Formation of Information Culture in Visually Impaired Adolescents through Innovative Technologies

Shynar Ussenbayeva[1], Laura Butabayeva[2,*], Aigerim Makhmetova[3], Aigerim Chulembayeva[4], and Saule Bulabayeva[5]

[1]Department of Special Pedagogy, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan
[2]Center for Inclusive Education, National Academy of Education named after Y. Altynsarin, Astana, Kazakhstan
[3]Department of Special Pedagogy, Abai Kazakh National Pedagogical University, Almaty, Kazakhstan
[4]Laboratory of Vocational Education for Children (Persons) with Disabilities, National Scientific and Practical Center for the Development of Special and Inclusive Education, Almaty, Kazakhstan
[5]Department of Special Pedagogy, Kazakh National Women's Teacher Training University, Almaty, Kazakhstan
Email: shinar.usenbaeva@gmail.com (S.U.); l.butabayeva@uba.edu.kz (L.B.); aigerim_amankizi@mail.ru (A.M.); gerain-87@mail.ru (A.C.); bulabaevas@mail.ru (S.B.)
*Corresponding author
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***Abstract*—This study explores the role of innovative technologies in supporting the autonomous development of information culture among adolescents with visual impairments—a population that frequently encounters limited access to digital literacy resources. The aim of the research was to evaluate the extent to which such technologies, particularly those incorporating artificial intelligence, contribute to the development of information literacy, critical thinking, and learner autonomy within this group. A total of 116 adolescents with varying degrees of visual impairment were divided into two groups: experimental and control. The experimental group engaged with adaptive AI-based educational tools, while the control group followed conventional instructional methods. ANOVA was employed to assess differences between groups, revealing that the experimental group significantly outperformed the control group: mean scores in information literacy were 78.3 versus 59.2, critical thinking skills reached 74.5 compared to 55, and learner autonomy was rated at 4.2 out of 5 versus 3.1. These findings underscore the potential of innovative technologies to foster a more inclusive and effective learning environment for adolescents with visual impairments.**

***Keywords*—information literacy, critical thinking, artificial intelligence, special education, adaptive educational technologies, inclusive learning**

I. Introduction

In the context of rapid advancements in digital technology and the informatization of society, the issue of information literacy has become particularly significant. Information literacy encompasses the ability to utilize information sources, think critically, and analyze and evaluate the reliability of acquired data [1]. A crucial element in this process is the independent development of information culture, which refers to an individual's ability to acquire the knowledge and skills necessary for information-related tasks [2]. These abilities are particularly important for visually impaired individuals who cannot access information sources due to physical limitations [3], and it is necessary to apply the latest information technologies to meet the needs of this category of users. One innovative trend supporting the independent development of information culture for visually impaired individuals is the integration of Artificial Intelligence (AI) technology, which automates the process of accessing information, facilitates identification and processing, and creates an inclusive environment [4]. Text-to-speech software, image recognition technology, and AI for information analysis and decision-making support open new opportunities for visually impaired individuals [5]. However, despite advancements in this field, questions remain regarding the effectiveness of these technologies in promoting access to basic information and fostering an inclusive information culture.

The fundamental issue lies in the fact that while innovative technologies significantly enhance visually impaired individuals' access to information resources, there has been insufficient research on their impact on the development of information utilization skills. Since AI can perform a significant portion of the analytical tasks typically carried out by humans, there is a risk that process automation may reduce users' autonomy and critical thinking abilities [6]. At the same time, it has been argued that AI technology, when appropriately integrated into educational and information processes, can enhance the autonomy and creativity of individuals who are visually impaired [7].

The motivation for new research stems from the need to better understand how innovative technologies can not only facilitate practical access to information but also enhance the fundamental skills required to analyze and utilize such information. As innovative technologies are rapidly integrated into all areas of life, including education and computing, it is crucial that these processes are inclusive of all types of users, including those with visual impairments. Ensuring that all citizens, regardless of physical disabilities, have equal access to information and educational resources is a major challenge for modern science and technology.

II. Literature Review

Much of current scientific research focuses on the application of innovative technologies to improve access to information for visually impaired people; however, there is still a lack of research on the impact of these technologies on the development of information literacy (a holistic process that includes not only access to information but also the ability to think critically, evaluate information and use it effectively) [8, 9]. The potential of innovative technologies to support visually impaired people is highlighted, with key areas being the development and implementation of automatic text-to-speech software solutions and object and

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face recognition technologies. These technologies can significantly improve the accessibility of information for visually impaired people [10–12]. Attention is also paid to the impact of innovative technologies on social inclusion and it is emphasised that new technologies create conditions that broaden the participation of people with visual impairments in social and educational processes [5, 13, 14]. An important issue often mentioned in the literature is the adaptation of innovative technologies to the individual needs of users, as researchers stress that universal solutions are not always effective, as different degrees of visual impairment require different technological approaches [15, 16]. Furthermore, the usability of these technologies is a crucial aspect, as studies confirm that the effectiveness of AI tools is significantly enhanced when they are tailored to the abilities and needs of specific users [17].

Despite the general positive impact of AI techniques, there are some inconsistencies in theoretical approaches to their use. A major challenge is that some studies tend to overestimate the role of technology in facilitating access to information for visually impaired people, while underestimating the importance of developing independent information processing and critical thinking skills. For example, it has been argued that innovative technologies may evolve to the extent that they automate the process of accessing information to the extent that users do not need to actively engage in information search and analysis, which may limit their information literacy skills [15, 18]. Another contradiction concerns the methodological approach to evaluating the effectiveness of these technologies. Studies are mainly based on quantitative evaluation methods that measure accessibility, processing time, and user satisfaction; however, these methods generally fail to assess the impact of the technology on the development of analytical and critical thinking and information literacy skills [12].

On the other hand, qualitative studies focus on users' subjective experiences, which makes it difficult to objectively assess the impact of technology [19]. Moreover, most studies focus on technical aspects, neglecting issues related to the long-term impact of technology on users' information literacy development. Another important limitation is related to the interdisciplinary nature of the research. Most research is purely technical and closely related to the field of information technology, which prevents integration with social sciences, education, and cognitive psychology [20]. There is a lack of research that explores the combination of technical aspects and the cognitive and social processes involved in developing autonomous information literacy using AI. Most research focuses on facilitating access to information, but not enough attention is given to developing the skills needed to analyse, evaluate, and use information [17]. It is important to bridge the gap between information access skills and the skills needed to manage information autonomously. This study aims to bridge this gap by applying a multidisciplinary approach to examine innovative technologies in the context of information literacy development for people with visual impairments. This study examines how the introduction of advanced technology solutions affects the development of independent information literacy among people with visual impairments. It also explores how these tools can serve as catalysts for cultivating the foundational skills necessary for thoughtful interpretation, discerning evaluation, and strategic application of data.

The core proposition is that carefully designing advanced technologies and seamlessly integrating them into educational and information systems can not only open pathways to knowledge access for individuals with visual impairments but also promote the development of information literacy that extends into critical thinking, analytical depth, and evaluative judgment. Conversely, developing AI systems without conscious adaptation or awareness of cognitive maturity can lead to reduced user confidence in navigating complex information environments.

III. Materials and Methods

A. Study Design

A quasi-experimental mixed-methods design was employed, combining quantitative (pre- and post-intervention testing) and qualitative (thematic analysis of observational and interview data) approaches. The quasi-experimental nature of the study was determined by ethical and practical constraints that made random assignment of participants unfeasible, as they were drawn from naturally existing educational groups within a specialized inclusive institution. All instructional sessions were conducted in standard classrooms equipped with specialized digital devices adapted for students with varying degrees of visual impairment.

The independent variable was the type of technological support (AI-based adaptive tools versus traditional assistive tools). The dependent variables included levels of information literacy, critical thinking, and student autonomy. The study proceeded through five main phases: participant recruitment and consent (May 1–10, 2024), baseline assessment (May 11–13, 2024), intervention (May 14–July 9, 2024), and post-intervention assessment (July 10–12, 2024).

B. Participants

The empirical component of the study involved 116 adolescents (aged 13 to 17; $M = 15.1$, SD = 1.2) enrolled at the Center for Inclusive Education of the Y. Altynsarin National Academy of Education in Astana, Republic of Kazakhstan. All participants had a diagnosed visual impairment, ranging from moderate visual acuity loss to complete congenital or acquired blindness. Of the total sample, 59 were male (50.9%) and 57 were female (49.1%).

Ethnic composition included Kazakhs ($n = 87$; 75.0%), Russians ($n = 21$; 18.1%), and other ethnic minorities such as Uzbeks, Uighurs, and Tatars ($n = 8$; 6.9%). In terms of socioeconomic status, most participants came from middle-income and working-class households, based on reported household income and parental employment. The majority (68.1%) reported an average monthly household income, while approximately 24.1% received state social assistance for families with children with disabilities.

Parental education levels varied: 39.7% of parents had vocational or technical education, 36.2% held higher education degrees, and 24.1% had completed only secondary education. A significant portion of families (61.2%) reported a monolingual Kazakh-speaking environment, 27.6% were bilingual (Kazakh-Russian), and 11.2% primarily spoke Russian or other minority languages.

A purposive sampling strategy was employed in close collaboration with institutional administrators and educational coordinators at the Center. Inclusion criteria were as follows:

- Official medical documentation confirming visual impairment;
- Enrollment in formal education;
- Prior experience with digital devices (smartphones, tablets, or computers);
- Absence of diagnosed cognitive comorbidities or neurodevelopmental disorders that might impair task comprehension.

Participant recruitment was conducted through informational sessions for students and parents, distribution of consent forms via school communication channels, and follow-up consultations with guardians. Participants were non-randomly but evenly assigned to either the experimental or control group (58 individuals each), ensuring proportional representation by age, gender, and type of visual impairment.

C. Procedure

Group 1 (experimental) utilized adaptive AI techniques, incorporating tools for data analysis and filtration, alongside software designed to interpret images, text, and audio information. These technologies were specifically designed to enhance users' autonomy while working with information.

The training programme lasted eight weeks, from 14 May 2024 to 9 July 2024, and included weekly sessions focused on using innovative technologies to address a range of information tasks, including research, analysis, evaluation, and information production. Participants in this group received individualized recommendations and guidance on the use of technologies. One of the primary mechanisms was adaptive artificial intelligence, which had the ability to adjust to users' individual needs and provide personalized recommendations based on their interactions with information. Machine learning algorithms were used for analyzing and filtering information in software products such as TensorFlow and PyTorch. Tools like Google Vision API were employed for image recognition, and OpenAI GPT-3 was utilized for working with text. The Google Vision API enables rapid recognition of objects, text, and other elements within images, facilitating access to information for users with disabilities. OpenAI GPT-3 is used for automatic text generation and performing complex natural language processing tasks, such as translation, editing, or creating new texts based on data. For audio processing, Google Cloud Speech-to-Text and IBM Watson Speech-to-Text were used for converting speech to text and interacting with users through voice commands.

Group 2 (Control) employed standard technology that provided basic access to information, such as text-to-speech software and Braille fonts, without the additional AI capabilities for analysis or information processing. The curriculum for this group also spanned eight weeks but focused solely on access to this information.

D. Assessment Instruments

To evaluate participants' information culture and literacy, a localized and adapted version of the Test of Information Literacy Skills (TILS) was administered. The original TILS conceptualizes information literacy as the ability to effectively and ethically locate, evaluate, and use information. For the purposes of this study, the instrument was translated into Kazakh and Russian, taking into account cultural and contextual specificities. For adolescents with visual impairments, the test was delivered in an audio format, pre-recorded and segmented into manageable portions with prompts for auditory responses. The test consisted of 30 multiple-choice questions and 5 scenario-based tasks covering areas such as source evaluation, information synthesis, ethical data usage, and digital navigation. The adapted version demonstrated high internal consistency (Cronbach's $\alpha = 0.89$).

To assess critical thinking disposition, a validated translation of the Critical Thinking Disposition Inventory–Chinese Version (CTDI-CV) was used. This instrument measures participants' readiness for critical thinking, logical reasoning, and evidence-based judgment across key domains such as truth-seeking, open-mindedness, analyticity, systematicity, and cognitive maturity. The Kazakh and Russian versions used in this study were culturally validated adaptations previously employed in secondary education contexts. The inventory consists of 75 Likert-scale items ranging from 1 (strongly disagree) to 6 (strongly agree). For students with visual impairments, administration was conducted in a manner similar to the TILS, using structured audio recordings. Reliability coefficients for the localized versions exceeded the acceptable threshold (Cronbach's $\alpha = 0.91$), and confirmatory factor analysis supported the original seven-factor structure.

To measure students' level of autonomy in the learning process, the Self-Directed Learning Readiness Scale (SDLRS) was utilized (Table A1). This diagnostic tool assesses general attitudes and motivational orientations toward independent knowledge acquisition. The SDLRS included 19 statements addressing core components of self-directed learning, including motivational competence, cognitive self-reflection, self-regulatory and planning skills, avoidance of external dependency, and positive engagement with learning challenges. Each item was rated on a 5-point Likert scale, where 1 indicated "almost never true of me" and 5 indicated "almost always true of me." An audio version was developed with clearly segmented intonation to guide participants through the questionnaire structure without relying on visual cues. The scale was translated and adapted according to internationally accepted guidelines for cross-cultural questionnaire validation. A preliminary pilot study demonstrated high internal consistency (Cronbach's $\alpha = 0.88$) and confirmed the scale's alignment with the established three-dimensional model of self-directed learning.

E. Data Collection

All assessments were conducted in small groups (3–5 students) within a quiet classroom setting, overseen by trained facilitators fluent in both Kazakh and Russian and experienced in inclusive education practices. Facilitators did not interfere with the content of participants' responses but provided assistance upon request. For students with severe visual impairments or comorbid disabilities, additional accessibility options were made available, including oral dictation of responses to a designated research assistant, under strict confidentiality and neutrality protocols. All response data were anonymized and securely stored in compliance with ethical guidelines established by the Institutional Research Ethics Committee. Participants were informed that their results would not affect their academic standing and that all data would be used exclusively for research purposes.

F. Data Analysis

The collected data were analyzed using statistical methods for the quantitative evaluation of test and questionnaire results, as well as qualitative analysis methods to interpret data from observations and interviews. To compare the results between groups, Analysis of Variance (ANOVA) was employed, allowing for the determination of differences in levels of autonomy and information culture between the experimental and control groups. Qualitative analysis of interview and observation data was conducted using thematic analysis, enabling the identification of key themes and patterns in participants' experiences with the technologies.

IV. Result and Discussion

To assess the information culture of participants before and after the educational program, standardized tests were administered to measure their ability to locate, analyze, critically evaluate, and utilize information. The average score for each group was calculated prior to the commencement of the program (pre-test) and following its completion (post-test).

Table 1. Average scores of information culture before and after training

Group	Pre-test (M ± SD)	Post-test (M ± SD)	ΔM
Experimental	42.8 ± 6.2	78.3 ± 5.4	+35.5
Control	41.9 ± 5.9	59.2 ± 6.7	+17.3

As shown in Table 1, both groups demonstrated an increase in information literacy levels after the training. The group that used AI-based technology tools showed significantly greater improvement compared to the control group, indicating that the technology products had a significant impact on the development of basic information analysis skills. Information autonomy was evaluated using a questionnaire that assessed the following aspects: the ability to independently search for information, the ability to independently analyze and evaluate information, and the ability to use acquired information to solve specific tasks.

The assessment was conducted on a scale from 1 to 5 (1—minimal level of independence, 5—maximum level of independence).

Table 2. Level of participants' autonomy before and after training

Group	Pre-test (M ± SD)	Post-test (M ± SD)	ΔM
Experimental	2.1 ± 0.8	4.2 ± 0.6	+2.1
Control	2.0 ± 0.9	3.1 ± 0.7	+1.1

According to the data presented in Table 2, the autonomy of participants in the experimental group significantly increased after the use of the innovative technology ($\Delta M = 2.1$). Improvements were also observed in the control group, although they were less pronounced ($\Delta M = 1.1$). The t-test indicated that the difference between the groups was statistically significant ($t(58) = 4.23$, $p < 0.01$).

Table 3. Level of critical thinking before and after training

Group	Pre-test (M ± SD)	Post-test (M ± SD)	ΔM
Experimental	38.7 ± 5.8	74.5 ± 6.1	+35.8
Control	39.2 ± 6.0	55.9 ± 5.9	+16.7

As shown in Table 3, critical thinking skills improved in both groups after completing the program; however, participants in the experimental group showed significantly greater improvement ($\Delta M = 35.8$). Therefore, AI techniques are important for improving critical thinking skills in visually impaired participants. The observations revealed several important aspects: Participants in the experimental group used the new AI features more frequently to search for additional information and demonstrated a higher level of autonomy in complex information processing tasks, especially when dealing with large data sets. Despite having access to standardised AI, participants in the control group often asked for help from third parties or trainers. This observation is consistent with the quantitative data and confirms the positive impact of innovative technology on user autonomy. Interviews with participants identified factors that influenced their effective use of the AI technology: the innovative technology was easy to use, and participants enjoyed large-scale information processing tasks. Some participants in the control group found it difficult to use the available tools and needed considerable support from the trainer. Both groups noted the need to adapt the technology to improve ease of use.

For the analysis of statistical significance between the groups, an independent samples t-test was used, and to assess the overall differences between the groups, an ANOVA was conducted. The difference in information literacy levels between the experimental and control groups after the training was statistically significant, $F(1, 58) = 19.34$, $p < 0.001$. The difference in information autonomy between the two groups after the training was also statistically significant ($t(58) = 4.23$, $p < 0.01$). The analysis of variance showed that there was a statistically significant difference in critical thinking levels between the two groups after training, $F(1, 58) = 22.67$, $p < 0.001$.

Innovative technologies have had a significant impact on the development of independent information utilization abilities among visually impaired individuals. While these results align with previous studies, they also reveal several differences that require further discussion and interpretation. These findings are consistent with research indicating that innovative technologies have a positive influence on the development of information utilization abilities among visually impaired individuals [11, 21]. It has also been argued that innovative technology provides users with new tools to analyze large amounts of information, enabling them to understand and navigate complex information flows more deeply and effectively [22]. However, other authors question the universality of the positive impact of innovative technologies on all aspects of information literacy, pointing out that while technology facilitates information access, it does not always contribute to the development of critical thinking or independence, particularly among users with physical disabilities [14, 23]. According to research, visually impaired individuals often rely on external assistance when searching for information, even when using advanced technology [24, 25]. Nevertheless, according to the results of this study, individuals in the AI group showed a significant improvement in their ability to independently search for and analyze information, confirming that modern technology is effective in bridging the information gap. Additionally, it has been pointed out that the effectiveness of new technologies can only be proven through sustained use, highlighting the need for individuals with visual impairments to adapt to new technologies over the long term [26]. Furthermore, some researchers suggest that innovative technologies may create specific barriers for visually impaired individuals due to the complexity associated with their installation or use [26, 27]. Although there are some discrepancies with previous studies, this study reinforces the hypothesis that innovative technology has a beneficial effect on the autonomous development of information literacy.

From a theoretical perspective, this study contributed to the evolving discourse on the structural components of information culture among individuals with sensory impairments. Information literacy, critical thinking, and learner autonomy are widely recognized as core elements of information culture; however, in adolescents with visual impairments, these components manifest through specific cognitive and neurocognitive patterns. The findings challenge the universality of existing approaches to the development of information culture and underscore the value of individualized and neurosensory frameworks. Notably, the integration of AI into educational practice not only mitigated sensory limitations but also stimulated higher-order cognitive processes.

Despite the representativeness of the study, several procedural and situational limitations influenced the strength of the interpretations and conclusions. The methodological framework did not fully account for the neurocognitive diversity of individual participants, which may have indirectly affected their capacity to master digital tools and optimize information-processing strategies. Furthermore, potential variations in the degree of visual impairment were not systematically examined, potentially resulting in differential sensory processing and subjective task-related challenges.

The study context was heavily dependent on the availability of a professional infrastructure that included technical support systems rarely found in general educational settings in other regions. This regional specificity limited the generalizability of the findings. Additionally, the research did not address complex ethical issues associated with AI use in education for adolescents with sensory impairments. Topics such as algorithmic fairness, risks of digital surveillance, psychological dependency on technology, and inequalities in digital accessibility fell outside the scope of the present analysis.

The political significance of this study emerged within a broader discourse situated at the intersection of governmental digital transformation policies, integrated development models, and global pressures that necessitate a redefinition of educational paradigms. The demonstrated effectiveness of AI integration in educational programs for learners with visual impairments affirmed the urgent need to establish new mechanisms of public governance in the domain of digital inclusion. This requirement transcends the mere modernization of technical infrastructure and calls for a shift in focus toward equitable access to knowledge and communication, dimensions historically restricted for marginalized populations.

Within the political framework of national digitalization strategies, the study laid the groundwork for reorienting financial planning and administrative priorities toward expanding access to high-tech educational services for vulnerable groups. It elevated the issue of cognitive justice to a political category—encompassing not only the right of individuals with special educational needs to access information but also their right to fully internalize and cognitively engage with that information. This shift highlights the necessity for novel forms of regulatory intervention in light of the rapid automation of educational environments.

V. Conclusion

The paper showed that the use of AI improves the accessibility of information for visually impaired adolescents and adapts content to their individual needs, while technologies (voice assistants and adaptive apps) provide visualization of information. After the experiment, the experimental group demonstrated a higher level of improvement across all measured aspects compared to the control group, as confirmed by statistically significant indicators. The average score for information literacy in the experimental group was 78.3, while in the control group, it was 59.2. A similar trend was observed in the development of critical thinking skills: the experimental group scored 74.5, compared to 55 in the control group, and the autonomy level was 4.2 in the experimental group and 3.1 in the control group. The higher the scores of the experimental group, the more we can see that using AI improves not only the ability to analyze and evaluate information but also the ability to make independent decisions in complex information environments.

This study found that using speech recognition technology removes barriers related to writing and allows adolescents to interact more freely with technology. Virtual and augmented reality technologies enhance the visualization of information, which is particularly important for adolescents with visual impairments. Additionally, using haptic feedback devices enables information to be perceived through both auditory and tactile senses, thereby improving content comprehension and memory retention.

The conclusion of this study emphasizes that developing social skills in visually impaired adolescents through AI technology has the potential to enrich educational experiences and increase independence in social environments. However, it is important to consider the negative aspects that may arise in this process. These include potential dependence on technology, limitations on physical activity, social isolation, reliance on technology quality, ethical issues, risks of delayed technology development, and fragmentation of information perception. Therefore, modern AI technology has a positive impact on the independent development of information utilization skills among visually impaired adolescents. However, it is also essential to consider the potential limitations and challenges associated with such innovations. These research findings can be utilized to develop more effective and comprehensive educational strategies to support the development of independent information utilization skills among visually impaired adolescents.

APPENDIX

Table A1. Self-directed learning readiness scale

Item No.	Statement
Instructions	This is a questionnaire designed to gather data on learning preferences and attitudes towards learning. After reading each item, please indicate the degree to which you feel that statement is true of you. There are no right or wrong answers. Please read each choice carefully and choose the response that best expresses your feeling. There is no time limit for the questionnaire. Try not to spend too much time on any one item; however, your first reaction to the question will usually be the most accurate.
Response Scale	1 = Almost never true of me; I hardly ever feel this way. 2 = Not often true of me; I feel this way less than half the time. 3 = Sometimes true of me; I feel this way about half the time. 4 = Usually true of me; I feel this way more than half the time. 5 = Almost always true of me; there are very few times when I don't feel this way.
Items	1. I'm looking forward to learning as long as I'm living. 2. I know what I want to learn. 3. When I see something that I don't understand, I stay away from it. 4. If there is something I want to learn, I can figure out a way to learn it. 5. I love to learn. 6. It takes me a while to get started on new projects. 7. In a classroom situation, I expect the instructor to tell all class members exactly what to do at all times. 8. I believe that thinking about who you are, where you are, and where you are going should be a major part of every person's education. 9. I don't work very well on my own. 10.If I discover a need for information that I don't have, I know where to go to get it. 11.I can learn things on my own better than most people. 12.Even if I have a great idea, I can't seem to develop a plan for making it work. 13.In a learning experience, I prefer to take part in deciding what will be learned and how. 14.Difficult study doesn't bother me if I'm interested in something. 15.No one but me is truly responsible for what I learn. 16.I can tell whether I'm learning something well or not. 17.There are so many things I want to learn that I wish there were more hours in a day. 18.If there is something I have decided to learn, I can find time for it, no matter how busy I am. 19.Understanding what I read is a problem for me.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

SU and SB conducted the research; LB analyzed the data; AM and AC wrote the paper; all authors had approved the final version.

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