frontiers | Frontiers in Education

TYPE Case Report
PUBLISHED 08 August 2022
DOI 10.3389/feduc.2022.979291

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OPEN ACCESS

EDITED BY
Hassan Ahdi,
Global Institute for Research Education and Scholarship, Netherlands

REVIEWED BY
Rakhshanda Fawad,
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Sehrish Aslam,
National Defence University, Pakistan
Tahirah Yasmin,
Quaid-i-Azam University, Pakistan

*CORRESPONDENCE
Khaled A. Abutayeh
k-abutayeh@ahu.edu.jo

SPECIALTY SECTION
This article was submitted to Higher Education, a section of the journal Frontiers in Education

RECEIVED 27 June 2022
ACCEPTED 11 July 2022
PUBLISHED 08 August 2022

CITATION
Abutayeh KA, Kraishan OM and Kraishan EQ (2022) The use of virtual and augmented reality in science and math education in Arab countries: A survey of previous research studies. *Front. Educ.* 7:979291. doi: 10.3389/feduc.2022.979291

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The use of virtual and augmented reality in science and math education in Arab countries: A survey of previous research studies

Khaled A. Abutayeh[1]*, Osamah M. Kraishan[1] and Eman Q. Kraishan[2]

[1]Department of Curriculum and Teaching, Al-Hussein Bin Talal University, Ma'an, Jordan, [2]Al-Hussein Bin Talal University, Ma'an, Jordan

The aim of this study was to present a survey of research relating to the use of virtual and augmented reality in science and math education in Arab countries after 2012. The research studies were collected from several sources that include a set of common Arabic research database, a set of English research database, and popular search engines. Thirty three research studies were found related to the use of virtual and augmented reality in science and math education in Arab countries. These studies were examined based on four variables: focus, research method, data collection tools, and geographical distribution. The results showed that most of the research related to uses of virtual and augmented reality in science and math education in Arab countries focused on students and their teachers and most of the researches followed the two-group experimental design, and the quantitative descriptive research. Regarding the methods of data collection most of the studies used test and questionnaires. In addition, most of the research studies were conducted in Saudi Arabia and Egypt. Based on the findings, a set of recommendations were presented.

KEYWORDS

virtual and augmented reality, science and math education, Arab countries, survey, previous studies

Introduction

Virtual reality is a computer-generated world that can be accessed using immersive devices such as helmets, gloves, and headphones. The virtual environment completely replaces the real world without reacting to its changes, while the user can influence it by immersing himself, for example, as in a video game. Virtual reality typically refers to the use of interactive simulations created with computer hardware and software to present users with opportunities to engage in environments that appear to be and feel similar to real world objects and events. Users interact with displayed images, move

and manipulate virtual objects, and perform other actions in a way that attempts to "immerse" them within the simulated environment thereby engendering a feeling of presence in the virtual world (Weiss et al., 2004, p. 1).

The previous definitions provide several elements of the virtual reality that include virtual world that represent the content of a particular medium, which may exist in the real world or exist only in the imagination of its creator, and is often designed in such a way that others can participate in it. The second element of virtual reality is the immersion that represents one of the most crucial elements that must be available for the success of the virtual reality experience (Carrozzino and Bergamasco, 2010; Shin, 2017). It can be defined as the "perception of being physically present in a non-physical world" (Freina and Ott, 2015). There are two types of immersion in virtual reality that include low- and high-immersion (Bowman and McMahan, 2007). The third element of virtual reality is the sensory feedback, where virtual reality can be used as a mean by which a user can experience an imagined reality through our physical senses such as sight, hearing, and touch and it is not necessary to use his/her imaginative abilities. The fourth element of virtual reality is the interaction as noticed in the previous definition. For virtual reality to appear real, it must respond to the user's movements, that is, interact with them and with the user him/her-self. Using the computer in this process makes achieving the interaction easy, and then the user also becomes interacting with objects, characters and places in this imaginary virtual world.

There are several types of technologies that can be used to create virtual reality used for educational purposes. The most common type is the display devices that include computers, phones, and tablets (Sagnier et al., 2021). These devices can be used to access virtual reality worlds such as the second life. However, there are more sophisticated technologies for virtual reality such as HTC Vive Pro, Oculus Quest, Samsung Gear VR, and Google Cardboard.

In the last decade, virtual reality technologies evolved from doubtful technology to be integrated in education and widely used and implemented for educational purposes. One of the main conceptions that lead for the lag of using virtual reality in education is that VR is created for entertainment only. However, the recent research studies showed the benefits of the use of virtual reality in education. Research studies have shown that the use of virtual reality in teaching would enhance students learning, performance, motivation and satisfaction with learning experience (Chang et al., 2019). The uses of virtual reality in education can be multifaceted. For instance, virtual reality can be used to facilitate collaboration among students in virtual world (Bricken and Byrne, 1993). Virtual reality can be used to cancel the time and the geographical barriers among learners and between learners and their instructors. In addition, virtual reality technologies have the capability to facilitate interactivity among learners in virtual world better than conventional video conference (Huang et al., 2010). Furthermore, virtual reality has great potential in facilitating training and simulation (Huang et al., 2010) with the possibilities of the world virtual experiences created to simulate completely reality, and the trainee can enter this experiment or scenario designed according to the nature of the purpose. One example of such use is the use of virtual reality in surgical operations (Li et al., 2017).

In addition, of virtual reality, augmented reality could be considered as type of virtual reality or as development of virtual reality. Augmented reality is the technology based on projecting virtual objects and information into the user's real environment to provide additional information, whereas virtual reality is based on projecting real objects into a virtual environment.

Virtual and augmented reality can play critical role in science and math education. In general, these technologies might be cheap and easy to use resources that help in teaching science and math. For instance, virtual physics labs contains 3-dimensional simulation of many experiments related to electrical and magnetic physics, thermal physics, electronics, modern physics, nuclear experiments, mechanics, waves and many more. In addition, virtual chemistry labs provide educational institutions and students with a wide range of constantly updated virtual chemistry experiments, covering the areas of general, analytical and organic chemistry. Students can learn and understand experiments without exposure to various risks while saving the recurring costs of purchasing chemicals and laboratory supplies.

There is complexity in math subjects that require students to mentally visualize the concepts and the elements of the course. Such complexity makes virtual reality technologies good tool to facilitate students' learning in such math courses. An example of math topic that need virtual reality to tech is geometry (Kaufmann et al., 2000).

The current study addressed the shortfall of research studies that examined the use of virtual realities in math and science education in Arab countries. Such topics received little attention in developing countries.

Literature review

Reviewing research studies has shown researchers' interest in the use of virtual and augmented reality in education. There are several studies that have been conducted on the use of virtual reality in education across the world. For example, Kavanagh et al. (2017) study aimed to present a review of literature on the use of virtual reality in education. Specifically, the paper aimed at reviewing the literature to identify the uses of and motivations for implementing virtual reality technologies in education. For the purpose of the study, 90 research papers discussed the use of virtual reality software for educational purposes were analyzed. The

results showed that virtual reality technologies were used to achieve different purposes that include facilitating learning by simulation, facilitating training, accessing limited resources, and facilitating distance education. In addition, the virtual reality technologies were used to achieve pedagogical purposes that include creating constructivist learning environment, facilitating collaboration among students, and facilitating learning using games. Furthermore, virtual reality technologies were used due to intrinsic factors such as increasing students' immersion, enjoyment and motivation, providing personalized learning experience, and facilitating deep learning.

In another study, Luo et al. (2021) aimed to provide a survey of the previous studies on the use of virtual reality technologies in education in terms of instructional context, instructional design, technological affordances, and research findings. For the purpose of the study, 149 articles were reviewed. The findings showed that the majority of the research papers (90%) were conducted in North America, Asia, and Europe. In addition, the majority of the research papers were conducted in three fields that include basic science, social science, health, and medicine. In relation to instructional design, the main focus of research papers between 2000 and 2009 was on the use virtual reality technologies to facilitate inquiry based pedagogy, whereas the major concern of research papers between 2010 and 2019 was on the use of virtual reality technologies for direct instruction. Furthermore, the finding showed that in the last decade the most used virtual reality technologies were computer and head-mounted display, respectively. In addition, the findings showed that 45% of the reviewed research papers followed experiential research design while 32% of the papers followed qualitative research design. It was shown that 13% of the papers followed quantitative research design that has no treatment or control groups, whereas 10% of the research papers followed survey design only.

Focusing on immersive virtual reality technologies, Radianti et al. (2020) conducted a study to review published research studies on the use of immersive virtual reality at universities. The review focused on several aspects of research. Some of these aspects include: the types of immersive virtual reality technologies, research designs, guided learning theories, and research domains. For the purpose of the study, 38 research papers were selected. The findings showed that the majority of the research papers (76%) used high-end head-mounted display. Regarding research designs, most research papers focused on documenting the overall development process of the virtual reality. The second popular research designs among the papers were the experimental design, usability and user test. In contrast, only 16 papers employed survey design. The qualitative design was not common among the papers, only five research papers used interviews and focus group discussion. Concerning the different learning theories that guide the implementation of virtual reality technologies for educational purposes, experiential learning was the most common one in the examined papers. The immersive virtual reality technologies were mostly used in engineering, computer science, and astronomy.

Focusing on the use of virtual reality technologies in science education, Durukan et al. (2020) conducted a study to review literature on the use of virtual reality technologies in science education based on some criteria that include: publication type, country origin, research design, sample or participants, investigated variables and situations. For the purpose of the study, 30 research papers were selected for the review. The findings showed that the majority of research papers were published in journals. Most of the papers were published in United States and Turkey. More than half of the research papers followed an experimental research design. The great majority of the papers focused on learning outcomes for undergraduate students and pre-service teachers.

The previous research studies showed that the use of virtual and augmented reality technologies in education have captured the attention of researchers across the world. The dates of the published research showed that virtual and augmented reality is an emerging technology that has been starting to take important place in education. The use of the virtual reality technologies in education are multifaceted. Different outcomes were found in reviewing the literature regarding the use of virtual and augmented reality technologies in education. The number of research papers that focused on the use of virtual and augmented reality technologies in science education is limited. In addition, there is a lack of research studies that examined the uses of virtual reality technologies in science education in Arab countries.

Objectives and study questions

The aim of this study was to present a review of research relating to the use of virtual and augmented reality technologies in science and math education in Arab countries after 2012. The study attempted to answer the following questions:

Question 1: What is the focus of research studies that examined the use of virtual and augmented reality in science and math education in Arab countries?
Question 2: What are the research methods employed by researchers on the use of virtual and augmented reality in science and math education in Arab countries?
Question 3: What are the methods of data collection employed by researchers on the use of virtual and augmented reality in science and math education in Arab countries?
Question 4: What are the geographical distributions of research studies that examined the use of virtual and augmented reality in science and math education in Arab countries?

Methods and procedures

The current study is a literature review research study. The aim of this study was to present a survey of research relating to the use of virtual and augmented reality technologies in science and math education in Arab countries after the year 2012. This review will provide a deeper understanding of scientific research in this field.

The procedures for conducting the current research paper are listed below:

First, the date of published research was selected to be between 2012 to present. The selection process was based on the fact that the use of virtual and augmented reality in education was not popular till the last decades in Arab countries.

Second, an extensive search on academic databases in both English and Arabic languages were performed to select research papers relating to the scope of the current research. The databases were also selected based on their popularity in Arab countries. The English databases were Elsevier Science Direct, ERIC, and IEEE Xplore. The Arabic databases were Arab Educational Information Network (Shamaa), a Directory of Free Arab Journals (DFAj). In addition, other popular search engines such as Google Scholar and Google were used.

Third, the criteria for selecting appropriate and relevant research papers for the aim of the study was also determined. The selected research studies have to be relevant to the use of virtual and augmented reality in science or its sub-disciplines. In addition, the selected research papers related to the Arabic context. Another criterion was that the selected research studies have to be either peer-reviewing research published in academic journals or conference.

Fourth, the selected research studies were classified first based on the following criteria: (1) year of publication, (3) Language (Arabic or English), and Topic (Math or Science). Then, they were reclassified based on the following criteria: (1) focus, (2) research method, (3) methods of collecting data, and (4) geographical distributions.

Results and discussion

To achieve the aims of the current research, a total of (33) research papers were selected. **Table 1** shows information about these papers research based on the publication year, language, and topic. Findings showed that the earliest research paper discussed the use of virtual and augmented reality in science and math education in Arab countries was published in 2015. That study examined the use of virtual reality in the development of some mathematical and scientific concepts for pre-school children and its impact on the development of their ability to imagine (Atifi and Al-Miliji, 2015). In 2016, one research paper, discussing the use of virtual and augmented reality in science and Math education in Arab countries, was published only. The paper examined the augmented immersive reality (AIR) technology for high school Chemistry education (Al-Qassem et al., 2016).

TABLE 1 Information about the selected research papers (n = 33).

Publication year	Frequency	Percentage
2015	1	3.0
2016	1	3.0
2017	2	6.1
2018	4	12.1
2019	14	42.4
2020	5	15.2
2021	6	18.2
Language		
Arabic	27	81.8
English	6	18.2
Topic		
Science	23	69.7
Math	8	24.2
Both science and math	2	6.1

Findings also showed that the number of research papers relating to the use of virtual and augmented reality in science and math education in Arab countries has increased after 2018 to reach its maximum percentage in 2019. After that, the number of research papers relating to that field has decreased. It was also found that most of the papers on the use of virtual and augmented reality in science and math education in Arab countries were published in the Arabic language (n = 27), whereas only about one—fifth (n = 6) of these studies were published in the English language. Furthermore, the results showed that the majority of the selected research papers were on the use of virtual and augmented reality in science education (n = 23, 69.7%), whereas only a quarter (n = 8, 24.2%) of the research papers were on the use of virtual and augmented reality in math education. Only two research papers were found to discuss the use of virtual and augmented reality in both science and math education. These research papers were under the title "the use of virtual reality in the development of some mathematical and scientific concepts for pre-school children and its impact on the development of their ability to imagine" (Atifi and Al-Miliji, 2015) and "The effect of augmented reality techniques on deductive thinking for first intermediate students in science and mathematics" (Al-Sabri and Al-Shukri, 2021).

In order to answer the first research question, namely, "What is the focus of research studies that examined

TABLE 2 Distribution of research papers on the of virtual and augmented reality in science and math education in Arab countries by research focus (n = 33).

Research focus	Frequency	Percentage
Students	20	60.6
Teachers	9	27.3
Designs	1	3.0
Mixed	3	9.01

the use of virtual and augmented reality in science and math education in Arab countries?," a statistical analysis was performed. Findings showed that research on the virtual and augmented reality in science and math education in Arab countries mainly focused on students (n = 20), teachers (n = 9), and designs (n = 1). Still, there were three research studies that had mixed focus. **Table 2** shows the distribution of research papers related to the use of virtual and augmented reality in science and math education in Arab countries based on their focus.

Most of the research studies that focused on students measured the effect of the use of either augmented reality or virtual reality on students' variables such as the effect of using augmented reality technology on the achievement of primary school students in science (AlSwayan, 2019); effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students (Elsayed and Al-Najrani, 2021); the impact of virtual reality on the development of some mathematical and scientific concepts for pre-school children (Atifi and Al-Miliji, 2015); the effect of the virtual physical laboratory in developing the intensity of observation and academic achievement for students of the fourth stage (Al-Hayawi and Hussien, 2020); the effect of using augmented reality on mathematics achievement among middle school students (Al-Ghamdi, 2020). Other studies addressed, for example, the use of augmented reality technology in developing some scientific concepts and information search skills among middle school students (Mansour, 2021); The effect of Teaching according to the augmented reality technology on the achievement to scientific fifth-grade students for biology (Hamdallah and Al-Dulaimi, 2020); the effect of augmented reality technology in simplifying abstract concepts in chemistry and reaching the level of deep understanding among first year secondary school students (Abbasi and Al-Gamdi, 2019); the effectiveness of employing augmented reality technology in teaching science to develop creative thinking skills (Salama et al., 2019); the impact of augmented reality on the development of scientific concepts among middle school students (Muhammad et al., 2019); the effect of using augmented reality technology on the achievement of primary school students in teaching science (AlSwayan, 2019); impact augmented reality technology on developing mathematical conceptual comprehension and cognitive curiosity among primary school students (Mohamed, 2019); the effect of augmented reality on the development of science processes in biology for secondary school students (Metwally and Al-fadli, 2019); the effect of augmented reality and simulation on the Achievement of Mathematics and Visual Thinking Among Students (Aldalalah et al., 2019); the effect of virtual lab in developing scientific thinking in a physics course for secondary school students (Al-Shehri, 2018); the effectiveness of using augmented reality technology in developing the conceptual comprehension of second year secondary school students in physics (AlFahed, 2018); the effect of 3D augmented reality applications to improve the quality of learning outcomes in physics for secondary school students (Al-Dafrawi, 2021); the effectiveness of employing the augmented reality technology in the development of the achievement of seventh grade students in chemistry (Aqel and Azzam, 2020); the effect of augmented reality techniques on deductive thinking for first intermediate students in science and mathematics (Al-Sabri and Al-Shukri, 2021); the effect of teaching according to the augmented reality technique on the visual thinking skills to scientific fifth-grade students for biology (AL-Dulaimi and Hamadallah, 2021).

All of the previously mentioned research papers focusing on students had conducted on the preschool and school students. One research study only focused on the university students that examined the use of 3D virtual reality applications to develop scientific concepts and improve attitudes toward biology course (Abdel-Maqsoud and Al-Baqmi, 2017).

From the analysis on the focus of these research papers relating to the use of virtual and augmented reality in science and math education in Arab countries, it appears that there was a limited number of research focusing on teachers and there were no one research focusing on managers and policy makers. The research papers that focused on teachers were science teachers' views of the nature and frequency of virtual lab implementation (Alneyadi, 2019); math teachers' view of the obstacles to employ virtual reality technology in teaching (Al-Aqali, 2018); teachers views of the reality and expectations of virtual laboratories in teaching science at the intermediate stage (Al-Shamrani, 2020); teachers views of the virtual laboratories requirements and obstacles of their use and ways to develop them (Bujaily, 2019).

Beside the opinions of the teachers on different aspects of the use of augmented and virtual reality in science and math education, some studies focused on examining their awareness of the concept of augmented reality technology and its uses in teaching (Al-Shehri, 2019). Another study focused on assessing of the competencies of science teachers for the application of augmented reality

TABLE 3 Distribution of research papers related to uses of virtual and augmented reality in science and math education in Arab countries by research methods (n = 33).

Research methods	Frequency	Percentage
Quantitative descriptive research	9	27.3
Qualitative descriptive research	1	3.0
Two-group experimental design	19	57.6
One-group experimental design	3	9.01
Quantitative descriptive research and two-group experimental design	1	3.0

TABLE 4 Distribution of research papers related to uses of virtual and augmented reality in science and math education in Arab countries by ways of collecting data (n = 33).

Methods of data collection	Frequency	Percentage
Questionnaire	7	21.2%
Test	20	60.6%
Interview questions	1	3%
Previous studies	2	6%
Others	3	9%

TABLE 5 Geographical distribution of research paper to uses of virtual and augmented reality in science and math education in Arab countries (n = 33).

Country	Frequency	Percentage
Saudi Arabia	14	42.4
Egypt	7	21.2
Iraq	4	12.1
Palestine	2	6.1
Jordan	1	6.1
UAE	3	6.1
Kuwait	2	6.1

(Al-Aboudi and Al-Saadoun, 2019). A study focused on teachers' readiness of integrating augmented reality (Jwaifell, 2019). One study that focused on teachers followed experimental design to assess the effectiveness of simultaneous virtual classes in developing the professional performance of mathematics teachers at the intermediate stage (Al-Omari, 2019). Another study focused on the efficiency of physics teachers' use of smart classes in the virtual environment and its relationship to their digital skills (Al-Sharif and Al-Swat, 2021).

The research papers that had mixed focus examined the specific designs of either virtual reality or augmented reality and its effect on students learning (Reda, 2018; Bader et al., 2019). Another study examined the specific designs of either virtual reality or augmented reality and its effect on teachers' acceptance of such technology (Al-Mutahhar, 2017).

In order to answer the second research question, namely, "What are the research methods employed by the researchers on the use of virtual and augmented reality in science and math education in Arab countries?," statistical analysis was performed to find numbers and percentages of research methods employed in the selected research papers. Findings showed that research related to the use of virtual and augmented reality in science and math education in Arab countries were varied. 19 research papers (57.6%) followed the two-group experimental design, 9 papers (27.3%) followed the quantitative descriptive research, whereas 3 papers (9.01%) used the one-group experimental design. Only one research paper followed the qualitative descriptive method and another one followed the quantitative descriptive and two-group experimental design. **Table 3** shows the distribution of research papers relating to the use of virtual and augmented reality in science and math education in Arab countries by research methods.

It is noticed from the analysis of research methods that researchers focused on low scale experimental design. Such finding indicates that the use of virtual and augmented reality in science and math education in Arab countries is still on the trial stage.

With regards to findings that relate to the third research question, namely, "What are the methods of data collection on the use of virtual and augmented reality in science and math?," the methods of data collection used in the research related to the use of virtual and augmented reality in science and math education in Arab countries were varied. The test (n = 20, 60.6%) was the most common research instrument in the research papers, followed by the questionnaires (n = 7, 21.2%). The use of interview questions and previous research studies were not common; only one study used interviews as a source for data collection and two studies used previous research studies as the main sources of data. There were three research studies that used different ways of data collection method. One of these studies used test and questionnaire to measure effectiveness of the augmented reality on improving the visual thinking in mathematics and academic motivation for middle school students (Elsayed and Al-Najrani, 2021). Another one used concept test, worksheets, and teacher's guide to build model of augmented reality and to test its effectiveness on correcting the misunderstanding of scientific concepts among primary school students (Reda, 2018). In addition, a study used cognitive achievement, skill performance note cards and a

questionnaire in designing 3D augmented reality applications to improve the quality of learning outcomes in physics (Al-Dafrawi, 2021). **Table 4** shows the distribution of research papers related to the use of virtual and augmented reality in science and math education in Arab countries by methods of data collection.

From the analysis of research methods and the type of instrument used for data collection, it appears that researchers focused on experimental research methods. This indicates that the actual use of the virtual and augmented reality in science and math education in Arab countries is limited to small scale trials.

In order to answer the fourth research question, namely, "What are the geographical distributions of research studies that examined the use of virtual reality in science and math education in Arab countries?," percentages and numbers were calculated. The findings showed that the geographical distribution of research relating to the use of virtual and augmented reality in science and math education in Arab countries is limited. In other words, the research papers selected as the main sample of the current study were from 7 countries out of 22 Arab countries. Most of the research relating to the use of virtual and augmented reality in science and math education in Arab world was conducted in Saudi Arabia (n = 14, 42.4%), Egypt (n = 7, 21.2%), Iraq (n = 4, 12.1%), the United Arab Emirates (n = 3, 9.1%), Palestine and Kuwait (n = 2), and Jordan (n = 1). **Table 5** shows the distribution of research papers related to uses of virtual and augmented reality in science and math education in Arab countries by their geographical distribution.

Findings showed that the countries that were mostly concerned with this type of research on the virtual and augmented reality in science and math education in Arab countries were Saudi Arabia and Egypt. The results related to the geographical distribution of research on the use of virtual and augmented reality in science and math education in certain areas in Arab world are similar to the results reported in other previous studies showing the distribution in Arab world in specific countries in the world (Luo et al., 2021).

By comparing research portfolio of Arab countries using SCImago research classification tool (SCImago, 2022), the results showed that Saudi Arabia and Egypt are on the top in terms of the number of published research papers compared to the rest of the Arab countries. In addition, in the current research study, the search was limited to the research relating to the use of virtual and augmented reality in science and math education in Arab countries published in Arabic and English languages. This, in turns, could limit the findings taking into consideration that some papers in North Africa (Arab countries) are published in French language.

Conclusion

The actual use of the virtual and augmented reality in science and math education in Arab countries is limited to small scale trials focusing on school students in limited number of Arab countries. The phenomenon of using virtual and augmented reality in science and math education needs more attention and research in the Arab world.

Recommendations

- There is a need to expand the research methods used in studying the use of virtual and augmented reality in the educational process in the Arab world and to focus on descriptive research rather than on empirical research.
- There is also a need to conduct larger scale studies that examine the implementation of virtual and augmented reality technologies in math and science education.
- Future research studies should address the use of virtual and augmented reality technologies in different majors.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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