders of the resources consumed by users, with the ultimate goal of promoting pro-environmental behaviours by making users aware of the impact of consumption on the environment [21].

With the development of science and technology, mobile interactive applications are no longer simply physical forms, but bridges for social communication, and are endowed with more emotional connotations [22]. The principles for implementing emotional design in mobile applications include concise and easy-to-recognize graphics, clear and reasonable layout at the visual level, and effective functions and timely feedback at the behavioural level [23]. Ant Forest has become a prominent representative among these pro-environmental mobile applications and is operated by Alipay, a large Chinese fintech company [24]. The gamified user experience provided by Ant Forest combines visual appeal, embedded rewards, interface operations and social interaction [25]. These experiences can ultimately be attributed to visual appeal based on visual feelings and user interactivity based on behavioural feelings.

2.2. Visual appeal in mobile application design

Visual appeal is described as a crucial feature of interactive applications that provides users with a pleasant experience through visual elements such as pictures, colours, fonts, shapes, etc. [26]. In addition, visual appeal is considered to be the user's perception of the aesthetics of interactive applications [27]. The design aesthetics in mobile applications are proven to have a positive effect on functionality, perceived value, and emotion [28]. Furthermore, the aesthetic appeal of a mobile application interface also has a positive effect on its visual quality [29].

In mobile application design, visual appeal effectively influences engagement and continuation intention in the user experience [30]. In Ant Forest, the main user experience comes from its gamified definition of users' pro-environmental behaviours and goals, and their display in the form of visual symbols. The gamified cartoon design elements in Ant Forest ensure the consistency of the overall style, thereby enhancing its visual appeal [31]. As a mobile environmental stimulus, visual appeal affects consumers' emotions and then their consumption intentions [32].

2.3. User interactivity in mobile application design

Interactivity in digital entertainment provides users with an attraction that transcends traditional user experiences of passive isolation [33]. Interactivity, cooperation and competition have positive effects on the services of pro-environmental mobile applications [34]. User interactivity includes various forms of people and people, people and devices, people and data, and people and algorithms, all of which have been proven to be closely related to user engagement [35]. The combination of user interactivity and design elements in mobile applications forms an overall interactivity combined with user-customised information to create a rich flow experience [36].

Interactivity is an important part of Ant Forest as a gamified information system [37]. In Ant Forest, users can cooperate and compete with friends, control devices to complete collections, accumulate sustainable consumption rewards, and complete the exchange of virtual and real trees, which covers the diverse forms of user interaction mentioned above [9]. This indicates that the interactivity of Ant Forest includes human-computer interaction and interpersonal interaction, both of which promote the perceived interest of Ant Forest and help increase user loyalty [38]. In addition, the interactivity perceived by users stimulates users' psychological intentions in the dimensions of controllability and playability, thereby affecting their behavioural intentions [39].

2.4. Perceived usefulness in Ant Forest

Perceived usefulness refers to the degree to which interactive technology is considered easy to use and control in Ant Forest, it makes users more aware of the value of the system [24]. The gamified interaction of Ant Forest not only brings users a happy experience, but also enhances their awareness of the usefulness of Ant Forest [14]. The perceived usefulness of Ant Forest is a determining factor in measuring user retention intention [40]. In research on mobile applications, perceived usefulness has been shown to be effective feedback from users on their interactive experience [41]. Furthermore, the perceived usefulness of the content and information presented in the application enriches and enhances users' perceived value [42].

2.5. Positive emotion in pro-environmental

Emotion drives human behaviour; it can make humans aware of the urgency of environmental protection and provide motivation to engage in pro-environmental behaviour [43]. Emotional factors in interaction design play an important role in arousing various positive emotions in users, including a sense of accomplishment, satisfaction, awe, flow and other psychological experiences [44]. The emotions generated by aesthetically based design elements are important for understanding how users form higher-level judgements such as appeals and perceived quality [45]. The pride generated by adopting pro-environmental technologies spills over into users'

pro-environmental behaviours in social business [46]. Furthermore, positive emotions are considered to mediate the relationship between motivation and engagement in psychological research [47].

2.6. Sustainable consumption in Ant Forest

A scenario that highly integrates sustainable consumption with gamified interaction is applied in Ant Forest [48]. The guidance on sustainable consumption is unique in Ant Forest. Ant Forest does not directly guide users to consume through the mobile application itself, but it helps them record the achievements brought about by sustainable consumption [1]. Ant Forest is actually green marketing around a sustainable consumption lifestyle, but it is also a concrete manifestation of corporate social responsibility in green public welfare [49]. Although Ant Forest represents the overall interests of the fintech company behind it, it has many potential roles in sustainable development, such as carbon emission reduction, land restoration, poverty alleviation, and the promotion of public health [50].

3. Theoretical Foundation and hypotheses development

3.1. Theoretical foundation

The Stimulus-Organism-Response (S-O-R) theory was proposed by Mehrabian and Russell [51] and was used to study consumer behaviour in previous research [52]. With the rapid development of mobile applications, the S-O-R theory has been applied in research related to mobile application design and user intentions [53]. The S-O-R theory shows good adaptability in the studies of aesthetic form and attractiveness of mobile applications [16]. Key attributes of interactive programmes such as aesthetics, interactivity, customisation, and ease of use are often verified together with users' engaging intention and behaviour through the S-O-R theory [54]. In addition, interactivity in mobile applications is also well explained by the S-O-R theory, especially involving users' positive emotional responses [55].

In this study, visual appeal and user interactivity are generally recognised as combined visual and behavioural stimulation and are used side by side in the S-O-R theory [26,56]. Therefore, this study applies visual appeal and user interactivity as 'Stimulus (S)' variables in the S-O-R theoretical framework. In the study of emotional interactions based on the S-O-R theory, the perceived usefulness of information as feedback to the organism is incorporated into the theoretical framework [57]. Therefore, this study applies perceived usefulness as the 'Organism (O)' variable. Furthermore, the user's sustainable consumption intention is usually applied as the 'Response (R)' variable in the S-O-R theoretical framework [58,59].

Based on the moderating role of positive emotion in the relationship between motivation and participation explained in the literature review above, the research applies it as a moderating variable in the theoretical framework. Therefore, a complete theoretical framework is assembled in this study (Fig. 2). The researchers classify direct-effect hypotheses and indirect-effect hypotheses as follows.

3.2. Direct-effect hypotheses

When a website's visual information is well organised, users rate the website as more attractive, and also rate it as easier to use and more useful [60]. The immersive experience brought by Internet interactive technology increases the perceived usefulness and enjoyment of potential consumers, while also stimulating their curiosity [61]. In addition, visual appeal and anthropomorphism determine users' utilitarian attitudes towards smart voice assistants [62]. Therefore, the researchers put forward the following hypothesis.

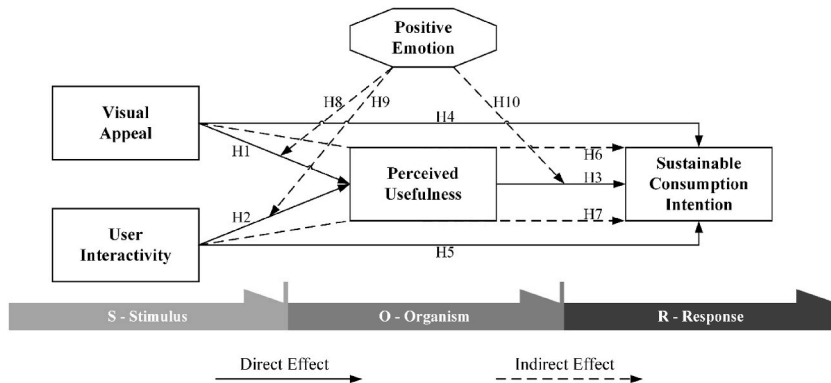**H1**.   Visual appeal positively influences perceived usefulness in Ant Forest.

Fig. 2. Theoretical framework of this study.

In massive open online courses, the operability of interface design is an important observation indicator of the perceived usefulness of the course, and its path coefficient is statistically significant [63]. System interactivity in e-learning is shown to have a positive and significant effect on perceived usefulness [64]. Moreover, website interactivity enhances users' perceptions of the usefulness and ease of use of online retail websites [65]. Therefore, the researchers put forward the following hypothesis.

H2. User interactivity positively influences perceived usefulness in Ant Forest.

The perceived usefulness of a brand's social media has a positive effect on its users' consumption intentions [66]. Perceived usefulness has a significant positive effect on users' continued and orderly use of shared bicycles in China [67]. The findings also show similar results in the study of the U.S. public's acceptance of self-driving cars [68]. Therefore, the researchers put forward the following hypothesis.

H3. Perceived usefulness positively influences the user's sustainable consumption intention in Ant Forest.

On a brand's website, visual appeal plays an important role in predicting business customers' purchasing impulses [69]. Virtual and augmented reality technologies provide pre-experiences with hotels so that consumers perceive visual appeal, thereby positively influencing their booking intentions [70]. Information posted on social media usually relies on visuals to generate emotional appeals, which are most effective in driving consumers' purchase intentions [71]. Therefore, the researchers put forward the following hypothesis.

H4. Visual appeal positively influences the user's sustainable consumption intention in Ant Forest.

In a study of live broadcast cases in China, interactivity has been proven to have a significant positive effect on viewers' behavioural intentions [72]. Augmented reality technology encourages consumers' exploratory behaviour by enhancing interactivity and directly influencing their purchase intentions [73]. Furthermore, the interactivity of social media communities for brand marketing has a positive effect on consumers' brand attitudes, brand loyalty, and purchase intentions [74]. Therefore, the researchers put forward the following hypothesis.

H5. User interactivity positively influences the user's sustainable consumption intention in Ant Forest.

3.3. Indirect-effect hypotheses

For consumer electronics products, interface and product form aesthetics have positive effects on consumers' purchase intentions through the intermediary of sustainable perceived value [75]. The positive effect of anthropomorphic advertising images on consumers' reactions is mediated by consumer attitudes [76]. Furthermore, visual aesthetics showed a correlation with perceived value, which in turn had a positive effect on sustainable consumption intentions in the case study of smartwatches [77]. Therefore, the researchers put forward the following hypothesis.

H6. Perceived usefulness positively mediates the relationship between visual appeal and the user's sustainable consumption intention in Ant Forest.

E-commerce combined with social media enhances perceived value by increasing interactions among users, thereby increasing their purchase intention [78]. In the context of live shopping, experience-centred shopping orientation plays a mediating role between social interaction and shopping intention [79]. In addition, perceived usefulness mediates the relationship between perceived ease of use and users' payment behaviour in mobile payment systems [80]. Therefore, the researchers put forward the following hypothesis.

H7. Perceived usefulness positively mediates the relationship between user interactivity and the user's sustainable consumption intention in Ant Forest.

Emotion plays an important role in the process of influencing users to form higher-level judgements based on aesthetic design factors [45]. Intrinsic and extrinsic visual cues show significant effects on healthy food consumers' positive emotions and hedonic perceptions [81]. In addition, website visual appeal, perceived ease of use, and positive emotions show comprehensive relationships with consumers' online consumption impulses in e-commerce [82]. Therefore, the researchers put forward the following hypothesis.

H8. Positive emotion positively moderates the relationship between visual appeal and perceived usefulness in Ant Forest.

The research results on social media show that positive emotion is an important variable influencing attitude, and attitude influences the user's social interaction [83]. Internet content that amplifies emotions has an effect on information dissemination and interaction, which leads Internet users who express more positive emotions to have a more positive attitude towards Internet products [84]. From the perspective of people with positive emotions, interactivity is more beneficial for interface evaluations of media content and website attitudes [85]. Therefore, the researchers put forward the following hypothesis.

H9. Positive emotion positively moderates the relationship between user interactivity and perceived usefulness in Ant Forest.

For upcycled products, emotional value has a significant positive effect on product attitude and purchase intention [86]. The propensity to trust positively moderates the relationship between perceived usefulness and ease of use on e-wallet usage intentions [87]. Furthermore, health awareness positively moderates the relationship between perceived usefulness and users' satisfaction with health mobile applications [88]. Therefore, the researchers put forward the following hypothesis.

H10. Positive emotion positively moderates the relationship between perceived usefulness and the user's sustainable consumption intention in Ant Forest.

4. Methodology

4.1. Research design

In order to verify the above theoretical framework, this study applied quantitative survey research methods and completed an online questionnaire survey using China's largest online questionnaire platform, 'Wenjuanxing.' [89] As an online platform, Wenjuanxing enables sampling to cover a wider range of geographical locations and living backgrounds with high validity [90]. The online questionnaire generated by the Wenjuanxing platform was quickly shared through WeChat, China's largest Internet instant messaging application, to ensure rapid dissemination among different social communities [91]. In addition, SmartPLS software further ensures the reliability and validity of this data analysis due to its expertise in the field of social science research [92].

Ant Forest has more than 550 million users in China [93]. Therefore, a sufficient sampling number must be ensured in quantitative research to improve the accuracy of the results [94,95]. This study applied the 'n = $z^2\sigma^2/e^2$' formula to calculate the minimum sampling size for an extremely large sampling population of 505 people [96] (Table 1). In order to ensure that the sampling results represent the overall situation of Ant Forest users as much as possible, the online questionnaires were asked to be spread out as much as possible in terms of gender, age and region when distributed through the Internet.

In the specific process of the online survey, Wenjuanxing platform widely recruited respondents from all over China based on the above requirement of the researchers, and maintained the anonymity of the respondents to ensure their personal rights. From the gender, age and regional population distribution ratio presented in the final data, the results of this sampling are basically in line with the demographic of Chinese mobile users [97,98]. Since the users of Ant Forest are mainly Chinese, the questionnaire was translated into Chinese, then distributed, and the collection of answer sheets was completed before January 2024. At the beginning of the questionnaire, the researchers set filtering questions to ensure that participants had experience using Ant Forest. In addition, the limitation of such questionnaires is mainly because the self-report method may lead to bias in the results.

4.2. Data collection and analysis

The questionnaire for this study consists of six parts, including demographic information (age, gender, education, and use of Ant Forest) and items corresponding to the five variables in the theoretical framework (Table 2). All survey items were developed from previous research and reviewed by three relevant field professionals. Some items are deleted because there are no relevant attributes in Ant Forest (such as equipment and products). The items are rated on a 'five-point Likert scale' (1 for strongly disagree, 5 for strongly agree) [99]. Before being officially used, the researchers organised a pilot study with 50 Ant Forest users. However, due to the relatively single source of users, the results are not included in the final result analysis. The Cronbach's Alpha values of all variables in the pilot study are higher than 0.70, proving that they have sufficient reliability.

This survey received responses from 603 participants, 586 of which were ultimately deemed valid due to complete answers, while the questionnaires from respondents who had not used Ant Forest were automatically eliminated by the survey platform. The overall demographic information of the participants is shown in Table 3.

5. Results

5.1. Measurement model

The Partial Least Squares Structural Equation Modelling (PLS-SEM) is used in this study, and Smart-PLS 4.0 software is used to analyse the results. The measurement model shows the convergent validity of all variables and items, which includes Factor Loading (FL), Cronbach's Alpha (CA), Composite Reliability (CR) and Average Variance Extracted (AVE) [102]. According to the measurement standards proposed by Hair et al. [102], the fact loading values of all survey items, also known as Indicator Reliability (IR) are greater than 0.708 in this study, the CA and CRvalues of all variables are greater than 0.7, and the AVE values are greater than 0.5, which shows the reliability of items and variables (Table 4). Visualised data is presented in Fig. 3.

Two criterions are used to test the discriminant validity of variables to ensure the rigour of the results: the Fornell & Larcker criterion and the heterotrait-monotrait (HTMT) criterion. In the Fornell & Larcker criterion, the square root of each variable's AVE has

Table 1
The Calculation of sampling size (adopted from Leavy, 2017).

n = $z^2\sigma^2/e^2$	
n	The size of the sample
z	The value of the standard normal variable at a given confidence level (1.96 for a 95 % confidence level)
σ	The standard deviation of the population (the standard deviation of the variable with the greatest variance has been taken)
e	The acceptable error (it is assumed to be 0.15)
Result: n = $(1.96)^2(1.72)^2/(0.15)^2 = 505.11 \approx$ **505**	

Table 2
List of Constructs, Codes, items and sources.

Constructs (Variables)	Item Codes	Questionnaire Items	Source
Visual Appeal (VA)	VA1	Ant Forest has generated an attractive experience.	[26]
	VA2	The design in Ant Forest is visually appealing.	
	VA3	The virtual environment in Ant Forest is quite attractive.	
	VA4	The Ant Forest provides an easy way to experience the virtual environment.	
	VA5	I found the virtual environment in Ant Forest visually appealing.	
User Interactivity (UI)	UI1	I am able to interact with Ant Forest.	
	UI2	I can operate Ant Forest without difficulty.	
	UI3	I interact with Ant Forest in various ways.	
	UI4	Ant Forest reacts quickly to my operation.	
	UI5	Using pro-environmental operations in Ant Forest helps me make decisions quickly.	
Perceived Usefulness (PU)	PU1	The information I get from interactions in Ant Forest is useful.	[57]
	PU2	The interaction in Ant Forest allows me to better understand purchase goals.	
	PU3	The interaction in Ant Forest enables me to make purchase decisions faster.	
	PU4	The information I get from interaction in Ant Forest is updated timely.	
Sustainable Consumption Intention (SCI)	SCI1	I will definitely consider buying a sustainable product.	[100]
	SCI2	I will prioritize a sustainable product when online shopping.	
	SCI3	I feel like buying a sustainable product.	
	SCI4	I will recommend a sustainable product to the people around me.	
Positive Emotion (PE)	PE1	I feel happy when viewing the contents in Ant Forest.	[101]
	PE2	I feel pleased when viewing the contents in Ant Forest.	
	PE3	I feel joyful when viewing the contents in Ant Forest.	
	PE4	I feel excited when viewing the contents in Ant Forest.	
	PE5	I feel delighted when viewing the contents in Ant Forest.	
	PE6	I feel satisfied when viewing the contents in Ant Forest.	

Table 3
Survey demographic Profile.

Category		Total (n = 586)	
		Frequency	Percentage
Age	18–29	177	30.20
	30–39	164	27.99
	40–49	111	18.94
	50–59	59	10.07
	60–69	55	9.39
	70–79	20	3.41
	80 & above	0	0
Gender	Male	282	48.12
	Female	304	51.88
Education	Below High School	27	4.61
	High School	145	24.74
	Undergraduate	332	56.66
	Postgraduate	82	13.99
Ant Forest Usage Duration	Below 1 month	178	30.38
	1 month–5 months	161	27.47
	6 months–1 year	152	25.94
	Above 1 year	95	16.21
Ant Forest Usage Frequency	Every few days	187	31.91
	Once per day	295	50.34
	Several times per day	104	17.75
Achievement in Ant Forest	Never collected 'green energy'	86	14.68
	Collected 'green energy' but never completed a planting	175	29.86
	Completed a planting	205	34.98
	Complete multiple plantings	120	20.48

a greater value than the correlations with other latent variables [103] (Table 5). In the HTMT criterion, the values of all scales are lower than 0.9 [104] (Table 6). Both of the above two criterions verify the discriminant validity of the variables in the theoretical framework.

5.2. Structural model

Among the direct-effect hypotheses, H1, H3, and H4 are accepted because their *P*-Values are all less than 0.05 and their β-Value values were positive [102]. The *T*-Values of these hypotheses are all greater than 1.96, indicating that they are significant at the 95 % confidence level [105]. In addition, among the accepted hypotheses, the f^2 value of H1 was judged to be large, the f^2 value of H3 was

Table 4
The results of measurement model.

Construct (Variable)	Item Code	FL (IR)	CA	CR (rho_a)	CR (rho_c)	AVE
Visual Appeal (VA)	VA1	0.920	0.939	0.940	0.954	0.805
	VA2	0.913				
	VA3	0.901				
	VA4	0.909				
	VA5	0.840				
User Interactivity (UI)	UI1	0.955	0.976	0.984	0.981	0.914
	UI2	0.967				
	UI3	0.965				
	UI4	0.977				
	UI5	0.915				
Perceived Usefulness (PU)	PU1	0.785	0.826	0.828	0.885	0.658
	PU2	0.833				
	PU3	0.834				
	PU4	0.791				
Sustainable Consumption Intention (SCI)	SCI1	0.852	0.847	0.855	0.897	0.686
	SCI2	0.845				
	SCI3	0.776				
	SCI4	0.837				
Positive Emotion (PE)	PE1	0.900	0.945	0.950	0.956	0.785
	PE2	0.927				
	PE3	0.875				
	PE4	0.834				
	PE5	0.907				
	PE6	0.871				
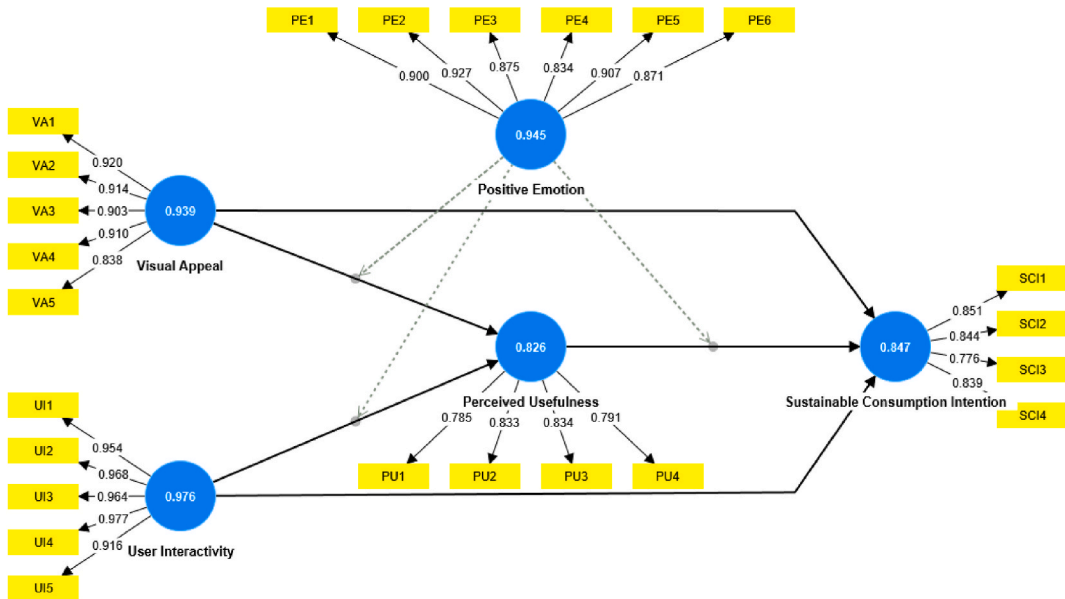
Fig. 3. The measurement model of this study (with factor loadings and Cronbach's Alpha).

Table 5
Discriminant validity (Fornell-Larcker criterion).

	VA	UI	PU	SCI	PE
VA	0.897				
UI	0.454	**0.956**			
PU	0.634	0.253	**0.811**		
SCI	0.532	0.275	0.571	**0.828**	
PE	0.474	0.686	0.220	0.330	**0.886**

Table 6
Discriminant validity (HTMT criterion).

	VA	UI	PU	SCI	PE	PE x VA	PE x UI	PE x PU
VA								
UI	0.473							
PU	0.717	0.277						
SCI	0.593	0.299	0.676					
PE	0.500	0.713	0.243	0.365				
PE x VA	0.197	0.105	0.149	0.208	0.024			
PE x UI	0.119	0.383	0.064	0.020	0.078	0.461		
PE x PU	0.140	0.048	0.031	0.170	0.017	0.712	0.263	

Table 7
The results of direct-effect hypotheses testing.

Hypotheses/Relationships	β-Value	Std. Bev	*T*-Value	*P*-Value	Decision	f^2	Effect Size
H1: VA - > PU	**0.678**	0.041	16.497	**0.000**	**Accept**	**0.535**	**Large**
H2: UI - > PU	0.051	0.049	1.001	0.317	Reject	0.002	None
H3: PU - > SCI	**0.424**	0.054	7.858	**0.000**	**Accept**	**0.176**	**Medium**
H4: VA - > SCI	0.179	0.055	3.280	**0.001**	**Accept**	0.025	Small
H5: UI - > SCI	−0.021	0.051	0.392	0.695	Reject	0.000	None

judged to be medium, and the f^2 value of H4 was judged to be small [106]. The complete data is presented in Table 7.

According to the analysis results, visual appeal is proven to have a positive and significant influence on perceived usefulness, and the effect is large. Perceived usefulness has a positive and significant influence on sustainable consumption intention, and the effect is medium. Visual appeal has a positive and significant influence on sustainable consumption intention, and the effect is small.

Among the indirect-effect hypotheses, H6 and H10 are accepted (Table 8). This indicates that perceived usefulness positively mediates the relationship between visual appeal and the user's sustainable consumption intention. And positive emotion positively moderates the relationship between perceived usefulness and the user's sustainable consumption intention.

The researchers further used the Variance Accounted For (VAF) criterion to measure the mediating effect of perceived usefulness. Table 9 shows the criterion proposed by Hair Jr. et al. [107]: no mediation (VAF <20 %), partial mediation (20 %≤VAF≤80 %), and full mediation (VAF >80 %). The mediating effect of perceived usefulness on the relationship between visual appeal and the user's sustainable consumption intention can be judged as full mediation.

In addition, the researchers applied the simple slope analysis method to detect the moderating effect of positive emotion on the relationship between perceived usefulness and sustainable consumption intention [108]. The slope of the rising line in Fig. 4 shows a gradually increasing trend, which means that the moderating effect of positive emotion increases with its own increase.

In summary, Fig. 5 shows the complete status of the structural model of this study. Furthermore, the value of R^2 for perceived usefulness and sustainable consumption intention as endogenous variables does not reach 0.5, which can be measured as reaching a medium level [102]. This shows that the factors that trigger Ant Forest's perceived usefulness and users' sustainable consumption intentions are not limited to visual appeal and user interactivity. In addition, the researchers also verified the model fit using the Normed Fit Index (NFI), which is considered to have a good fit once its value exceeds 0.9 (Table 10) [109].

6. Discussion

Based on the quantitative analysis results above, the researchers summarised the discussions, which include: 1) Visual appeal shows a large positive effect on the perceived usefulness of Ant Forest, but user interactivity unexpectedly shows no significant effect; 2) Ant Forest's perceived usefulness shows a significant positive effect on the user's sustainable consumption intention; 3) Ant Forest's perceived usefulness fully mediates the relationship between visual appeal and the user's sustainable consumption intention; 4) Positive emotion moderates the relationship between perceived usefulness and sustainable consumption intention, and the moderating effect will be improved as positive emotion increases. More detailed discussions are carried out below.

First, visual appeal is considered the most important feature of the Ant Forest interactive system, which integrates visual elements

Table 8
The results of indirect-effect hypotheses testing.

Hypotheses/Relationships	Indirect Type	β-Value	Std. Bev	*T*-Value	*P*-Value	Decision
H6: VA - > PU - > SCI	Mediation	**0.288**	0.042	6.795	**0.000**	**Accept**
H7: UI - > PU - > SCI	Mediation	0.022	0.021	0.987	0.324	Reject
H8: PE x VA - > PU	Moderation	−0.006	0.042	0.137	0.891	Reject
H9: PE x UI - > PU	Moderation	0.036	0.043	0.788	0.431	Reject
H10: PE x PU - > SCI	Moderation	**0.098**	0.031	3.133	**0.002**	**Accept**

Table 9
The VAF Value of the Mediating Effect (Adopted from Hair Jr et al., 2017).

Indirect Effect $= \beta_{H1} \times \beta_{H3}$	0.287
Total Effect $= \beta_{H1} \times \beta_{H3} + \beta_{H4}$	0.312
VAF $=$ Indirect Effect/Total Effect	91.99 %
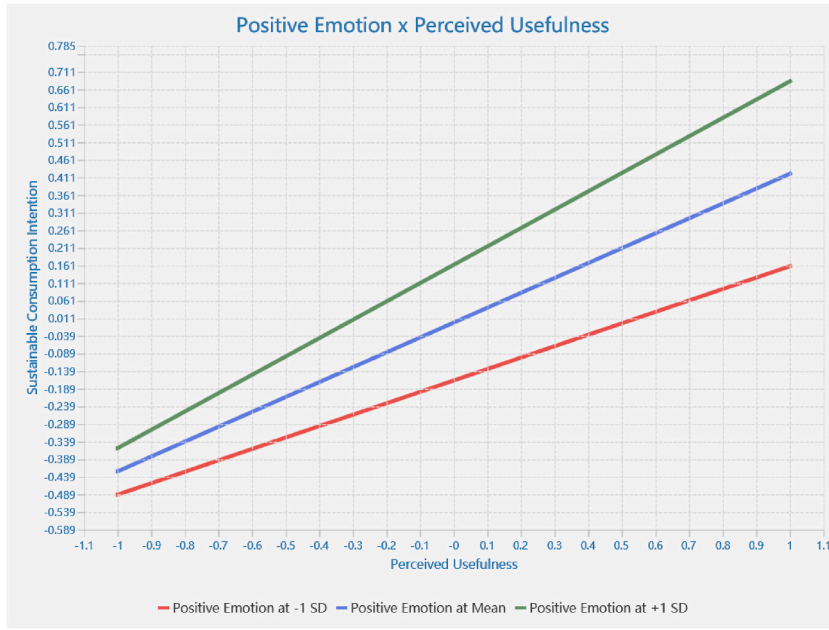
Fig. 4. Simple slope analysis of the moderating effect.
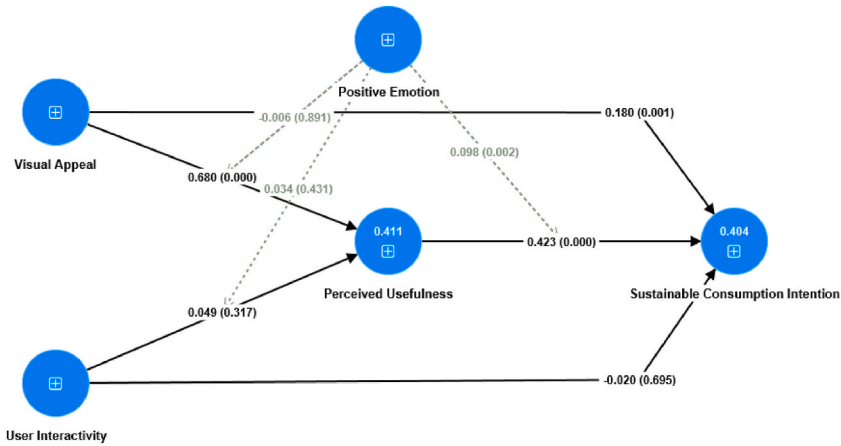
Fig. 5. The Structural Model of This Study (with β-Value, P-Value and R^2).

Table 10
Model fit with NFI.

	Saturated Model	Estimated Model
NFI	0.901	0.901

(e.g., pictures, colours, fonts, shapes, etc.) through gamified design to form a pleasant user experience [26]. The visual appeal of Ant Forest allows users to experience the reality and practicality of sustainable consumption records after cartoon design. Moreover, the visual elements provided by Ant Forest, such as photos of protected areas, plant maps, and certificates of awards, not only provide users with environmental information, but also attract their continued attention. When these kinds of information are well organised and show users the effect of their sustainable consumption behaviour on these information sources, users will perceive the usefulness of Ant Forest as an interactive application [60]. In contrast, users of Ant Forest are not very demanding about user interactivity, and they do not seem to think that the interactivity of Ant Forest influences its usefulness. This may be related to the fact that Ant Forest users' engagement motivations generally tend to be pro-environmental achievement rather than enjoyment [48].

Second, the perceived usefulness of Ant Forest directly and effectively enhances the user's sustainable consumption intention. The interactive design of Ant Forest allows users to understand that environmental protection can be carried out in an easy-to-control way, which reflects the value of pro-environmental mobile applications [24]. Ant Forest encourages users to maintain their correct behaviour by quantifying the results of users' sustainable consumption, which is more effective than simply persuading users to consume sustainably [1]. In addition, the environmental information provided in Ant Forest has also greatly enriched and enhanced users' perceived value, making them aware of the correctness of sustainable consumption [42].

Third, the perceived usefulness of Ant Forest plays an important mediating role in the framework of the S-O-R theory, which enables the visual appeal of Ant Forest to more effectively influence users' sustainable consumption intentions. If the mediating effect of perceived usefulness is ignored, the direct effect of Ant Forest's visual appeal on the user's sustainable consumption intention is very small. This shows that the psychological aesthetics of interactive interfaces need the mediation of perceived value to better influence consumers' purchase intentions [75].

Fourth, positive emotion plays a moderating role in the interaction design of Ant Forest. The moderating effect of positive emotion is not shown in the stimuli phase of the S-O-R theory, but in the response phase. The positive emotions of Ant Forest users do not simply come from the hedonic stimulation brought by the gamified interactive experience, but more from the sense of accomplishment brought by planting trees and promoting environmental protection [14,110]. Therefore, this also explains why the moderating effect of positive emotion on visual appeal and user interactivity is not obvious. Users must first recognize the perceived usefulness of Ant Forest in order to better promote their sustainable consumption intentions under the influence of positive emotions. And judging from the test results of the moderating effect, the greater the sense of accomplishment brought by pro-environmental behaviour in the Ant Forest, the more obvious the positive emotion moderating effect.

In summary, mobile application developers should consciously promote positive emotional experiences in emotional design [111], and should pay special attention to the stimulating effect of visual appeal. Designs emphasising visual aesthetics and emotional preferences enhance the competitiveness and reputation of products [112]. Mobile application developers should enhance the visual appeal of their products to make consumers feel excited and fluent when using them, thereby triggering their positive response [113]. In addition, developers can further promote consumers' sustainable behaviours by adding more guidance on their positive emotions in mobile application functions.

7. Conclusion

7.1. Theoretical significance

This study emphasises the importance of the S-O-R theory in emotional design [114–116]. In the framework based on the S-O-R theory, the researchers focused on the importance of visual appeal for pro-environmental mobile applications. The process of visual appeal influencing the user's sustainable consumption intention in the application has also been further explored. In addition, positive emotion has been shown to have a positive moderating effect on the S-O-R theory in the context of pro-environmental interaction design [6]. The expanded S-O-R theory with the moderating variable can help interaction developers engaged in emotional design to better utilise users' positive emotions to maintain their sustainable behaviours.

7.2. Practical significance

Emotionally linking mobile application interaction design with user feedback is at the core of this study [117]. Therefore, this study demonstrates Ant Forest's successful experience in pro-environmental mobile application design, and emphasises that visual design takes precedence over interaction design in meeting the needs of pro-environmental users. Although the samples of this study came from a single application, Ant Forest, it has a huge number of users in China and the user group is relatively mature, so the research results are highly representative among pro-environmental mobile applications. In addition, the researchers also obtained the result that exploiting users' positive emotions in interaction design enhances the user experience of the application. The research results show practical significance for the development of pro-environmental mobile applications.

7.3. Limitations & future directions

The R^2 of endogenous variables shows a medium value level in the structural model, which means that there may be more factors influencing the perceived usefulness of Ant Forest and the user's sustainable consumption intention. The lack of exploration and detection of these possible factors constitutes the main limitation of this study. Furthermore, user interactivity fails to influence perceived usefulness as shown in other application studies [64,65,118]. Therefore, the future direction of research can be set to explore

more factors that influence pro-environmental mobile applications and more methods to enhance the effect of user interactivity through emotional design. In addition, future researchers can also test the representativeness of this study in other mobile applications involving emotional design.

Ethics Declarations

- This study was reviewed and approved by Research Center in Communication University of China, Nanjing, with the approval number: 2023/CUCN/IRB/0058.
- All participants provided informed consent to participate in the study.

Data availability statement

The data that supports the findings of this study is openly available in https://figshare.com/at https://doi.org/10.6084/m9.figshare.25144232.

CRediT authorship contribution statement

Yunxi Feng: Writing – original draft, Supervision, Resources, Methodology, Formal analysis, Conceptualization. **Li Zhao:** Writing – review & editing, Writing – original draft, Supervision, Software, Methodology, Data curation, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:Li Zhao reports financial support was provided by Jiangsu Provincial Department of Education. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e38521.

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