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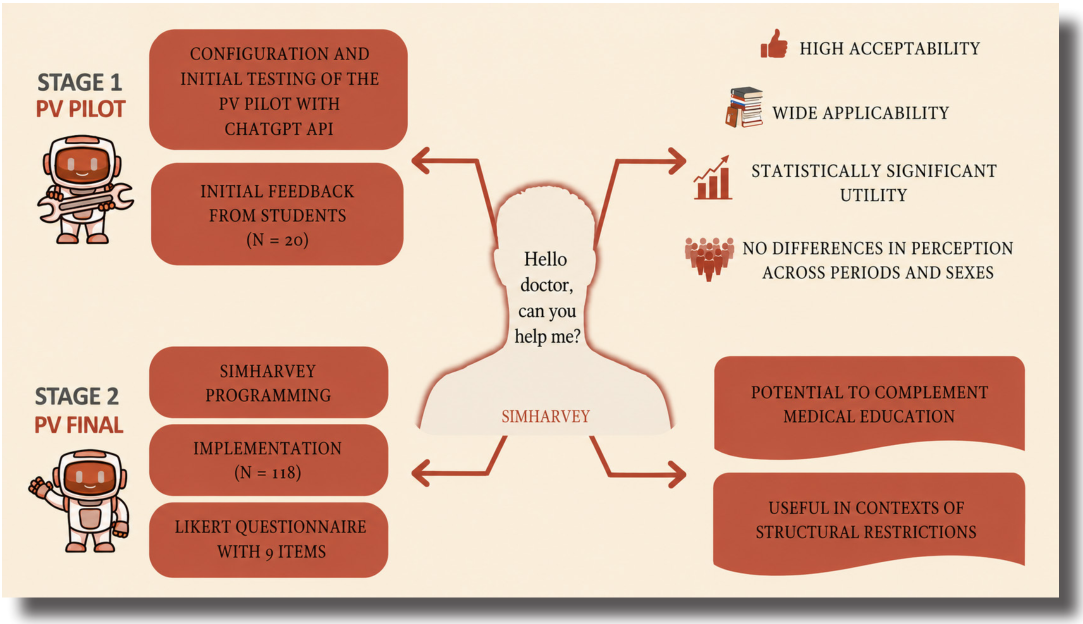
Creation of a virtual patient for application in medical student education

Matheus de Lima Botelho[1] Lara Milhomem Campos[2] Leonardo Alves Soares[1] Gabriel Rodrigues Brito[1]
Mateus Silva Santos[1] Leonardo Luiz Ludovico Póvoa[1] Jussara Resende Costa[1]

[1]Universidade de Gurupi – UnirG. Paraíso do Tocantins/TO, Brasil.
[2]Universidade Federal do Tocantins – UFT. Palmas/TO, Brasil.
E-mail: matheuslb8@hotmail.com

Graphical Abstract



Highlights

- *Application of a new medical teaching methodology.*
- *The tool was validated as useful in clinical examination training.*
- *No significant difference was found between sexes and academic semesters, signaling cross-sectional utility.*
- *The perception of usefulness was statistically significant.*

Abstract

The clinical examination remains a cornerstone of medical training; however, the expansion of medical schools and structural limitations have reduced practical opportunities, favoring the use of active methodologies and virtual patients based on artificial intelligence (AI). This study aimed to develop an original AI-based virtual patient (VP) and evaluate its acceptance and applicability as a complementary tool for teaching medical semiology. This was an exploratory and experimental study with a mixed qualitative-quantitative approach, approved by an Ethics Committee, involving medical students who had completed Semiology I. The project was conducted in two stages: creation of a pilot VP using the ChatGPT API, grounded in updated clinical guidelines; and development of the original VP (SimHarvey) on its own platform. The methodological approach consisted of a nine-item Likert questionnaire assessment, with descriptive and non-parametric inferential statistical analyses. A total of 118 students participated, with high tool acceptance and means above 4.0/5.0 for satisfaction, utility in clinical examination training, learning, confidence, and recommendation. No significant differences were found regarding sex or academic stage, and the overall perception was significantly above the neutral point ($p<0.001$). The findings indicated that the AI-based VP favored clinical reasoning, anamnesis organization, and the simulation of diverse clinical scenarios, corroborating the literature on virtual patients as effective and accessible educational strategies. SimHarvey proved to be a low-cost, well-accepted tool with relevant potential to complement medical training, without replacing real clinical practice, being especially useful in contexts with structural constraints.

Keywords: Artificial Intelligence. Patient Simulation. Teaching. Medical Education. Diagnosis.

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INTRODUCTION

The diagnostic process dates back to the origins of Greek medicine, when medical reasoning was based exclusively on anamnesis and physical examination, albeit with a certain degree of systematization[1]. In contemporary times, the development of laboratory and imaging tests enabled advances in clinical management, ensuring efficacy and greater precision; however, the clinical examination remains an irreplaceable pillar, as it is the aspect that best preserves the human dimension of care[2].

In this sense, the discipline of semiology represents the first experience of practical application of theoretical knowledge. However, various factors have compromised this, such as the increase in the number of medical schools and structural deficiencies in institutions. Between 2013 and 2019, the number of medical school places in Brazil increased from 20,522 to 37,242, with growth concentrated in the country's interior. The state of Tocantins, for example, has approximately 42 places per 100,000 inhabitants – the highest density in the country[3].

To mitigate these limitations, the use of active methodologies has expanded, such as Problem-Based Learning (PBL) – developed in 1960 by Howard Barrows – which uses simulated patients to develop clinical competencies. Recently, this approach has evolved toward the virtual patient (VP), capable of reproducing practical scenarios, whose pedagogical efficacy has already been demonstrated[4]. However, high-fidelity simulators carry high costs and limited access, while simpler models lack interactivity[5]. Given this, it is essential to develop more accessible, dynamic, and customizable simulation methodologies. The application of artificial intelligence (AI), grounded in machine learning and deep learning, emerges as a possibility, providing immediate and individualized feedback, assisting students in their improvement[6].

Thus, the incorporation of technologies can support the consolidation of knowledge even in situations rarely encountered in practice, complementing real contact and enhancing medical skills[7]. Given this, the present study aimed to develop an original AI-based VP and subsequently apply this tool to medical students at the Universidade de Gurupi – UnirG, so that it could be evaluated. From this, important feedback was collected for future improvements and for the creation of an application that assists in continuing medical education.

MATERIALS AND METHODS

This was an exploratory and experimental study with a mixed qualitative-quantitative approach. The project was based on the elaboration of an AI-based tool applied to the understanding of medical education, evaluated by UnirG students following acceptance and approval granted by the Research Ethics Committee (REC).

Students of both sexes, duly enrolled in the medical course and who had fully completed the Semiology I discipline – at the end of the third semester – were selected. Students below the fourth semester, under the legal age, or who did not sign the Informed Consent Form (ICF) were excluded. Of the approximately 200 students who met the established criteria, an ideal sample size of 132 participants was defined, considering a 95% confidence interval and a 5% margin of error.

Regarding data collection, an original questionnaire was used comprising 9 Likert-style questions (1 = strongly disagree; 5 = strongly agree), addressing issues related to usability, conversational realism, language, learning, and technical limitations of the tool. Furthermore, in the last optional question, students could leave suggestions about the VP, the excerpt being: "Use this field to mention positive and negative aspects of the tool; additionally, provide ideas on how you think AI can be more effective and useful for your learning" – the question used in the questionnaire.

In view of the study's objectives, a two-stage project approach was adopted; this enabled an initial situational diagnosis, understanding of the strengths and weaknesses of this type of tool, and technical grounding for the development of the original VP (SimHarvey).

Initially, the first stage of the project was based on conducting a "field study" and gaining a better understanding of the needs a VP should meet for teaching. For this purpose, the Application Programming Interface (API) of ChatGPT was used as a basis for developing the pilot VP, through the "CriarGPT" tool, with the application of specific prompts and customized databases made available on the OpenAI website[8]. In this way, by adding updated books and guidelines – such as the 2025 arterial hypertension guideline and the psychopathology and semiology of mental disorders[9,10] –greater reliability of the content was ensured. Furthermore,

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the prompts included basic instructions the agent should follow, such as: "you are a virtual patient", "only respond when questioned", and "use only the provided sources".

After creation, the agent was sent to physicians for feedback collection and improvement of certain aspects. Subsequently, through non-probabilistic convenience sampling, 20 students were selected for application. At this stage, they were able to interact with the bot, perform the anamnesis, and at the end of the session received feedback on the interaction and the link to the questionnaire. Once the student signed the ICF, they could answer the questionnaire (9 questions), providing the basis for the creation of SimHarvey.

After the first test, the second stage of the project began, based on the development and evaluation of the tool by medical professors and students. The steps were: programming of the bot; submission to professors; improvement of aspects and application.

The authors themselves carried out the programming of the agent. Through the private API Key, a secure connection with the OpenAI servers was established[8]; with this, a session was created with the model configured in the workflow (task flow given to the bot) of the server, returning with a temporary token, enabling the opening of the chat without exposing user keys.

Furthermore, the JavaScript code was hosted on GitHub (a hosting platform) and the ChatKit component was imported – responsible for creating a chatbot in an HTML outside of the ChatGPT website8. From this, the website could be customized and the bot configured – aiming for greater stability and the absence of a daily usage limit. To this end, a communication flow was implemented in which the user accesses the website and the script requests the authentication token. After this step, the token validates the user's session, enabling the use of the tool. The chatbot then displays the conversation interface and exchanges messages between the user and the model configured in the workflow. In this process, no sensitive data is stored.

For the creation of the VP itself and its specifications, prompts were used in the workflow such as "you are a virtual patient", "you should only respond when questioned by the user", and "do not provide information using technical language". With these steps, it was possible to create the bot named "SimHarvey", specialized in being a patient with cardiovascular conditions, with a database updated with the main cardiovascular guidelines[9].

Following the same principles as the first stage, this stage used a QR code that directed users directly to the VP's website, where instructions were available. During use, the student could encounter diverse cases such as myocardial infarction, heart failure, and coronary artery disease. Once the interaction was complete, the student entered the command "end of consultation"; the bot then sent an evaluation of the anamnesis, with points to be reviewed/studied, as well as the link to the questionnaire – the same one used in the first stage.

After these stages, data were obtained for subsequent validation and evaluation of the tool through the statistical analyses described below. Furthermore, the evaluative variables of the questionnaire were transformed into quantitative ones from the coding of the five-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree).

Descriptive statistics were performed by calculating the mean, standard deviation, median, and minimum and maximum values of each question separately. The normality of data distribution was evaluated using the Shapiro–Wilk test, which revealed that all variables presented non-normal distribution ($p < 0.05$). Accordingly, non-parametric statistical methods were adopted for inferential analyses.

For the analysis of qualitative data arising from the open and optional question in the form, Content Analysis in the Thematic-Categorical approach proposed by Laurence Bardin was used. The procedure rigorously followed the three chronological phases of the method: (1) pre-analysis; (2) exploration of the material, with the isolation and coding of registration units (significant phrases and keywords); and (3) treatment of results and interpretation, which enabled the systematic grouping of participants' discourses into thematic categories.

RESULTS

A total of 118 medical students participated in the study. Table 1 shows the distribution and description of participants' profiles. A predominance of female sex was observed (65.3%), while males represented 34.7% of the sample. Regarding age group, the majority of participants were between 18 and 25 years of age (74.6%). In relation to academic semester, there was a higher concentration of students in more advanced semesters, with emphasis on the 7th (45.8%) and 8th (28.0%).

Table 1 - Descriptive distribution of participant profiles – Paraíso do Tocantins, 2025.

Variable	Category	Frequency (n)	Percentage (%)
Sex	Female	77	65.3
	Male	41	34.7
Age group	18 to 25 years	88	74.6
	26 to 30 years	15	12.7
	Over 30 years	15	12.7
Academic semester	3rd semester	1	0.8
	4th semester	19	16.1
	5th semester	10	8.5
	6th semester	1	0.8
	7th semester	54	45.8
	8th semester	33	28.0

Regarding the 9 questionnaire items aimed at assessing the user experience, whose responses were systematized in Table 2, the majority demonstrated high satisfaction with the interaction with the bot, totaling 76.3% of positive evaluations, while 19.5% were neutral and only 4.2% expressed disagreement. Regarding the contribution to clinical examination training, 89.0% agreed, compared to 8.5% neutral responses and 2.5% disagreement.

In the assessment of the naturalness and realism of the AI language, 76.3% indicated agreement, 18.6% remained neutral, and 5.1% disagreed. Furthermore, ease of use was also broadly recognized, with 82.2% positive responses, 13.6% neutral, and 4.2% negative.

The methodology's potential to enhance learning when combined with real practice had broad acceptance (94.0% agreement), with minimal disagreement (0.8%). In the same vein, 91.5% considered the tool applicable across all disciplines, while only 3.3% disagreed.

The belief that the resource increases confidence in real practice was expressed by 88.1% of participants, and 89.9% stated they would recommend the AI to other students. Finally, 89.0% recognized the methodology's potential to minimize learning deficits in infrequent clinical conditions, with only 3.3% negative responses. Such information is presented in greater detail in the table below.

Table 2 - Descriptive distribution of questionnaire responses – Paraíso do Tocantins, 2025.

Question	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Satisfaction	1.7% (2)	2.5% (3)	19.5% (23)	40.7% (48)	35.6% (42)
Training	0.8% (1)	1.7% (2)	8.5% (10)	44.1% (52)	44.9% (53)
Language	1.7% (2)	3.4% (4)	18.6% (22)	46.6% (55)	29.7% (35)
Intuitive use	0.8% (1)	3.4% (4)	13.6% (16)	52.5% (62)	29.7% (35)
Learning	0.8% (1)	0% (0)	5.1% (6)	43.2% (51)	50.8% (60)
Potential	0.8% (1)	2.5% (3)	5.1% (6)	39% (46)	52.5% (62)
Confidence	0.8% (1)	0.8% (1)	10.2% (12)	39.8% (47)	48.3% (57)
Recommendation	0.8% (1)	0% (0)	9.3% (11)	40.7% (48)	49.2% (58)
Improvement	0.8% (1)	2.5% (3)	7.6% (9)	41.5% (49)	47.5% (56)

Regarding the optional qualitative question contained in the form, 38 responses were obtained, which corroborated and deepened the quantitative findings. The grouping of responses gave rise to Category 1: Pedagogical Potentialities and Stimulation of Clinical Reasoning, in which participants emphasized that the VP favored understanding of the case and simulation of care, especially in the initial cycles: "*It is a completely different study method that leads the student to develop this clinical reasoning*" (Student 09). There was consensus that the experience was "*very useful for practicing consultations, excellent for students in the 3rd and 4th semesters who are just beginning to see patients*" (Student 11), acting as a dynamic resource for anamnesis organization and diagnostic structuring.

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In this light, the responses also supported the interpretation of neutral or disagreeing answers, consolidating into Category 2: Technical Barriers and Demands for Improvement. In the technological aspect, system freezes and API instabilities were reported: "*The AI presented an error almost every time I tried to interact with it*" (Student 21) and "*The platform freezes on some questions [...] and ends up being quite irritating*" (Student 28). From a pedagogical perspective, students pointed out a lack of clarity regarding the need to describe therapeutic management, generating a misalignment with the final score issued by the bot: "*It is evaluating our therapeutic management, even though we have not provided it*" (Student 22), which demonstrated that "*we cannot stop at the diagnosis, we have to provide the treatment as well, and this is not clear in the initial command*" (Student 20). Finally, explicit demands emerged for expanding the clinical scope of the tool, suggesting the "*addition of physical examination, as well as complementary tests such as ECG, blood count, and cardiac markers, [to provide] greater depth to the AI*" (Student 13).

Regarding the overall perception of the AI tool, the mean of responses to the 9 Likert-scale questions was calculated for each of the 118 valid participants. Women presented a mean perception of 4.341 (±0.539), a median of 4.333, ranging from 2.889 to 5.000. Men obtained a mean of 4.092 (±0.739), median of 4.000, with a range of 1.000 to 5.000. The non-parametric Mann-Whitney U test, appropriate for independent ordinal data, revealed the absence of statistically significant difference between sexes ($U=1290.5$; $p=0.102$), indicating that the observed numerical difference ($\Delta=0.249$) is consistent with sampling variability.

For analysis by academic stage, participants were classified into early semesters (≤5th semester; n=31) and advanced semesters (≥6th semester; n=87), totaling 118 valid cases. Early-stage students presented a mean perception of 4.367 (±0.494), median of 4.333, and a range of 3.556 to 5.000. Advanced students obtained a mean of 4.225 (±0.659), median of 4.111, ranging from 1.000 to 5.000. The Mann-Whitney U test identified no significant difference between groups ($U=1424.0$; $p=0.457$), confirming that the positive perception of the tool (~4.2/5) remains consistent throughout the undergraduate program, despite the slight numerical superiority of early-stage students ($\Delta=0.142$).

Inferential analysis demonstrated that overall perception of the AI tool was significantly above the neutral point (3.0), with a mean of 4.254 (median=4.222) and Wilcoxon signed-rank test $W=6794.0$; $p<0.001$. Specifically, utility in clinical examination training (Q2) reached a mean of 4.305 (median=4.0; $W=5749.5$; $p<0.001$), while practical confidence (Q7: mean 4.339) and recommendation (Q8: mean 4.373) also clearly exceeded neutrality ($p<0.001$ for both), with 55.9% of overall perceptions above 4.0 (t-test vs 4: $t=4.426$; $p=0.000011$).

DISCUSSION

In light of the results presented in this study, high acceptance and a significantly positive perception of the AI-based VP (SimHarvey) among students were observed. The means obtained across the nine questionnaire items were consistently above 4.0 points on a five-point scale, with a statistically significant difference relative to the neutral point ($p < 0.001$), evidencing that the favorable perception is not attributable to chance but rather to a positive evaluation of the tool.

Regarding inferential analyses, the tests performed comparing sexes and academic semesters on tool perception yielded interesting results, with no significant differences in either test. This result, combined with the other findings, suggests utility both in the consolidation of initial concepts and in the refinement of students in more advanced stages. Furthermore, the slight numerical superiority in perception among early-semester students (mean of 4.367 versus 4.225) may reflect a greater impact of the tool in initial phases, when contact with real patients is still limited. This finding resonates with scientific evidence[11], which demonstrates greater prioritization of clinical reasoning teaching during the internship relative to clinical and pre-clinical phases, suggesting that complementary methodologies may be particularly valuable in the initial construction of this competency.

Thus, the high proportion of agreement regarding the VP's contribution to clinical examination training aligns with the literature, which identifies it as an effective instrument for the development of clinical reasoning, allowing students to be exposed to diverse clinical situations – including those rarely encountered in daily care practice[7]. It is therefore understood that the use of a VP stands out as an effective educational strategy, by enabling the simulation of realistic and controlled scenarios, contributing significantly to the acquisition and refinement of medical skills[4,7].

Simulation[12] allows students to encounter in advance the errors that, when made in real care situations, would pose imminent risk to patient safety. This aspect is particularly relevant in semiological education, where the development of clinical reasoning occurs through an interactive process of formulation and testing of diagnostic hypotheses. Realistic simulations with a VP have demonstrated that this modality generates satisfaction and self-confidence among students, constituting an important educational tool[13]. The possibility of safely repeating scenarios, without risk to the patient, allows the student to make mistakes, learn from them, and refine their skills.

Along these lines, participants reported benefits such as enhanced understanding of the clinical presentation, realistic simulation of consultations, development of diagnostic reasoning, and improvement in anamnesis organization – although these constitute subjective perceptions regarding the tool, given the absence of verification by objective parameters. Furthermore, the data revealed areas of possible improvement in the tool, such as more human-like language, greater website stability, and the addition of complementary tests to the interaction. This demonstrates the participants' engagement and maturity in evaluating the technology, as well as the identification of clear areas for evolution. One example is the perception regarding the realism of language and interaction with the AI, which, despite good acceptance, presented the highest rate of disagreement, indicating an area to be improved – something that can be addressed in future versions.

Therefore, AI-mediated teaching methodology offers relevant pedagogical advantages, particularly immediate and personalized feedback. This feedback, when well-structured, proved essential for clinical learning, especially when provided immediately after the observed performance, as evidenced by studies on feedback as a learning strategy in medical education[14].

In this regard, it is essential to clarify that, in accordance with the literature, the tool presented herein does not propose to replace clinical practice with real patients, but rather to complement it in a substantive manner. This complementarity is essential, as the clinical examination remains an irreplaceable cornerstone of medical training.

It is also important to highlight as a crucial distinguishing aspect of this study its application in a university located in the interior of the country, in the state with the highest density of medical school places in Brazil – 42 per 100,000 inhabitants[3]. Medical schools in the state – such as UnirG, where this study was conducted – face structural challenges typical of accelerated higher education expansion, such as overcrowded clinical training settings and insufficient capacity to accommodate all students. In this context, the development of accessible, dynamic, and personalized simulation methodologies is a necessity.

In this same vein, traditional high-fidelity simulators carry high costs and limited access[5], making them unfeasible for many institutions in the interior. As demonstrated in the literature, high-fidelity simulators range from USD 10,000 to USD 100,000, depending on the brand and available features[5]. In contrast, the approach developed in this study – based on AI and hosted on low-cost platforms – offers a pedagogically affordable and effective alternative. Well-prepared scenarios can thus be obtained more accessibly without losing substantial impact on learning.

Furthermore, the high recommendation rate and strong agreement regarding the potential for application across different disciplines reinforce the scalable and adaptable nature of the developed model. This teaching strategy therefore constitutes a promising educational tool, given that the primary requirements are: a smartphone and an internet connection – something particularly compatible with the context of universities in the interior, where the accelerated expansion of places demands creativity and complementary teaching approaches.

CONCLUSION

Based on the research findings, the study's objective was achieved, with the tool presenting high acceptance and a significantly positive perception regarding its utility in the training of clinical management.

This study contributes to medical education in that it encompasses the creation, evaluation, and validation of the tool by students. The solution addressed in this study constitutes a low-cost tool in terms of dissemination and maintenance, with significant complementary impact on the medical training of students in both initial and advanced semesters. This is particularly noteworthy since, when combined with real clinical rotations, the instrument can increase both the technical and humanistic capacities of medical training. Thus, SimHarvey does not compete with real clinical practice, but rather complements it.

Indeed, the study fits within the contemporary debate on the appropriate role of technology in medical education, demonstrating that technological tools – when aligned with updated clinical guidelines and explicit pedagogical objectives – can represent accessible alternatives to high-fidelity simulations, something essential in the context of the internalization of medical education.

Nonetheless, it is important to recognize the inherent limitations of the methodology used. First, this is a single-center study based solely on perceptive measures of acceptance, which limits the generalization of results – particularly with respect to different educational contexts or those with distinct epidemiological characteristics. Although the sample of 118 participants is adequate for statistical analyses, multicenter studies involving other medical schools in Tocantins and other regions would provide more robust evidence. Second, the study evaluated user perception and satisfaction, but did not include an objective assessment of learning or comparison with control groups using alternative methodologies. Future studies should include experimental designs that allow comparison of learning gains between students who used the VP and those subjected only to traditional methodologies.

Additionally, it was not possible to assess the long-term impact of VP use on students' clinical competencies, including performance in subsequent assessments, in supervised clinical practice, or in progression examinations. It would be relevant to follow student cohorts throughout their academic trajectory to verify whether tool use correlates with better performance in objective assessments of clinical reasoning.

Thus, the findings of this study underscore the need for the creation of new technologies, while also pointing to limitations and new perspectives for future research to evaluate such methodologies. Furthermore, the tool created, being a first version, still presented issues related to language and website stability; however, given the high acceptance and feedback provided by students, it will be possible to implement changes and improvements for future versions. Therefore, further studies – with multicenter, longitudinal, and double-blind designs – are needed for greater methodological validation.

Consequently, in the specific context of Tocantins – marked by the accelerated expansion of medical school places and the need to provide excellence in training with limited resources – tools such as this gain strategic relevance. They represent an opportunity to democratize access to quality educational resources and to contribute to the training of physicians better prepared to meet the health needs of the population.

CRediT author statement

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All authors have read and agreed to the published version of the manuscript.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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