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The Interaction Mechanism of Short Video Platform Usage Experience on the Subjective Well-Being of China's Rural Elderly

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Against the backdrop of deepening population aging in China, the phenomenon of empty-nest elderly in rural areas has become increasingly prominent. This study explores the impact of Douyin usage on the subjective well-being (WB) of rural empty-nest elderly, constructing a research model based on the stimulus-organism-response (SOR) framework. The model integrates seven constructs: interactivity, entertainment, relative advantage, compatibility, habit, flow experience, and WB. Data were collected through questionnaires from 407 elderly respondents in rural Sichuan Province, analyzed using a hybrid approach combining partial least squares structural equation modeling (PLS-SEM) and artificial neural network (ANN). PLS-SEM results show that interactivity and entertainment value significantly enhance WB through direct and indirect effects mediated by usage habit and flow experience. Entertainment value exerts a stronger influence on flow experience, while interactivity plays a more pivotal role in cultivating usage habits. The ANN analysis validates the model's robustness, reveals nonlinear interactions among constructs, and ranks the relative importance of predictors, aligns broadly with the findings of PLS-SEM. The findings not only expand the theoretical understanding of digital technology use and elderly well-being but also offer empirical support for digital solutions to rural aging governance.

The phenomenon of the "empty nest" is rapidly proliferating across Asian societies amid accelerating urbanization, with China exhibiting a particularly striking trajectory[1]. As millions of working-age individuals migrate from rural areas to urban centers, the rural landscape is becoming increasingly "hollowed out," leaving behind a disproportionately large aging population. Empty nesters now account for more than half of China's elderly, and 65% in rural regions alone[2]. This demographic shift has triggered profound emotional and social dislocations, particularly among elderly individuals who live alone due to their adult children's long-term absence[3]. These individuals are not merely deprived of physical care—they also suffer from deep emotional loneliness and reduced social participation[4], significantly elevating their risks of psychological disorders. This emerging mental health crisis poses a dual challenge for both families and the broader public health system[5,6]. Empty nest life reveals a widening gap in emotional support among rural elders, manifesting in pervasive experiences of loneliness[7], anxiety, and depression[8]. The intergenerational separation driven by socio-structural change fundamentally undermines the traditional model of familial eldercare. Meanwhile, TikTok, one of the world's fastest-growing social media platforms[9], is rapidly expanding into rural markets, emerging as a new digital frontier for older adults[10]. Enabled by widespread mobile internet access, short-form video platforms now offer not only diverse content consumption but also user-friendly tools for content creation and personal expression[11]. This digital intervention is reshaping rural elders' social lives by providing a virtual conduit for emotional expression and informational exchange, thus challenging geographic isolation. Indeed, growing evidence suggests a significant positive association between social media use and improved well-being among older adults[12,13]. However, existing studies on quality of life improvements among empty nesters remain largely confined to health behaviors[14] and familial support mechanisms[15], with limited focus on how digital media may influence their subjective life experiences. Indicators of better mental health, including happiness, self-esteem,

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and reduced loneliness, are critically underexplored within the context of aging and digital engagement[16]. Furthermore, empirical research on how older adults use platforms like TikTok to renegotiate aging remains in its infancy[10].

As a representative digital media platform, TikTok utilizes an algorithm-driven content recommendation mechanism to deliver content tailored to the interests of rural empty-nest elderly. Notably, research has established a relationship between TikTok usage and mental health impacts[17]. This platform possesses one of the most sophisticated algorithmic systems, rendering it more addictive than other social media platforms[18]. For rural empty-nest elderly, this technological affordance enables rapid immersion into video-generated atmospheres, facilitating temporary escape from loneliness and solitude during viewing sessions, which provides immediate emotional comfort. Simultaneously, the platform's interactive features, such as liking, commenting, and sharing, facilitate social connections between empty-nest elderly and other users. Through these engagements, this demographic perceives enhanced self-value and experiences the warmth of social care, thereby alleviating loneliness and strengthening self-identity. Current scholarly discourse on short-video platforms for elderly populations primarily examines: user behavior characteristics[19], interface design adaptability[20], and usability parameters. Building upon existing research while addressing a critical gap, this study investigates how TikTok's experience design extends its influence to psychological dimensions.

In response, this study adopts the Stimulus–Organism–Response (SOR) framework, integrating Diffusion of Innovations Theory and Flow Theory to examine how TikTok use reshapes life experiences among rural empty nesters. Specifically, we introduce TikTok's platform-specific attributes as stimuli, investigate how the interplay between entertainment content and rural cultural elements facilitates psychological flow, and assess their downstream effects on loneliness alleviation, life satisfaction, and cultural identity reinforcement. The model also tests moderating factors such as intergenerational support and neighborhood imitation. By constructing a rural-contextualized SOR model, this research aims to uncover the mechanisms by which digital engagement transforms aging experiences and inform future designs of inclusive digital interventions for aging populations in under-resourced regions.

Literature review and research hypotheses
Literature
Originally proposed by Mehrabian and Russell[21], the stimulus–organism–response (SOR) model has become a foundational theory in environmental psychology and has since been widely adopted in fields such as marketing, consumer behavior, and digital technology research[22,23]. The model posits that external environmental stimuli (S) influence an individual's internal cognitive and emotional states (O), which in turn lead to specific behavioral responses (R). Particularly in the context of consumer psychology, the SOR framework underscores the importance of understanding how external cues activate internal psychological mechanisms that ultimately shape decision-making and behavioral outcomes[24]. Recent studies have extended the SOR paradigm to digital environments, including applications in artificial intelligence services[25] and short-form video platforms. For instance, prior research has investigated how features of short video apps influence users' willingness to share content[26,27] and drive purchase intentions[28]. These studies typically examine motivations for media use, behavioral continuance among college students[29], and the impact of platform interactivity and algorithmic recommendation on e-commerce engagement[30].

However, research on social media usage among older adults has largely focused on barriers such as the digital divide, technology resistance, or addictive behaviors[31,32]. The use of technology for communication and learning correlates with self-efficacy, indicating that digital literacy not only enhances quality of life but also improves functional performance among older adults[33]. Digital self-efficacy specifically plays a pivotal role in modulating elderly users' responses to digital stimuli. Notably, older users with higher digital self-efficacy are more likely to perceive short-video platforms as accessible tools. While the relationship between self-efficacy and usage intention is non-significant in middle-aged cohorts, a robust positive effect exists among the elderly[34]. This heightened self-efficacy mitigates anxiety and fosters deeper engagement. Furthermore, enhanced social media self-efficacy improves elderly users' self-esteem and reduces loneliness[35].

TikTok, one of China's most popular short video platforms, offers a highly stimulating digital environment through diverse content ecosystems and accessible interaction features. Although originally branded as a virtual playground for younger users, TikTok has seen increasing engagement from older adults, some of whom have become prominent creators with millions of followers[10]. Elderly users engage with content aligned with their interests, such as health advice, daily living tips, or traditional opera performances[36]. For empty-nest elders—often isolated and emotionally underserved—such emotionally resonant content serves as a potent psychological stimulus. These stimuli (S), when aligned with users' affective and cognitive needs, activate internal mediators (O), including emotional flow and habitual engagement. This ultimately leads to observable behavioral outcomes (R), such as enhanced well-being and life satisfaction. The SOR model thus provides a comprehensive framework to map the dynamic process from external digital stimulation to internal processing and emotional response.

Based on this theoretical foundation, the present study employs the SOR framework to explore the mechanisms by which TikTok usage affects subjective well-being among rural empty-nest elderly users.

Stimulus (S): External platform stimuli, including interactivity, entertainment value, relative advantage, and compatibility, serve as key environmental triggers.

Organism (O): Internal psychological states, usage habits, and flow experience function as mediating variables that bridge stimulus and response.

Response (R): The outcome variable, well-being, reflects the emotional and cognitive responses resulting from sustained engagement with platform stimuli.

This integrative approach contributes a novel, context-sensitive application of the SOR model in aging research, offering both theoretical and practical insights into how digital platforms like TikTok may enhance the life experience of isolated elderly populations in rural China.

Stimulus variables and hypothesis development

Interactivity

In the context of social media studies, numerous scholars have affirmed that platform attributes, such as interactivity, entertainment, and relative advantage, have significant impacts on users' psychological states and behavioral outcomes[37–39]. As a prototypical short-form video platform, TikTok exhibits strong interactivity through features such as real-time commenting, bullet chats, and live co-broadcasts. These affordances transform users from passive recipients into active participants, enhancing both emotional value and engagement. According to Xi and Hamari[40], interactive environments intensify users' sense of presence by enabling them to manipulate and influence their digital surroundings. Thus, interactivity, as a stimulus (S), may trigger internal psychological responses (O) and ultimately influence user outcomes (R).

H1a: Interactivity (IN) has a positive effect on users' habit formation (HB) in TikTok usage.
H1b: Interactivity (IN) has a positive effect on users' flow experience (FT).
H1c: Interactivity (IN) has a positive effect on users' perceived well-being (WB).

Entertainment

Entertainment is another critical stimulus within short video platforms, functioning as a central driver of user engagement and retention[37]. As Negash et al.[41] suggest, entertainment aims to induce pleasure and captivate attention. Lo et al.[42] further argue that intrinsic enjoyment is vital to consumer satisfaction and continued digital media use. The entertaining nature of TikTok, manifested through humorous content, special effects, and viral challenges, offers emotional relief and immersion, thereby enhancing hedonic value and overall satisfaction[43,44].

H2a: Entertainment (EN) has a positive effect on users' habit formation (HB) in TikTok usage.
H2b: Entertainment (EN) has a positive effect on users' flow experience (FT).
H2c: Entertainment (EN) has a positive effect on users' perceived well-being (WB).

Relative advantage

The Diffusion of Innovations Theory[45] highlights four core factors that shape innovation adoption: the nature of the innovation itself, communication channels, time, and the surrounding social system[46,47]. Drawing from Diffusion of Innovations Theory, relative advantage and compatibility are critical innovation attributes that influence adoption rates. For late-adopter elderly users, TikTok's relative advantage and compatibility reduce adoption barriers, aligning with the theory's emphasis on innovation characteristics driving behavioral change.

Within this framework, relative advantage refers to the extent to which an innovation is perceived as superior in terms of efficiency, usability, or performance[48]. TikTok embodies these advantages through real-time interactivity, intelligent algorithmic recommendations, and a highly engaging content ecosystem[49,50]. The attributes of an innovation are critical determinants of its adoption rate, encompassing relative advantage, compatibility, complexity, trialability, and observability[51]. This theory has been widely applied in fields such as technology adoption and social media usage[52–54]. Rural empty-nest elderly individuals are categorized as late adopters of digital technologies, and their acceptance of platforms is more heavily reliant on their perception of innovation attributes. Studies have shown that elderly individuals with high motivation can achieve knowledge levels comparable to, or even higher than, those of young people[55]. However, older adults often encounter more difficulties in adopting technologies, such as a gradual decline in visual and auditory abilities, and reduced flexibility leading to typing challenges[56]. Thus, the Diffusion of Innovations Theory provides a core theoretical foundation for understanding the selection of relative advantage and compatibility as stimulus variables (S) in this study.

Relative advantage refers to the perceived superiority of an innovation over existing alternative solutions. TikTok demonstrates relative advantages over traditional forms of entertainment and aligns with the elderly's lifestyle rhythms and technical capabilities. Its advantages compared to traditional entertainment and its compatibility with elderly users' daily routines and technical proficiency precisely meet the specific needs of this group. Importantly, the app's design is optimized for diverse age groups and technological abilities. It features a simple interface and algorithmically personalized content, enhancing usability across demographics[57]. As such, the relative advantage of TikTok may influence both internal cognitive responses and behavioral outcomes.

H3a: Relative advantage (RA) has a positive effect on users' habit formation (HB) in TikTok usage.
H3b: Relative advantage (RA) has a positive effect on users' flow experience (FT).
H3c: Relative advantage (RA) has a positive effect on users' perceived well-being (WB).

Compatibility

Compatibility, defined as the degree to which an innovation aligns with users' existing values, needs, and experiences, is a critical determinant of technology adoption[58]. Prior studies have demonstrated the positive influence of compatibility on behavioral intention and user satisfaction[59,60]. TikTok's success lies partly in its ability to accommodate diverse cultural expressions and emotional needs, while also supporting self-realization and social interaction[61]. By simplifying content creation processes and supporting fragmented usage patterns, TikTok has effectively integrated itself into the daily lives of elderly users, including empty nesters. Compatibility between users' skill levels and task demands during interaction facilitates the emergence of flow experience[62]. This alignment enhances user engagement and reduces entry barriers.

H4a: Compatibility (CB) has a positive effect on users' habit formation (HB) in TikTok usage.
H4b: Compatibility (CB) has a positive effect on users' flow experience (FT).

H4c: Compatibility (CB) has a positive effect on users' perceived well-being (WB).

Organism variables and hypothesis development

Habit
Habit refers to the degree to which a behavior becomes automatic through repeated practice, enabling individuals to perform actions with minimal cognitive effort[63]. As Lu et al.[64] point out, cultivating healthy digital habits can significantly improve the living experience and quality of life among older adults, particularly those living alone. Habits reduce decision-making uncertainty and enhance individuals' sense of behavioral control, thereby improving psychological satisfaction[65]. For older users, who often experience cognitive decline, the formation of stable and routine digital usage patterns is especially critical[66]. TikTok's age-friendly interface and rich social features help reinforce these usage patterns among elderly users. By lowering learning costs and aligning with daily behavioral tendencies, the platform facilitates long-term engagement. Previous studies have confirmed that habit plays a pivotal role in the continued use of digital technologies[67]. Habit automatically manifests an individual's psychological disposition[68], representing an internalized behavioral tendency formed through repeated platform use, rather than an immediate emotional response. The formation of habit reduces cognitive effort and enhances behavioral control, serving as a mediator between platform characteristics and well-being.

H5: Habit (HB) has a positive effect on users' perceived well-being (WB) in TikTok usage.

Flow experience
The concept of flow describes a mental state in which individuals become fully immersed in an activity, characterized by deep focus, loss of self-consciousness, and a sense of control over the environment[69]. It represents the intrinsic motivation for a certain activity and can generate satisfying pleasure and enjoyment[70]. Flow is a powerful predictor of user satisfaction, behavioral intention, and media loyalty[71]. High-quality interaction design reduces perceived technological complexity, allowing users to achieve immersive engagement[72]. On TikTok, flow is closely tied to content relevance and the depth of interaction. When rural empty-nest elders encounter content that aligns with their interests—such as traditional opera, health advice, or family-oriented storytelling—they often enter a time-distorted state of concentration and enjoyment[73]. This immersive state enhances emotional pleasure and may trigger "social contagion effects," such as sharing content and initiating peer interactions. Although flow theory has been validated in VR, gaming, and online learning contexts[74,75], its application to the digital experiences of rural elderly users remains underexplored.

H6: Flow experience (FT) has a positive effect on users' perceived well-being (WB) in TikTok usage.
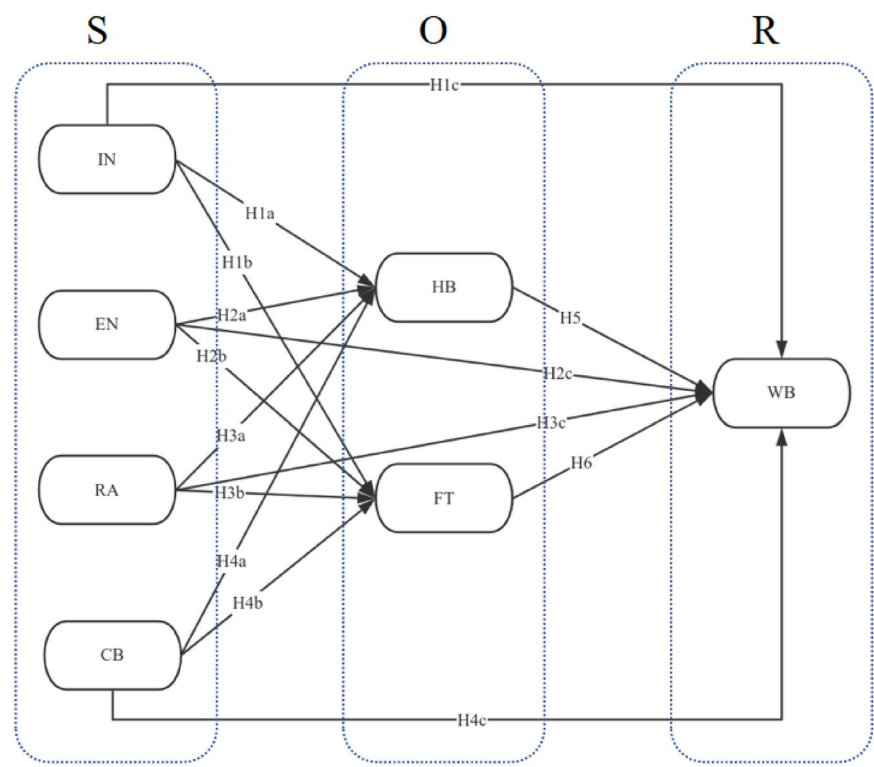
Response variable
In the S–O–R model, the response (R) encompasses users' emotional and behavioral outcomes, including attitudinal shifts and behavioral intentions[76]. Among these, subjective well-being (WB) has emerged as a key psychological indicator reflecting emotional balance, social confidence, and mental resilience[77]. Empty-nest elders, those who live alone or only with a spouse, often face a lack of daily care and emotional support[5]. For rural empty-nest elderly, WB is manifested through reduced loneliness, enhanced life satisfaction, and strengthened cultural identity, which are direct outcomes of sustained engagement with platform stimuli. Well-being may manifest through reductions in stress and loneliness, improvements in emotional regulation and attention, and increased self-esteem[78]. Currently, some scholars have taken subjective well-being as R[79,80]. By addressing the emotional void of empty-nest life, TikTok transforms digital engagement into a psychosocial intervention, where WB serves as the measurable endpoint of this process. TikTok, by offering nostalgic content, social interaction opportunities, and age-relevant content streams, enables older users to fulfill emotional and psychological needs. These interactions reduce loneliness and amplify positive emotional experiences, thereby enhancing overall well-being. In this context, TikTok serves not just as a digital entertainment platform but as a psychosocial intervention tool, mediating the pathway from external digital stimuli to internal psychological fulfillment.

Based on the above discussion and analysis, the study proposes the following hypotheses, as illustrated in (Fig. 1).

Methods
This study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to validate the hypothesized relationships. A structured questionnaire was designed comprising two sections. The study was approved by the Ethics Committee of Macau Polytechnic University, and all methods were performed in strict accordance with the relevant guidelines and regulations. The first section collected demographic data, while the second focused on measuring core constructs using items adapted from established and validated scales drawn from prior literature to ensure measurement reliability and construct validity[81]. To tailor the instrument to the research context, several items were linguistically and contextually adjusted. The final instrument included 7 constructs and 21 items, each measured using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) (Table 1). To ensure clarity and cultural appropriateness, the instrument underwent two rounds of pre-testing. In the first round, 12 older adults were randomly selected to assess item readability. Based on their feedback, minor revisions were made to enhance comprehensibility. In the second round, a pilot survey was conducted with 13 rural empty-nest elderly individuals from Langzhong City, Sichuan Province. Particular attention was paid to regional dialect variations and local expressions, with further refinements made accordingly.

Employing a door-to-door convenience sampling approach, formal data collection was conducted from January to June 2025. This study focused specifically on rural empty-nest elderly residing in high-density areas of Sichuan Province, including Chengdu, Leshan, and Nanchong. To ensure data integrity, face-to-face interviews formed the primary method, leveraging direct engagement to maximize informational completeness. Despite inherent limitations in generalizability, convenience sampling remains methodologically appropriate

IN: Interactivity, EN: Entertainment, RA: Relative Advantage, CB: Compatibility, HB: Habit, FT: Flow Experience, WB: Well-being

Fig. 1. The theoretical model.

Questionnaire constructs and items	References
IN1: I find it easy to interact with others on TikTok, such as liking, commenting, using voice messages, or making videos	
IN2: TikTok makes me feel that I can have two-way communication with video creators or other users	82,83
IN3: I feel that I can easily learn and use TikTok's interactive functions	
EN1: Watching TikTok makes me feel relaxed and happy	
EN2: The videos on TikTok are usually interesting or catch my attention	84
EN3: I usually use TikTok as a way to pass the time and unwind	
RA1: I find TikTok more convenient than other video apps	
RA2: I use TikTok because it has the kind of videos I want to watch	85,86
RA3: Compared to other video apps, I prefer using TikTok	
CB1: I think the way TikTok works is suitable for me	
CB2: TikTok has the kind of content that matches my interests	87
CB3: I often like to watch TikTok during my spare time each day	
HB1: I'm used to watching TikTok every day	
HB2: If I don't watch TikTok, I feel like something is missing	63
HB3: I've become so used to using TikTok that it feels natural to me	
FT1: When I watch TikTok, I become very focused	
FT2: I often lose track of time when watching TikTok	88
FT3: The features of TikTok (such as video browsing, interaction, and video recording) often keep me fully engaged	
WB1: Watching TikTok improves my mood	
WB2: I feel relaxed and comfortable when using TikTok	89
WB3: TikTok makes my life feel more enjoyable	

Table 1. Questionnaire constructs and items.

for exploratory research[90]. To mitigate measurement bias, our team refined questionnaire phrasing during the pre-test phase by adapting terminologies to dialectal variations in Langzhong City, Sichuan. This linguistic calibration guaranteed consistent comprehension of digital usage behavior items across Chengdu, Leshan, and Nanchong respondents, reducing cultural-linguistic distortion risks. During formal fieldwork, identify and prioritize remote households using local administrative registers, actively counterbalancing spatial distribution skew inherent to convenience sampling. To ensure respondent eligibility, a brief screening was administered before participation, asking: "Have you used TikTok in the past six months?" "Do you currently live alone (or only with your spouse)?"Only those answering "yes" to both were included in the sample[91]; others were excluded from further participation. A total of 407 valid questionnaires were ultimately collected, exceeding the recommended subject-to-parameter ratio of 10:1 for structural equation modeling applications[92]. Of the 407 valid questionnaires collected, the gender distribution was relatively balanced: 50.6% female and 49.4% male. Monthly income was concentrated between 2000 and 5000 CNY, accounting for 44.7% of the sample. In terms of educational background, 86.7% of respondents had received elementary education or below. Furthermore, 84.8% of elderly participants reported that their children visited them no more than five times per year. These sample characteristics are highly consistent with the known demographic and social profiles of rural empty-nest elderly populations in China. Table 2 presents the complete demographic data.

Results
Reliability and internal consistency
To assess the reliability of the measurement model, both factor loadings and cross-loadings were examined. Item loadings exceeding 0.70 were considered acceptable, indicating strong indicator reliability[93]. All items in this study met or exceeded the threshold, confirming item-level reliability[94]. Furthermore, both Cronbach's α and Composite Reliability (CR) values for all constructs ranged between 0.70 and 0.95, satisfying the standard for internal consistency. These results suggest that the constructs reliably measure the intended latent variables without redundancy or overfitting[94]. To control for common method variance (CMV), we employed Harman's single-factor test using SPSS 25.0. The unrotated principal component analysis revealed that the first factor accounted for only 29.320% of the total variance, which is well below the critical threshold of 50%. This indicates that common method bias is not a serious concern in this study[95]. Convergent validity was evaluated using the Average Variance Extracted (AVE) metric. All constructs exhibited AVE values above 0.50, indicating that more than half of the variance in the indicators was captured by the latent constructs, thus confirming sufficient convergent validity[96]. To test for multicollinearity, the Variance Inflation Factor (VIF) values were computed for all indicators. The VIF values ranged between 1.437 and 3.060, well below the conservative threshold of 5.0[97]. These results demonstrate that no significant multicollinearity exists among the observed variables, satisfying the assumptions required for structural equation modeling. The Standardized Root Mean Square Residual (SRMR) value was assessed to evaluate the overall model fit. The SRMR value was found to be less than 0.08, indicating that the model exhibits an acceptable level of fit and is well-suited for predictive analysis[96]. As shown in Table 3, the data demonstrate that the measurement model exhibits good internal consistency, item reliability, and convergent validity.

For discriminant validity, we followed the example of Fornell and Larcker[93,98], where the square root of the AVE should exceed its highest correlation with items in different constructs (Table 4). To further ensure the robustness of discriminant validity and mitigate potential biases associated with PLS-SEM—such as overestimation of indicator loadings or underestimation of inter-construct correlations—the Heterotrait–Monotrait Ratio (HTMT) was also calculated. The highest HTMT value observed was 0.813, which is below the conservative threshold of 0.85 for conceptually unrelated constructs. According to Hair and Alamer[99], a threshold of 0.90 is acceptable for conceptually related constructs. The HTMT results further affirm the absence of discriminant validity concerns in this study.

Category	Subcategory	Frequency	Percentage
Gender	Male	201	49.4
	Female	206	50.6
Income	<1000	42	10.3
	1000–2000	112	27.5
	2000–5000	182	44.7
	5000+	71	17.4
Education	No education	171	42.0
	Primary school	182	44.7
	Middle school	31	7.6
	High school+	23	5.7
Child Visits/Year	1time	48	11.8
	3 times	155	38.1
	5 times	142	34.9
	7+times	62	15.2

Table 2. Demographic data.

Construct	Item	M	SD	FL	CA	CR	AVE
IN	IN1	2.968	1.372	0.926	0.797	0.882	0.714
	IN2	2.857	1.495	0.778			
	IN3	2.980	1.530	0.824			
EN	EN1	3.012	1.481	0.901	0.820	0.893	0.736
	EN2	2.973	1.493	0.838			
	EN3	3.096	1.510	0.833			
RA	RA1	3.027	1.406	0.926	0.823	0.895	0.740
	RA2	3.091	1.479	0.833			
	RA3	2.983	1.496	0.818			
CB	CB1	2.951	1.424	0.920	0.840	0.904	0.758
	CB2	2.993	1.519	0.849			
	CB3	2.990	1.536	0.841			
HB	HB1	2.504	1.036	0.947	0.812	0.888	0.729
	HB2	2.563	1.228	0.879			
	HB3	2.627	1.174	0.719			
FT	FT1	2.953	0.926	0.831	0.737	0.851	0.656
	FT2	3.096	1.093	0.788			
	FT3	3.007	1.141	0.810			
WB	HA1	3.189	0.831	0.940	0.836	0.901	0.754
	HA2	3.130	1.114	0.828			
	HA3	3.152	1.132	0.832			

Table 3. Scales for reliability and validity of the measurement model. *M* Mean, *SD* standard deviation, *FL* factor loading, *CA* Cronbach's α, *CR* composite reliability, *AVE* average variance extracted.

Construct	HB	IN	WB	CB	EN	FT	RA
HB	0.854						
IN	0.363	0.845					
WB	0.538	0.508	0.868				
CB	0.258	0.006	0.359	0.871			
EN	0.336	0.091	0.543	0.013	0.858		
FT	0.378	0.417	0.654	0.316	0.452	0.810	
RA	0.063	−0.007	0.299	0.009	0.061	0.307	0.860

Table 4. Results of the discriminant validity test.

Structural model and hypothesis test

To assess the predictive relationships between exogenous and endogenous variables, the bootstrap resampling method in PLS-SEM was employed with 5000 bootstrap samples to estimate standard errors and test the statistical significance of path coefficients. As shown in Fig. 2 and Table 5, the model demonstrates strong explanatory power. The coefficient of determination (R^2) for the dependent variable well-being (WB) reached 0.721, indicating that over 72% of the variance in well-being can be explained by the model's predictor variables, well above the threshold for a large effect size ($R^2 \geq 0.67$)[100]. Additionally, habit (HB) and flow experience (FT) yielded R^2 values of 0.290 and 0.522, respectively, both exceeding the effect threshold ($R^2 \geq 0.200$), suggesting robust construct-level explanatory power. The predictive relevance (Q^2) was evaluated using the blindfolding procedure. The resulting Q^2 values were:WB: 0.694, HB: 0.274, FT: 0.509. All values exceeded the recommended benchmarks of 0.02 (small), 0.15 (medium), and 0.35 (large), confirming that the model possesses strong out-of-sample predictive accuracy[101]. The structural model analysis revealed that all six predictors exerted significant positive effects on users' perceived well-being. Specifically, interactivity (H1c: β = 0.377, p < 0.001), entertainment (H2c: β = 0.396, p < 0.001), relative advantage (H3c: β = 0.234, p < 0.001), compatibility (H4c: β = 0.280, p < 0.001), habit (H5: β = 0.142, p < 0.001), and flow experience (H6: β = 0.104, p = 0.008) all demonstrated statistically significant and positive relationships with well-being. Regarding habit formation, interactivity (H1a: β = 0.335, p < 0.001), entertainment (H2a: β = 0.299, p < 0.001), and compatibility (H4a: β = 0.252, p < 0.001) were found to significantly promote the development of user habits, whereas the effect of relative advantage (H3a: β = 0.045, p = 0.304) was not statistically supported. As for flow experience, all four stimulus variables—interactivity (H1b: β = 0.382, p < 0.001), entertainment (H2b: β = 0.395, p < 0.001), relative advantage (H3b: β = 0.284, p < 0.001), and compatibility (H4b: β = 0.307, p < 0.001)—exhibited significant positive effects, confirming their importance in facilitating immersive user experiences on the TikTok platform.

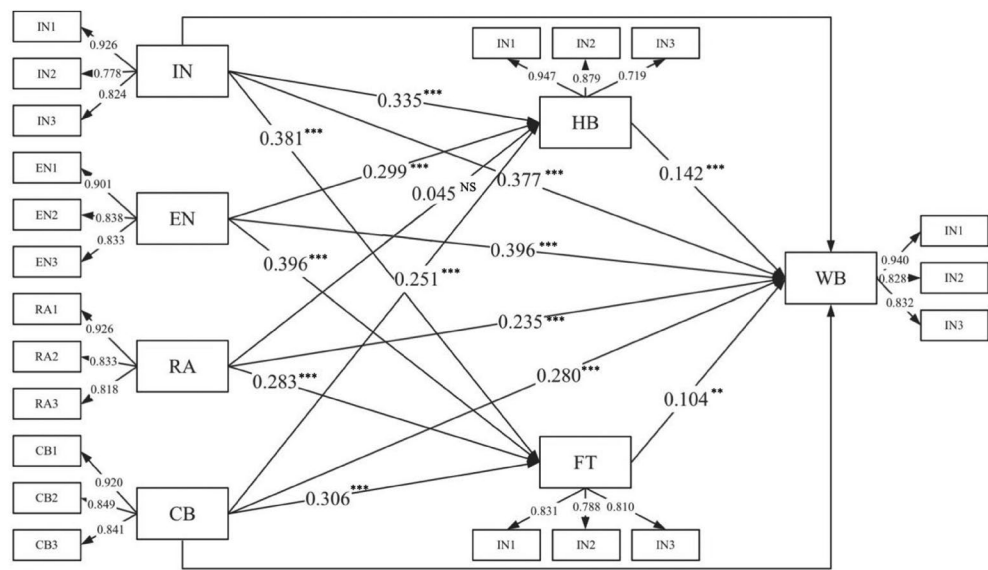**Fig. 2**. The theoretical model.

Construct	Hypothesis	Path	R²	β	P	Hypothesis supported
WB	H1c	IN→WB	0.721	0.377	0.000	Yes
	H2c	EN→WB		0.396	0.000	Yes
	H3c	RA→WB		0.234	0.000	Yes
	H4c	CB→WB		0.280	0.000	Yes
	H5	HB→WB		0.142	0.000	Yes
	H6	FT→WB		0.104	0.008	Yes
HB	H1a	IN→HB	0.290	0.335	0.000	Yes
	H2a	EN→HB		0.299	0.000	Yes
	H3a	RA→HB		0.045	0.304	No
	H4a	CB→HB		0.252	0.000	Yes
FT	H1b	IN→FT	0.522	0.382	0.000	Yes
	H2b	EN→FT		0.395	0.000	Yes
	H3b	RA→FT		0.284	0.000	Yes
	H4b	CB→FT		0.307	0.000	Yes

Table 5. Hypothesis testing and path coefficient.

Mediating effect test

The mediation analysis further revealed the indirect mechanisms by which stimulus variables influence perceived well-being through the organism constructs of HB and FT (Table 6). For EN, the indirect path EN→FT→WB (95% CI [0.011, 0.074]), indicating that entertainment positively enhances user well-being by stimulating immersive flow experiences. In comparison, the EN→HB→WB pathway demonstrated a slightly stronger effect (95% CI [0.025, 0.073]), suggesting that entertainment also improves usage experience by fostering habit formation, highlighting its dual role in both short-term engagement and long-term behavioral integration. For IN, the indirect effect through habit (IN→HB→WB, 95% CI [0.008, 0.053]) was stronger than that through flow (IN→FT→WB, 95% CI [0.018, 0.057]). Both paths were significant and positive (95% CIs excluding 0), indicating that interactivity not only enhances immediate enjoyment via flow states but also reinforces sustainable user engagement through habit development. In the case of CB, the CB→HB→WB path showed a moderate and significant effect (95% CI [0.022, 0.066]), suggesting that compatibility contributes meaningfully to usage experience by facilitating the formation of habitual behaviors. Meanwhile, the CB→FT→WB path demonstrated a weaker effect (p = 0.011), the practical effect of compatibility on stimulating flow is less stable and relatively limited, though it still plays a non-negligible role in the immersive experience. As for RA, the RA→FT→WB pathway was statistically significant but relatively weak (95% CI [0.009, 0.058]), suggesting that the perceived superiority of the platform contributes to user well-being primarily through momentary flow experiences, with a small but stable positive effect. However, the indirect path RA→HB→WB (95% CI [0.011, 0.072]) was not significant. This implies that relative advantage has extremely limited power to drive long-term user habits, and its perceived benefits are more likely linked to immediate gratification than to routine behavioral reinforcement.

	Effect	SD	T	P	95% CI	
EN→FT→WB	0.041	0.016	2.552	0.011	0.011	0.074
EN→HB→WB	0.043	0.011	3.736	0.000	0.025	0.073
IN→HB→WB	0.048	0.012	3.953	0.000	0.008	0.053
IN→FT→WB	0.040	0.016	2.524	0.012	0.018	0.057
CB→HB→WB	0.036	0.010	3.619	0.000	0.022	0.066
CB→FT→WB	0.032	0.013	2.533	0.011	-0.006	0.021
RA→HB→WB	0.006	0.007	0.967	0.333	0.011	0.072
RA→FT→WB	0.029	0.012	2.552	0.011	0.009	0.058

Table 6. Hypothesis testing and path coefficient.

SEM–ANN hybrid analysis

To enhance the explanatory and predictive capabilities of the model, this study integrates Structural Equation Modeling (SEM) with Artificial Neural Networks (ANN) to capture both linear causal relationships and complex nonlinear interactions in the dataset. While SEM is well-suited for testing causal structures in a theory-driven framework, ANN excels at modeling intricate, nonlinear patterns that may not be well-captured through traditional linear approaches[102–104].

Building on the validated SEM results, a hybrid SEM–ANN model was developed to refine prediction accuracy and explore latent patterns, combining the confirmatory power of SEM with the adaptive learning capability of multilayer feedforward neural networks[105]. The ANN architecture used in this study comprises three layers: an input layer, a hidden layer, and an output layer[106]. Three distinct neural network models were constructed to predict key endogenous variables WB、HB, and FT, based on the significant predictors identified through SEM. Model A was designed to predict WB. The input layer consisted of IN, EN, RA, CB, HB, and FT, with WB as the single output node (Fig. 3). Model B aimed to predict HB. Its input variables included IN, EN, and CB, and the output was HB. Model C was developed to predict FT. The input layer included IN, EN, RA, and CB, with FT as the output. Their design leverages the causal validation power of SEM with the nonlinear approximation strength of ANN, enabling a more nuanced understanding of user behavior patterns and deepening insight into the mechanism through which TikTok usage affects the well-being of rural empty-nest elderly users.

Neural network architecture and predictive accuracy

The hybrid SEM–ANN analysis was implemented using multilayer perceptron (MLP) neural networks, with predictive performance evaluated through tenfold cross-validation[106]. This approach ensures the model's generalizability while minimizing the risk of overfitting. The full dataset was randomly partitioned into ten equal folds: 90% of the data was used for model training, and the remaining 10% was reserved for independent testing[107,108]. Both the hidden and output layers employed the sigmoid activation function, enabling the network to model nonlinear mappings between predictors and outcomes. Before training, all input variables were normalized to a [0,1] range to improve convergence efficiency and ensure compatibility across features. The training process was governed by backpropagation, and model fit was assessed through the Standardized root mean square residual (SRMR), confirming adequate model specification[109]. The root mean square error (RMSE) values were used to evaluate prediction accuracy (Table 7). The average RMSE for the training sets ranged between 0.079 and 0.145, while the RMSE for the testing sets remained between 0.080 and 0.143, indicating strong convergence and robust predictive performance[110]. These results validate the use of the SEM–ANN hybrid model as a complementary analytical technique capable of capturing both the theoretically grounded causal structure and the complex nonlinear relationships embedded within user behavioral data.

Sensitivity analysis

To assess the relative importance of each input factor in predicting the target outcomes, a sensitivity analysis was conducted for the ANN models (Tables 8, 9). This technique quantifies the impact of each input neuron or factor on the output neuron by evaluating their contribution to the prediction process[111]. Specifically, determinant importance was used to calculate the normalized importance, which represents the ratio of each variable's influence relative to the most influential predictor, expressed as a percentage[112]. The analysis was performed across all three neural network models—Model A (predicting well-being), Model B (predicting habit), and Model C (predicting flow experience). Based on the results, the predictors were ranked by their normalized importance to determine which factors played the most critical role in driving each target construct. This ranking provides valuable insights into the nonlinear explanatory power of each stimulus and organism variable.

Comparison of ANN and PLS-SEM results

A comparative analysis between the PLS-SEM and ANN models was conducted to examine the consistency of variable importance rankings across methodologies (Table 10). In Model A (predicting well-being), noticeable differences were observed in the ranking of entertainment (EN) and interactivity (IN) between the two methods. This discrepancy suggests the potential presence of latent or interactional factors influencing the effects of EN and IN—factors that may be obscured in real-world complexity and not fully captured by the linear modeling approach of PLS-SEM[113]. These findings indicate that ANN's nonlinear learning capability can uncover variable interdependencies that may be undetected in traditional SEM frameworks[114]. In contrast, for Model B (habit) and
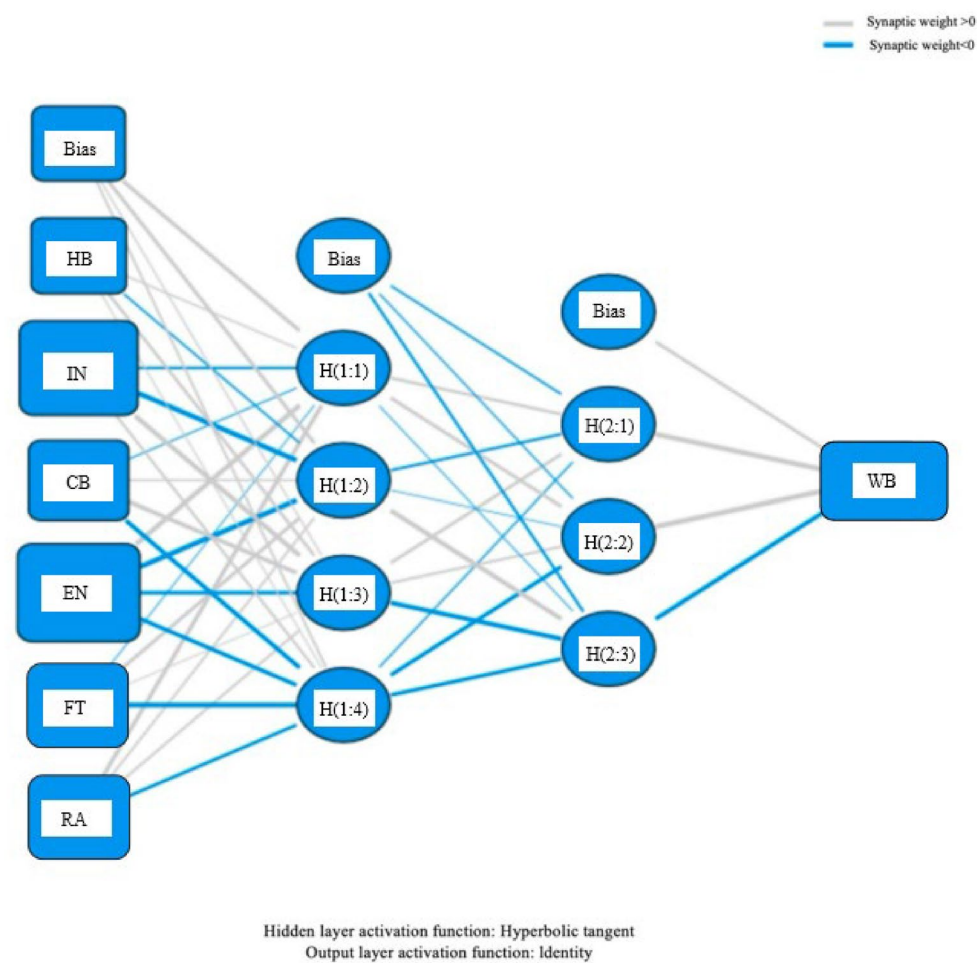
Fig. 3. ANN model A.

	Model A		Model B		Model C	
	Training	Testing	Training	Testing	Training	Testing
1	0.098	0.085	0.149	0.124	0.113	0.105
2	0.079	0.073	0.144	0.156	0.106	0.121
3	0.079	0.061	0.154	0.133	0.108	0.102
4	0.079	0.078	0.147	0.154	0.106	0.099
5	0.080	0.091	0.145	0.132	0.105	0.108
6	0.080	0.086	0.147	0.143	0.104	0.109
7	0.079	0.081	0.148	0.145	0.101	0.114
8	0.083	0.086	0.147	0.145	0.101	0.114
9	0.084	0.073	0.145	0.140	0.106	0.095
10	0.079	0.085	0.145	0.157	0.103	0.107
Mean	0.082	0.080	0.147	0.143	0.105	0.107
SD	0.006	0.009	0.003	0.011	0.004	0.008

Table 7. RMSE values of the ANN model.

Model C (flow experience), the ranking of independent variables showed strong alignment between PLS-SEM and ANN results, reinforcing the stability and reliability of the structural model. This consistency affirms that the causal pathways validated through SEM are also supported by ANN's predictive strength. Such convergence is particularly important because ANN accounts for both linear and nonlinear relationships, thus providing a higher-resolution validation of causal structure[115]. Overall, the close agreement between the two approaches—especially in Models B and C—demonstrates the robustness of the PLS-SEM model and supports its suitability

Network	HB	IN	CB	EN	FT	RA
1	0.285	0.141	0.109	0.088	0.248	0.128
2	0.107	0.231	0.171	0.227	0.111	0.153
3	0.101	0.246	0.172	0.233	0.099	0.149
4	0.114	0.238	0.167	0.235	0.102	0.143
5	0.145	0.23	0.159	0.237	0.091	0.138
6	0.11	0.221	0.159	0.234	0.132	0.145
7	0.099	0.225	0.177	0.248	0.101	0.151
8	0.141	0.249	0.156	0.232	0.08	0.142
9	0.115	0.213	0.177	0.22	0.14	0.134
10	0.131	0.23	0.152	0.248	0.094	0.145
Mean	0.135	0.222	0.160	0.220	0.120	0.143
Importance (%)	60.8%	100%	72.1%	99.1%	54.1%	64.4%

Table 8. Sensitivity analysis for ANN model A.

	Model B			Model C			
	IN	EN	CB	IN	EN	RA	CB
1	0.397	0.305	0.297	0.308	0.369	0.145	0.179
2	0.375	0.305	0.32	0.29	0.294	0.207	0.209
3	0.271	0.391	0.339	0.353	0.302	0.229	0.216
4	0.414	0.324	0.262	0.274	0.296	0.203	0.227
5	0.387	0.318	0.295	0.278	0.31	0.193	0.219
6	0.381	0.301	0.318	0.298	0.282	0.179	0.241
7	0.379	0.313	0.308	0.287	0.292	0.193	0.228
8	0.379	0.29	0.331	0.287	0.298	0.196	0.22
9	0.365	0.307	0.328	0.251	0.292	0.213	0.244
10	0.373	0.323	0.304	0.284	0.279	0.208	0.229
Mean	0.372	0.318	0.310	0.291	0.301	0.197	0.221
Importance (%)	100%	85.5%	83.3%	96.7%	100%	65.4%	73.4%

Table 9. Sensitivity analysis for ANN Model B and C.

	Path	PLS-SEM Beta (β)	Rank	SEM-ANN sensitivity analysis	Rank
Model A	HB->WB	0.142	5	60.8%	5
	IN->WB	0.377	2	100%	1
	CB->WB	0.280	3	72.1%	3
	EN->WB	0.396	1	99.1%	2
	FT->WB	0.104	6	54.1%	6
	RA->WB	0.234	4	64.4%	4
Model B	IN->HB	0.335	1	100%	1
	EN->HB	0.299	2	85.5%	2
	CB->HB	0.252	3	83.3%	3
Model C	IN->FT	0.382	2	96.7%	2
	EN->FT	0.395	1	100%	1
	RA->FT	0.284	4	65.4%	4
	CB->FT	0.307	3	73.4%	3

Table 10. Comparison between PLS-SEM and ANN results.

for explaining behavioral mechanisms in the context of TikTok usage among rural elderly. Moreover, the hybrid SEM–ANN approach enriches the interpretation of causal influence by offering complementary perspectives on the strength, stability, and interaction of key predictors[116].

Discussions

The findings of this study underscore the profound impact of short-form digital media, particularly TikTok, on the psychological well-being of empty-nest elderly individuals. Existing research has shown that this population is significantly more prone to depressive symptoms than their non-empty-nest counterparts[117], and digital entertainment platforms offer promising avenues for improving their mental health[118]. Enjoyment-oriented media consumption is a key driver of technology adoption among older adults, as it satisfies emotional needs and enhances pleasure, thereby promoting sustained usage[119]. From a product attribute perspective, interactivity plays a critical role. Rich interactive experiences not only enhance user enjoyment (H1c) but also foster habit formation (H1a). Features such as comments, likes, and video-sharing mechanisms facilitate repeated usage, while real-time, responsive interaction forms the foundation for immersive flow states (H1b). This finding suggests that platform designers should prioritize real-time feedback and personalized interaction interfaces to elicit stronger flow experiences and emotional engagement[88]. Entertainment also directly enhances users' emotional states (H2c), and its impact on flow (H2b) exceeds that of interactivity, suggesting that engaging content more effectively draws users into focused attention. Furthermore, entertainment promotes habitual use (H2a), indicating that localized and interest-based content ecosystems are essential to maintaining user retention among elderly users. Relative advantage, while positively associated with well-being (H3c), plays a more limited role in shaping habit (H3a), reflects the functional primacy principle governing elderly technology adoption: older adults systematically prioritize core functionality and usability over advanced features, with perceived advantage contributing to psychological outcomes only after these basic functional needs are met[120,121]. Crucially, this context-dependent nature of technological determinants extends to compatibility, as evidenced by divergent empirical findings: while Liao et al.[122] documented compatibility's significant positive effect on satisfaction in goal-directed health device contexts, Choi et al.[123] observed no significant impact of TikTok usage on habit formation in entertainment-driven environments. This fundamental divergence originates from task nature variance, outcome variable disparity, and elderly engagement patterns, collectively underscoring how gerontechnology effects are contingent upon alignment between technological attributes and population-specific motivational frameworks. Relative advantage does positively influence flow (H3b), suggesting that innovation can still stimulate curiosity and engagement. Elderly users, particularly those new to digital media, are more likely to embrace platforms that offer emotionally resonant, intuitive experiences[124]. Compatibility strongly correlates with enhanced well-being (H4c), and by lowering usage barriers, it also promotes habit formation (H4a). However, poor compatibility can disrupt flow (H4b). These results emphasize the importance of age-friendly design features, such as interface simplicity and offline accessibility, especially for rural users facing unstable network conditions. Habituation (H5) significantly predicts well-being, consistent with prior findings that habitual behavior strengthens positive affective responses[125]. Similarly, flow (H6) positively affects well-being, though its impact is most potent when balanced with appropriate levels of content challenge and feedback. When digital experiences align with users' lifestyles, they generate a sense of control and technological self-efficacy[126]. Routine use also reduces cognitive effort, reinforcing satisfaction, similar to patterns observed in social gaming[127].

TikTok's interactivity and entertainment attributes positively influence psychological outcomes through the mediating roles of habit and flow. These results provide actionable design strategies for age-friendly digital platforms: enhancing interactive functionality, focusing on interest-based entertainment, and optimizing system compatibility. The ANN-based sensitivity analysis further confirmed these priorities. In Model A, IN and EN ranked highest, confirming that both social engagement features and content enjoyment are central to enhancing well-being. Other variables (CB, RA, FT) followed in decreasing order of importance, suggesting that emotional connectivity and ease of use take precedence over deep immersion for this demographic. In Model B, IN ranked highest with 100% relative importance, underscoring that repeated social feedback strongly reinforces behavioral regularity, while EN(85.5%) and CB(83.3%) followed as secondary influencers. Notably, in Model C, EN (100%), IN (96.7%), and CB (73.4%) emerged as key drivers of immersive flow experiences, with RA contributing moderately (65.4%).

Conclusions

This study integrates the Stimulus–Organism–Response (S–O-R) framework, Diffusion of Innovations theory, and Flow theory to offer a multidimensional understanding of digital media usage among empty-nest elderly users. It confirms that interactivity and entertainment, as core external stimuli, enhance life satisfaction through the mediating mechanisms of habit and flow. These results expand the theoretical scope of the S–O-R model to address the unique dynamics of intergenerational separation and social disconnection in aging populations. PLS-SEM validated linear causal relationships, while ANN uncovered nonlinear synergies, threshold effects and compensatory interactions between TikTok's attributes, innovation diffusion factors, and empty-nesters' emotional gratification. This dual approach models nonlinear dynamics in elderly users' digital behavioral responses, enhancing theoretical insights. Practically, the findings offer a roadmap for improving digital platforms targeting rural older adults. Developers should prioritize real-time interaction and design intergenerational communication features to capitalize on the habit-forming potential of interactivity. Additionally, localized, culturally relevant content ecosystems should be created to heighten engagement. Compatibility should be optimized across devices and network conditions, particularly in underdeveloped areas. Finally, platform design should shift from highlighting technical specifications to emphasizing intuitive functionality and emotional value, aligning with older users' preference for simplicity and usefulness.

This study has several limitations, future research could conduct cross-regional and cross-population comparative studies. Second, the study adopts a cross-sectional design, which does not capture the long-term effects of TikTok usage on psychological well-being. Longitudinal studies are recommended to track these

dynamics over time. Finally, future work may build on the integrated S–O–R–Innovation Diffusion model to explore digital media's role in reducing loneliness, incorporating constructs such as social capital and digital empowerment. Neuroscientific tools could also be employed to investigate the physiological mechanisms underlying flow experiences in older adults.

Data availability

The data supporting the findings of this study are available from the corresponding author, Junping Xu, upon reasonable request.

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Author contributions

X.L. Li designed the research framework, analyzed data, interpreted results, wrote and revised the paper, and supervised the research. N. Tang and H.F. Zhang contributed to research design, data collection, and paper improvement. J.P. Xu participated in data—related work, provided technical support, reviewed relevant content,set the research direction, guided the study, and offered theoretical and resource support.

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The authors declare no competing interests.

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Informed consent statement

Informed consent was obtained from all subjects involved in the study.

Additional information

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