

# Promoting Migrant Adolescent Resilience Through a Virtual Reality Videogame: A Randomized Trial

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## Abstract

**Purpose:** This study explores the effects of a customized virtual reality (VR) role-playing videogame, “the Transfer Student,” on the psychological resilience of Chinese rural-to-urban migrant adolescents, a population significantly underrepresented in resilience intervention research. **Method:** Sixty-two migrant adolescents (ages 12–17) were randomized to play the videogame (intervention), where the character overcame challenges as a rural student adapting to an urban school, or watch VR-based scenic videoclips (control). **Results:** The intervention group showed moderate-size improvements in resilience at immediate post-test, compared with the control (Hedge’s  $g = 0.47$ ,  $SE = 0.32$ ). Additionally, participants’ level of immersion in the virtual environment was significantly related to intervention effects. **Discussion:** The findings preliminarily support the feasibility and efficacy of this VR-based game as a digital resilience intervention approach for migrant adolescents. Future research should test this approach in larger, more diverse samples.

## Keywords

adolescent, digital intervention, migrant, RCT, resilience, virtual reality

Rapid urbanization worldwide has caused over 740 million internal migrants moving within their national borders. Internal migrants face many challenges, such as inequitable public service provision and lower socioeconomic status (UNDP, 2009). As a result, children in internal migrant families often experience adjustment difficulties and present more mental health problems (UNESCO, 2018). China, one of the largest urbanization hotspots, has 71 million internal migrant children, who constitute 24% of its national child population (National Bureau of Statistics of China et al., 2023). Migration can be an empowering as well as a depriving process. On the one hand, by moving from rural, poorer areas to more economically vibrant cities, migration facilitates children’s personal growth, expands their peer network, and brings them more economic opportunities. On the other hand, due to China’s vast urban–rural inequality and host cities’ institutional discrimination against rural migrants, migrant children are marginalized as “villagers in the city” who have restricted access to public schools, substandard educational quality, and low socioeconomic status, while losing meaningful social support from their hometown communities (Lu, 2023).

The double-edged impact of migration warrants resilience promotion among migrant children that utilizes their support resources to cope with challenges. Resilience is “the process and outcome of successfully adapting to difficult or challenging life experiences, especially through mental, emotional,

and behavioral flexibility and adjustment to external and internal demands” (American Psychological Association, 2014). Greater resilience contributes to higher life satisfaction, more positive affect, as well as reduced depression and anxiety (Hu et al., 2015). Resilience is particularly important to migrant children, as they not only need to complete typical developmental tasks such as performing adequately in school and building positive peer relationships, they must also cope with additional stressors such as adjusting to new environments (Motti-Stefanidi, 2019). Research of Chinese migrant children showed that protective factors—such as future aspiration, peer support, and good school experiences—buffered migration’s negative impact (Lu, 2023). Another study found that interpersonal resilience—as indicated by social capital in family, school, peer and community—facilitated better psychosocial outcomes among Chinese migrant youth (Wu, 2017).

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Resilience is a dynamic process of adaptation that can be trained and practiced (Chmitorz et al., 2018). Most resilience promotion programs are facilitated by mental health professionals and provided in group settings. Common intervention strategies target participants' self-efficacy, cognitive appraisal, cognitive flexibility, problem solving, self-esteem, self-regulation, active coping, and social skills (Alvord et al., 2016). Many resilience interventions adopt cognitive behavioral therapy, mindfulness, and psychoeducation approaches (Liu et al., 2020; Pinto et al., 2021). However, a recent systematic review showed that these resilience interventions have yielded smaller effects in children than in adults, possibly because it was easier for adults to access and adhere to intervention content (Liu et al., 2020).

## Virtual Reality-Based Serious Game: A Potential Resilience Promotion Approach

Recent increase in health technology use, particularly during the COVID-19 pandemic, has popularized digital resilience interventions, which have shown positive effects on resilience and mental health (Ang et al., 2022). An emerging form of digital intervention is *serious games*, or videogames for non-entertainment purposes (Diaz-Orueta, 2016), that are facilitated by *virtual reality* (VR), a computer-generated system that creates an immersive environment by combining sensory processes such as visual, audio, and touch (Cullen et al., 2021). Serious games can help the player focus on specific goals and achieve learning outcomes through the ongoing interactions between the player and the game and the sensory stimuli such as graphics and sounds. Therefore, well-designed serious games can facilitate intrinsic learning motivation, promote social skills such as perspective taking, and enhance higher-order cognitive skills such as problem solving (Shute & Ke, 2012). Furthermore, VR can enhance therapeutic effects by replicating everyday scenarios and simulating real-world stressors in a customized virtual environment, which is more controllable by the therapists and more cost-effective than real-life stress exposure (Cullen et al., 2021; Fleming et al., 2017; Li et al., 2014).

Emerging empirical evidence suggests that virtual serious games have promising effects in mental health treatments. In particular, digital games' popularity among young people makes them a highly valuable potential tool for adolescents' mental health intervention (Li et al., 2014). For example, in a study of *Personal Investigator*, one of the first games that integrated three-dimensional design in psychotherapy, Coyle et al. (2005) used a videogame to help clinically referred adolescents address mental health problems such as anxiety and depression. Their pilot study found that the game helped engage adolescents in therapy, kept adolescents focused on therapeutic tasks, and made the therapy process more enjoyable. Navigating the three-dimensional virtual environment also gave adolescents a sense of control in

therapy (Coyle et al., 2005). In another example, a systematic review of 10 randomized trials found game-based digital interventions significantly reduced depression ( $d = -0.47$ ), and games that used VR exposure therapy showed the largest effect ( $d = -0.67$ ; Li et al., 2014).

In terms of intervention delivery, VR-based serious games' effectiveness may vary by several factors. Common factors include *embodiment*, to what extent participants feel the virtual body as if it was their physical body (Kilteni et al., 2012); *presence*, participants' subjective sense of being in the virtual environment (Witmer & Singer, 1998); *immersion*, technical aspects that increase participants' sense of presence in a virtual environment (Wilkinson et al., 2021); *self-efficacy*, participants' beliefs in their ability of performing tasks and behaviors to achieve specific goals (Bandura, 1977), which positively predicts participant motivation and comfort level in virtual environments (Orvis et al., 2009); *engagement*, to what extent participants initiate and complete activities with positive emotions (e.g., interest and curiosity) (Skinner & Belmont, 1993); and *usability*, to what extent participants can achieve goals effectively, efficiently, and satisfactorily (ISO, 2019). In general, better intervention experience for participants would make VR-based digital interventions more effective, but which factors are relevant to migrant adolescents' resilience promotion necessitates further exploration.

## The Current Study

The current study addresses several knowledge gaps. First, although researchers highlighted the importance of resilience to migrant populations, there is a lack of clear interventions specifically for the migrant community. A recent systematic review identified 90 studies that mentioned immigrants and refugees' resilience promotion, among which only five were intervention studies, such as programs to improve immigrants' language skills and health literacy (Ciaramella et al., 2022). Because contextual factors significantly distinguish which types of resilience interventions work for which populations in which settings (Liu et al., 2020), it is important to tailor interventions based on migrant adolescents' life context and test the intervention effectiveness in this under-represented population in resilience intervention research. Moreover, recent research shows promising effects of VR-based serious games, particularly among younger populations, but this new approach has mostly been used in mental health symptom treatments (e.g., reducing depression) rather than preventions (e.g., building resilience), which calls for more strength-based interventions among vulnerable populations.

Second, participant characteristics matter, as there are no universal approaches to resilience interventions. A review of 268 studies found that resilience interventions' outcomes differed by participant age and gender, among other factors. However, there is no general conclusion about these

moderation effects due to the heterogeneity of study populations, contexts, and intervention approaches (Liu et al., 2020). For serious game interventions, levels of familiarity with videogame content and dynamics may interfere with people's access to this medium (Ceranoglu, 2010), which suggests the importance to test moderating effects of participants' previous videogaming experience.

Third, factors that may influence general VR-based serious games' effectiveness—such as level of immersion in the virtual environment, level of participant engagement in the game, and game usability—remain under-explored. Which factors are specifically relevant to migrant adolescents' resilience promotion is unknown.

Using a randomized controlled trial, this study evaluates the effects of a VR-based digital game intervention on enhancing migrant adolescents' psychological resilience. Given the lack of context-specific resilience interventions considering this population's unique adaptation challenges, we developed a customized VR videogame for Chinese migrant adolescents called *The Transfer Student* (see Method section for detailed description). In this story-driven, role-playing game, the participant acts as a student recently moved from a rural area, completing tasks of adapting to a new school in the city. Our hypotheses are:

Hypothesis 1. Compared with the control group, the intervention is more effective in improving migrant adolescents' psychological resilience.

Hypothesis 2. Intervention effectiveness varies by participant characteristics, including age, sex, and previous videogaming experience.

Hypothesis 3. Better intervention experience, such as higher levels of embodiment and immersion in the virtual environment, is related to greater intervention effect.

## Method

### Participants

This study was approved by the Tsinghua Shenzhen International Graduate School Bioethics Committee (#2022-3). The protocol was retrospectively registered in the Chinese Clinical Trial Registry (ChiCTR2400081729). All participants provided informed consent and parental consent. From March to June 2023, we recruited participants from two district public libraries in Shenzhen, a southern Chinese metropolis where migrant children represent almost 70% of students in local schools (Han et al., 2020). Our inclusion criteria were migrant children who are in middle and high school age, do not have local permanent residency, and have no history of adverse reactions to wearing VR devices or playing videogames.

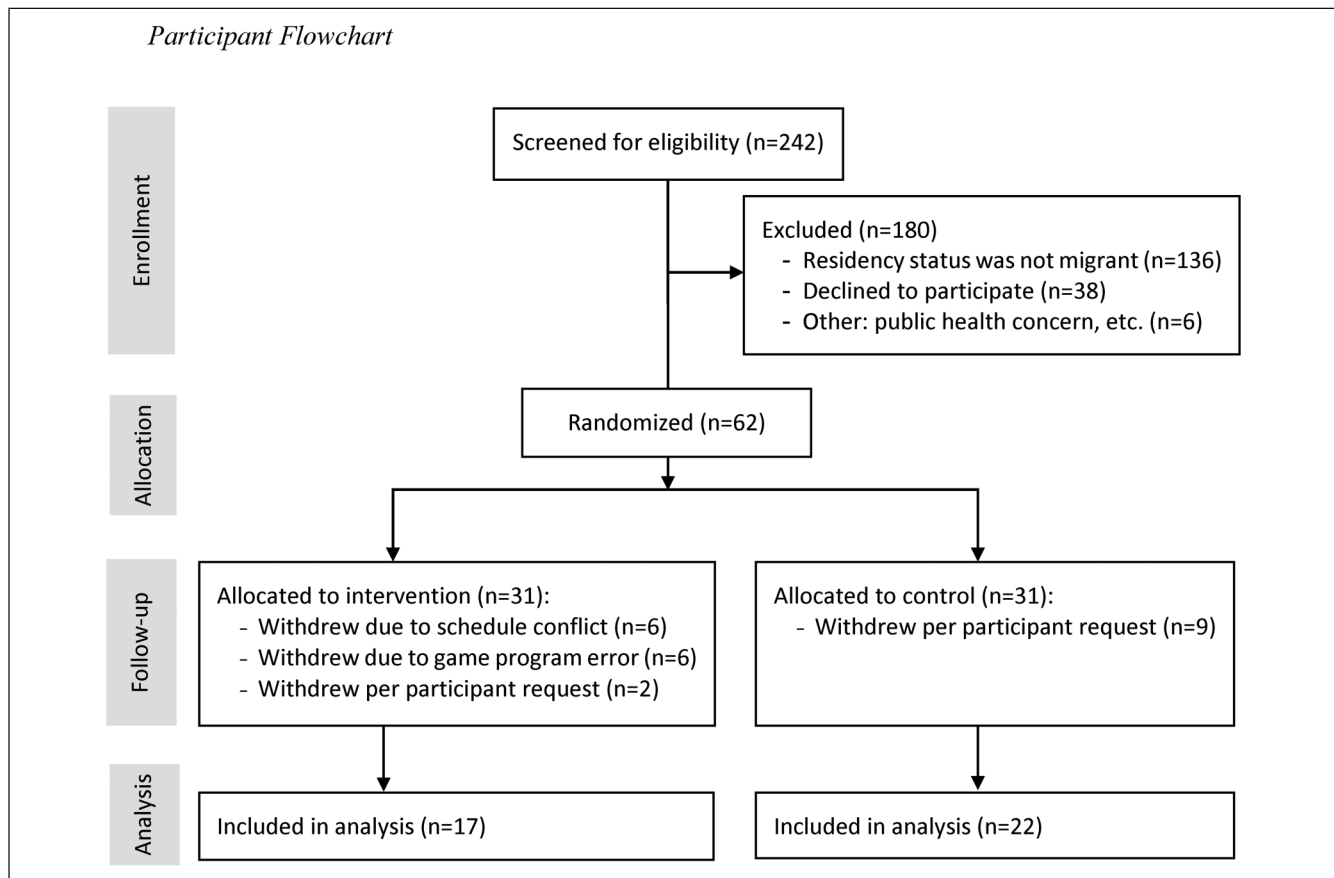
Figure 1 presents the participant flowchart. To achieve a statistical power of 0.8 with a 5% significance level and an

effect size (Cohen's  $d$ ) of 0.48 based on a meta-analysis of resilience-focused RCTs for adolescents (Pinto et al., 2021), 38 participants were required for repeated measures analysis of variance for within-between group interactions (using G-Power 3.1). Assuming a 26% attrition rate based on a previous intervention study of Chinese migrant children's psychosocial adjustment (Lu et al., 2018), we aimed to recruit at least 52 participants. To account for some potential missing values, after eligibility screening, a research assistant randomized 62 participants into an intervention and a control group on a 1:1 ratio using a computerized random number generator. Excluding 23 withdrawn participants, our analytic sample size was 39.

### Intervention

Our research team designed the customized videogame, *The Transfer Student*, based on the Multisystemic Resilience Framework for migrant youth, which argues that migrant youths' resilience is shaped by the interplay among their *intrapersonal* microsystem (e.g., genetic, neurological, and psychological factors such as self-esteem, problem solving, and optimism), *interpersonal* mesosystem (e.g., family relationship, teacher-student interactions, peer relationship, and sense of belonging in school and community), and *institutional* macrosystem (e.g., culture, religion, and social policy) (Wu & Ou, 2021).

The game starts with the participant meeting with the school principal, a virtual character, during which the participant answers questions that assess their preintervention resilience level. The participant then completes a series of tasks: (1) giving a self-introduction in class, which enhances self-efficacy (intrapersonal) and sense of belonging (interpersonal); (2) resolving a misunderstanding and helping a classmate, which requires emotional regulation, problem-solving skills, cognitive flexibility (intrapersonal), and trust of peers (interpersonal); (3) listening to a teacher's story about their migration history, which helps the participant appreciate different perspectives (intrapersonal), build trust with teachers (interpersonal), and identify similarities between urban and rural cultures (institutional); (4) collaborating with a classmate on a challenging task through problem-solving skills, optimism, self-efficacy (intrapersonal), and social skills (interpersonal); (5) breaking up a fight between two classmates through problem-solving skills (intrapersonal) and social skills (interpersonal); (6) volunteering at school, which increases self-esteem (intrapersonal), sense of belonging (interpersonal), and school inclusiveness (institutional); and (7) running for class president, which requires self-efficacy, optimism (intrapersonal), and school inclusiveness (institutional). The game ends with an epilogue, in which the participant meets with the school principal character again and completes the postintervention resilience assessment. Table 1 describes the intervention contents and goals; Supplemental Figure 2 presents visualization examples.



**Figure 1.** Participant Flowchart.

Through this storyline, the intervention targets all three systems of resilience—intrapersonal: cognitive flexibility, optimism, problem solving, self-efficacy, self-esteem, and self-regulation; interpersonal: social skills, trust building with peers and teachers, and sense of belonging; and institutional: school inclusiveness and cultural concordance. Participants cultivate their intrapersonal resilience by coping with simulated daily-life challenges in a VR environment and exploring different coping strategies through completing tasks by trial and error. They also build interpersonal resilience by developing trust and social skills as they interact with virtual characters. Additionally, they develop a sense of school inclusiveness by receiving positive feedback in these virtual interactions and enhance cultural concordance by identifying rural–urban similarities. Overall, the intervention empowers participants to experience successful coping through accumulative goals, from getting to know the school to eventually becoming a class leader. These step-by-step successes reinforce participants’ resilience building over time.

### Procedure

On average, each intervention-group participant played the VR-based game for 35 min. Each control-group participant

watched a VR-based video that lasted for the same length (e.g., scenic relaxation videoclips). This control group design allows participants to experience VR environments with the same equipment without involving any resilience training components, which aimed to minimize bias from participant attrition. We used a single-blind study design, where participants were not aware of group assignment. The intervention was conducted in a quiet library study room with a research team member’s onsite assistance. The experiments used the PICO Neo3 VR headset. Participants completed a brief pretest and post-test at the beginning and the end of the game (or video for the control group), respectively.

### Measures

Our primary outcome was adolescents’ psychological resilience, measured through the Connor–Davidson Resilience Scale-10 (CD-RISC-10) (Connor & Davidson, 2003). The scale includes 10 items about flexibility, self-efficacy, emotional regulation ability, optimism, and stress coping ability. Participants rated each item on a five-point scale from 0 (not at all true) to 4 (true nearly all the time). Higher sum scores indicate greater resilience. This scale has been validated in Chinese populations (Yu & Zhang, 2007) and

**Table 1.** Intervention Protocol.

Chapter	Task	Content	Average Duration	Intervention Goal
1. Prelude: Meeting the school principal	Have a conversation with the principal	The player completes the CD-RISC-10 through the conversation	3min	Pretest
2. Self-introduction	Introduce yourself in class	The player introduces themselves on their first day at the new school	4min	Self-efficacy; sense of belonging
3. Helping a classmate	Find Mei's lost book	A classmate, Mei, thought the player took her book. The player talks to Mei, finds clues of where it was lost, and resolves the misunderstanding	5min	Self-regulation; problem solving; cognitive flexibility; trust building
4. The teacher's story	Learn about the homeroom teacher's life history	Knowing that the player just moved to the city, the teacher shares her own story of moving to the city and joining this school. The player receives teacher's support and changes stereotype of urban residents	4min	Cognitive flexibility; trust building; cultural concordance
5. Toy block collaboration	Work with Ling to build toy blocks	Knowing that the player is new to the school, a classmate, Ling, volunteers to work on a toy block building challenge with the player. They complete the challenge together	3min	Problem solving; optimism; self-efficacy; social skills
6. Breaking up a fight	Stop Di and Feng from fighting	Two students, Di and Feng, got into a fight in the gym. The player talks to both of them and resolves the conflict	4min	Problem solving; social skills
7. Volunteering at school	Organize the cafeteria and the lab	The school cafeteria and lab are messy. The player cleans them up and receives acclaim from schoolmates and teachers	5min	Self-esteem; sense of belonging; school inclusiveness
8. Running for class president	Campaign and run for class president	The player analyzes their own values and strengths, runs for class president, and achieves the end-goal	4min	Self-efficacy; optimism; school inclusiveness
9. Epilogue: Meeting the school principal again	Have a conversation with the principal	The player completes the CD-RISC-10 through the conversation	3min	Post-test

CD-RISC-10 = Connor-Davidson Resilience Scale-10.

showed adequate reliability in Chinese adolescents (She et al., 2020). We adapted the items based on the intervention context. For instance, the item “can deal with whatever comes” was adapted to “can deal with whatever happens in school” (Cronbach's  $\alpha = 0.90$  in our study).

Our secondary outcome was adolescents' experience during the intervention, which was measured through real-time behavioral data collected throughout the game and included six domains: embodiment, immersion, presence, self-efficacy, engagement, and usability. First, *embodiment* was measured by how long it took the participant to complete a toy block building task, which requires real-virtual hand coordination (Supplemental Figure 3). Faster completion indicates more movement consistency, or greater embodiment. Second, *immersion* was measured by how much time the participant's eyes focused on areas-of-interest (e.g., the virtual characters during conversations) through eye movement tracking (Supplemental Figure 4). Longer eye-focus time indicates greater immersion. Third, *presence* was measured by the participant's distance from virtual characters. Shorter

distance indicates stronger presence in the virtual *social* environment. Another indicator was the proportion of participants' self-initiated moves (e.g., picking up a book) to total number of moves. More self-initiated moves indicate stronger sense of presence in the virtual *physical* environment.

Fourth, *self-efficacy* was assessed through six self-rated questions. For instance, when a teacher character asks, “How confident are you in introducing yourself to the class?” The participant responds on a scale of 1 (I don't think I can do it) to 4 (I'm very confident). Higher scores indicate greater self-efficacy. Fifth, *engagement* was measured by the percentages of explored virtual areas (Supplemental Figure 5) and completed side tasks. More area exploration and more side task completion indicate greater engagement. Sixth, *usability* was measured by how long it took the participant to finish the game tutorial and error rate (the number of erroneous moves divided by all moves). Faster tutorial completion and lower error rates indicate higher intervention usability. In addition, participants answered brief demographic questions, including



their age (in years), sex (1 = male, 0 = female), and previous videogaming experience (1 = often played videogames, 0 = never or rarely played).

## Data Analyses

We used generalized least squares regression of participants' resilience scores on their group (intervention vs. control), time (pretest vs. post-test), and group  $\times$  time interaction, while clustering standard errors by individuals to account for the potential correlation between each individual's pretest and post-test scores. We also conducted subgroup analyses by sex, age group, and whether the participant played videogames before. We followed Borenstein et al.'s (2009) and Morris' (2008) recommendations to calculate effect size based on standardized mean difference in pretest–post-test-control designs. The effect size is denoted by Hedge's  $g$ , which corrects for bias in small samples. Last, we used principal component analysis to identify underlying intervention experience variables, followed by  $t$  tests to compare how intervention effectiveness (i.e., resilience improvements) varied by participants' intervention experience. Stata 18 was used for all analyses.

## Results

As shown in Table 2, the participants were mostly male (72%), average aged 14 years (range 12–17), moved to Shenzhen before elementary school (62%), and never or rarely played videogames (54%). The intervention and control groups' baseline characteristics did not differ significantly.

Pre–post resilience mean score comparisons and regression analyses supported our hypothesis 1: Compared with the control group, the intervention was more effective in improving migrant adolescents' psychological resilience. As shown in Supplemental Table 6, the intervention group's resilience scores increased from pretest ( $M = 26.12$ ,  $SD = 3.85$ ) to post-test ( $M = 28.47$ ,  $SD = 3.87$ ), whereas the control group did not (pretest  $M = 26.05$ ,  $SD = 5.77$ ; post-test  $M = 26$ ,  $SD = 5.79$ ). As shown in Table 3, the group  $\times$  time interaction was significant,  $B = 2.4$ ,  $SE = 0.64$ ,  $p = .0006$ . In other words, compared with the control group, the intervention group's resilience scores increased by 2.4 more points from pretest to post-test. The intervention showed a moderate effect size, Hedge's  $g = 0.47$ ,  $SE = 0.32$ .

Subgroup analyses supported our hypothesis 2: Intervention effectiveness varied by participant characteristics, including age, sex, and previous videogaming experience. As shown in Supplemental Table 6, all subgroups of intervention participants' resilience scores significantly increased from pretest to post-test, whereas subgroups of control participants did not. Table 3 shows that the intervention seemed more effective for female adolescents ( $g = 0.49$ ,  $SE = 0.56$ ) than male ( $g = 0.43$ ,  $SE = 0.38$ ); older adolescents

( $g = 0.61$ ,  $SE = 0.52$ ) than early adolescents ( $g = 0.36$ ,  $SE = 0.39$ ); and participants without prior gaming experience ( $g = 0.60$ ,  $SE = 0.44$ ) than those with prior gaming experience ( $g = 0.31$ ,  $SE = 0.45$ ). Our post hoc power analyses showed that the observed power was acceptable (above 0.80) for full-sample analysis and subgroup analyses of female, late adolescents, and participants without prior gaming experience. However, the statistic power was below 0.80 for male, early adolescents, and those with prior gaming experience. Therefore, these subgroup analyses should be interpreted with caution given their limited power.

Last, analyses of real-time behavioral data partially supported our hypothesis 3: Better intervention experience was related to greater intervention effect. Notably, this relationship was only found for immersion in the virtual environment but not other variables. As shown in Table 4, our principal component analysis identified three underlying components of participants' intervention experience: performance, immersion, and exploration. First, *performance* included four variables that indicate how efficiently or confidently the participant achieves tasks: block building completion time, self-efficacy, tutorial completion time, and error rate. Second, *immersion* included three variables that indicate to what extent the participant was immersed in the physical and social virtual environment: eyes focus, distance to virtual characters, and interaction with objects. Third, *exploration* included two variables that indicate the participant's autonomous exploration in the virtual environment: map exploration and side quest completion.

Table 5 shows that participants' immersion was significantly related to their resilience improvements,  $t = 2.16$ ,  $p = .047$ . On average, highly immersed participants increased resilience by 3.43 points from pretest to post-test ( $SD = 2.15$ ), whereas low-immersed participants only increased by 1.6 points ( $SD = 1.35$ ). The other two intervention experience components—performance and exploration—were not significantly related to intervention effects.

## Discussion and Applications to Practice

Our findings support the effectiveness of using VR technology and digital game intervention to enhance resilience in disadvantaged migrant adolescents who face adaptation challenges. Although increasing VR interventions and serious games have been used for treating mental health symptoms, such as depression (Fleming et al., 2017), anxiety, and posttraumatic stress disorder (Carl et al., 2019), there is limited research of VR serious games that focus on prevention, such as building coping skills in school-children. In contrast to deficit-based treatment models, resilience-promotion interventions focus on building strengths, including self-efficacy, self-regulation, and problem solving (Alvord et al., 2016). Our results suggest that these strength-building processes can be effectively

**Table 2.** Baseline Characteristics and Group Comparison.

	Mean or N (% or SD)			Group Comparison		
	Total (N = 39)	Intervention (n = 17)	Control (n = 22)	$\chi^2$	t	p
Resilience	26.08 (4.97)	26.12 (3.85)	26.05 (5.77)		−0.04	.96
Sex						
Male	28 (72%)	12 (71%)	16 (73%)	0.02		.88
Female	11 (28%)	5 (29%)	6 (27%)			
Age	14.05 (1.28)	14.18 (1.47)	13.95 (1.13)		−0.53	.60
Timing of migration						
During school age	15 (38%)	7 (41%)	8 (36%)	0.09		.76
Before elementary school	24 (62%)	10 (59%)	14 (64%)			
Previous videogaming experience						
Experienced	18 (46%)	9 (53%)	9 (41%)	0.56		.46
Inexperienced/Never	21 (54%)	8 (47%)	13 (59%)			

developed through a digital game format in a virtual environment.

Our intervention effect may be attributed to multiple factors. Previous research suggested that psychological resilience can be improved through repeated brief exposure to negative experiences in situations that allow people to successfully cope with the experience (Rutter, 2013). In line with this argument, our intervention exposes children to brief stress experiences by simulating common challenges in a virtual environment, such as overcoming peer problems and navigating new school environments.

Moreover, this VR-based serious game intervention approach appears to be particularly conducive to adolescents, given our relatively large effect size ( $g = 0.47$ ) compared with previous intervention approaches. For instance, a recent meta-analysis of 197 studies showed a smaller average effect on individuals' resilience across age groups ( $g = 0.44$ ), including an even smaller effect on children and adolescents ( $g = 0.30$ ) (Liu et al., 2020). It is possible that a VR-based digital game intervention is more accessible to adolescents due to its brevity and schedule flexibility. Its interactive, experiential learning format may also help adolescents follow instructions more easily, which may be more appealing to younger populations than traditional modalities such as psychoeducation.

We found subgroup differences that warrant further exploration. Our intervention seems particularly effective for female, older adolescents, and those without previous gaming experience. The gender difference is consistent with Liu et al.'s (2020) meta-analysis of resilience interventions, which found larger effect on female ( $g = 0.34$ ) and mixed-sex groups ( $g = 0.45$ ) than male ( $g = 0.13$ ).

In terms of age difference, whereas our intervention showed larger effect on older adolescents, a previous review of 20 digital resilience trainings (the majority of which focused on adults) showed that participants' age did not significantly predict resilience outcomes (Ang et al., 2022). A possible reason of our result is that older Chinese

adolescents have increasing academic stress, more sleeping problems, and more worries about their future than their younger counterparts (Yu et al., 2022). Resilience promotion can therefore help older adolescents better cope with these stressors and yield greater improvements.

In addition, the intervention appeared more effective for participants without prior gaming experience. Because people become more aroused and broadly focused when experiencing new environments (Witmer & Singer, 1998), adolescents without prior digital gaming experience may find the intervention more interesting, yielding a larger effect. Although previous research raised the concern that unfamiliarity with digital environments could impede potential participants' access to this medium (Ceranoglu, 2010), our results indicate that a VR-based digital game approach may potentially extend mental health interventions to populations who may not access help otherwise (Fleming et al., 2017), such as adolescents. However, the small subgroup sample sizes render our analyses exploratory and our results tentative. Future replication studies should use larger samples to assess the effects of gender, age, and prior gaming experience.

Our findings also highlight the importance of immersive intervention experience. Previous research suggests that immersion makes people directly interact with the environment and feel themselves as part of it (Witmer & Singer, 1998). To enhance participants' immersion, we emphasized dynamic interactions with the virtual environment, including physical interactions (e.g., virtual hands that simulate real body effects) and social interactions (e.g., dialogs with virtual characters). We also used real-life settings relevant to adolescents' daily lives, such as classrooms and school cafeteria, which involved detailed designs such as adjusting lighting and props (e.g., blackboard, desk) (Supplemental Figures 6 and 7). All these design features aim to ensure an immersive experience, which influences intervention effectiveness (detailed system requirements and software specifications are available upon request).

**Table 3.** Regression Analysis of Intervention Effect on Resilience and Subgroup Analysis by Sex, Age, and Previous Game Experience.

	Subgroup Analysis																				
	Full Sample (N = 39)			Male Adolescent (n = 28)			Female Adolescent (n = 11)			Early Adolescent <sup>b</sup> (n = 25)			Late Adolescent <sup>b</sup> (n = 14)			Have Gaming Experience (n = 18)			No Gaming Experience (n = 21)		
	B (SE) <sup>a</sup>	p		B (SE)	p		B (SE)	p		B (SE)	p		B (SE)	p		B (SE)	p		B (SE)	p	
Intervention	0.07 (1.56)	.96		0.33 (1.49)	.83		-0.43 (4.38)	.92		0.25 (2.09)	.90		-0.25 (2.46)	.92		-3 (2.11)	.17		2.44 (2.10)	.26	
Time	-0.05 (0.45)	.92		0.13 (0.56)	.83		-0.5 (0.74)	.52		0.21 (0.62)	.73		-0.5 (0.62)	.43		0.44 (0.74)	.56		-0.38 (0.57)	.51	
Intervention × time	2.40 (0.64)	.0006		1.71 (0.72)	.02		4.1 (1.28)	.009		1.97 (0.83)	.03		3.17 (1.08)	.01		1.44 (0.90)	.13		3.26 (0.97)	.003	
Constant <sup>c</sup>	26.05 (1.24)			26.5 (0.95)			24.83 (4.12)			25.93 (1.63)			26.25 (2.09)			28.56 (1.52)			24.31 (1.72)		
Effect size <sup>d</sup>	0.47 (0.32)			0.43 (0.38)			0.49 (0.56)			0.36 (0.39)			0.61 (0.52)			0.31 (0.45)			0.60 (0.44)		

Note.

<sup>a</sup>Robust standard errors (SE) in parentheses adjusted for clusters in each individual.

<sup>b</sup>Early adolescents: age 12 to 14; late adolescents: age 15 to 17.

<sup>c</sup>p < .001 for constant in all analyses.

<sup>d</sup>Effect size is indicated by the standardized mean difference (SMD), calculated by the difference between the intervention group's pre-post mean change and the control group's pre-post mean change, divided by the pooled pretest standard deviation, which provides a more precise estimate of the sampling variance (Morris, 2008). The SMD was adjusted to correct small-sample bias. The adjusted effect size is denoted by Hedge's g.

We use school as the virtual intervention setting because schools are a key context for migrant children's development and adjustment (Motti-Stefanidi, 2019). Experiencing success in school activities may be a universal resilience process that fosters children's personal attributes such as self-agency (Rutter, 2013). Supporting this argument, our results suggest that accomplishing school tasks in a virtual environment did improve migrant adolescents' resilience. However, because resilience is context specific (Rutter, 2013), there is no one-size-fits-all intervention approach. Resilience interventions' effects depend on the population, intervention setting, and intervention type (Liu et al., 2020). Therefore, future interventions should tailor their content to the specific needs of their target population. For instance, while our study focuses on migrant adolescents' adaptation in school settings, future research may extend resilience promotion to family and community environments, and future interventions for non-migrant students may target different intervention goals such as academic stress.

Our study has several limitations. First, we used a single-blind design because the interventionist needed to assist with the VR equipment on site. We also used a control condition (viewing scenic videoclips) that appears weaker in participant engagement and immersion due to resource constraints. The differences in engagement levels may have contributed to intervention outcome difference. Nonetheless, the novelty effect of the unfamiliar VR videogame experience can also impose additional cognitive load on participants, causing more distractions and lower learning outcomes (Miguel-Alonso et al., 2024). If resources allow, future research may minimize risks of bias by using separate research assistants in a double-blind design; using a more active control condition, such as playing a nonresilience-related VR game; and adding a tutorial for all participants to mitigate the novelty effect during their initial VR experience.

Second, given our small, homogeneous sample (Chinese migrant adolescents), our findings warrant further replication in larger and more diverse samples, such as migrant adolescents from other cultures and nonmigrant adolescents. In addition, because the pretest, intervention, and post-test were done in one sitting, participants' baseline data were not collected if they did not show up for the intervention, and participants' data were not stored if they withdrew before the intervention reached the end. As a result, while the high dropout rate (particularly in the intervention group) can introduce potential biases, we could not analyze the dropout participants' characteristics. Future research can redesign the intervention by allowing interim data collection (such as storing data after each game chapter) and adding an exit assessment before participants leave the virtual environment if they wish to withdraw.

Third, while we used real-time behavioral data to objectively measure participants' intervention experience (e.g., using eye movement tracking to assess immersion), future studies may add self-reported surveys to evaluate



**Table 4.** Factor Loading in Principal Component Analysis of Game Experience Items Among Intervention-Group Participants (Rotated, N = 17).

Variables <sup>a</sup>	Component 1: Performance	Component 2: Immersion	Component 3: Exploration
Block building completion time <sup>b</sup>	.47		
Self-efficacy	.43		
Tutorial completion time <sup>b</sup>	.46		
Error rate <sup>b</sup>	.50		
Eyes focused on interest areas		.56	
Distance to virtual characters <sup>b</sup>		-.50	
Extent of interaction		.59	
Virtual area exploration			.51
Side task completion			.72

Note. <sup>a</sup>All variables were standardized.

<sup>b</sup>Reverse coded variables when creating index.

**Table 5.** t-Test Results of Resilience Pre-Post Change Scores by Game Experience Components.

	n	Resilience Change Mean (SD)	Group Comparison	
			t	p
Performance				
Below average	9	2.22 (2.05)	0.29	.77
Above average	8	2.5 (1.85)		
Immersion				
Below average	10	1.6 (1.35)	2.16	.047
Above average	7	3.43 (2.15)		
Exploration				
Below average	11	2.09 (1.87)	0.76	.46
Above average	6	2.83 (2.04)		

participants' subjective experiences. Correlating these objective measures with self-reported measures, such as perceived immersion and engagement, will provide a more comprehensive understanding of participants' experience.

Last, while we only assessed participants' resilience at pretest and post-test, future research may evaluate long-term effects with follow-up assessments. While we used CD-RISC-10 because of its brevity, future studies may use

additional domain-specific measures such as the 28-item Child and Youth Resilience Measure, which includes individual capacities, relationships with caregivers, and contextual factors that facilitate sense of belonging (Ungar & Liebenberg, 2011). The underlying mechanisms of resilience improvement, such as increase in self-efficacy and sense of belonging, are also worth further exploration.

Despite these limitations, our findings preliminarily support the feasibility and effectiveness of a brief VR-based digital intervention in promoting Chinese migrant adolescents' resilience. Our results suggest that schools' integrating tailor-made VR-based digital games into their psychoeducation curricula or extracurricular activities could promote migrant students' resilience. As our game is relatively brief, self-paced, and self-guided, this digital intervention approach may be cost-effective for schools that lack manpower or capacity in psychoeducation or school counseling. The standardized game design and game contents make it easy to replicate this intervention across schools. The digital format also allows large-scale implementation across geographic locations. Therefore, this intervention can be an efficient way to enhance migrant students' resilience. Notably, Chinese migrant students are often enrolled in lower-resourced schools compared with urban students (Lu, 2023). As digital devices become increasingly popular in educational settings, local governments should allocate more resources to schools enrolling many migrant students, such as financial support to purchase VR equipment, to bridge the digital divide and mitigate mental health inequalities.

## Author Contributions

SL was involved in formal analysis, methodology, and writing—original draft; SN in conceptualization, funding acquisition, project administration, and writing—review; and TB in conceptualization, data curation, investigation, and writing—original draft.

## Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Informed Consent

All participants provided informed consent and parental consent.

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## Data Availability

This study is retrospectively registered with the Chinese Clinical Trial Registry, ChiCTR2400081729, date of registration: March 11, 2024. Deidentified participant data are available to researchers who provide a methodologically sound proposal for use and on reasonable request to the corresponding author.

## Supplemental Material

Supplemental material for this article is available online.

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