Research Article

Evaluation of IoT-Enabled Interactive UI Design Effect Based on the Discrete Mathematical Model

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Received 30 July 2022; Accepted 26 September 2022; Published 3 October 2022

Academic Editor: Muhammad Zakarya

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Today, the Internet of Things (IoT), often referred to as smart home technology, is used by many individuals in their daily life. The majority of IoT devices include a companion mobile application that consumers must install on their tablet or smartphone to operate, configure, and interface with the IoT device. Multiple kinds of IoT systems have grown in popularity alongside the growth of information engineering. The accessibility of a user interface (UI) in an IoT system is becoming increasingly crucial. This causes major issues with accuracy and evaluation time. This research suggests a discrete mathematical model for IoT-enabled interactive UI design impact assessment approach to address the concerns of low evaluation accuracy and long evaluation time in existing interactive UI design effect evaluation methods. It creates an IoT-enabled interactive UI design effect assessment index system using interactive UI design vision, hearing, and feeling. It gets IoT-enabled interactive UI design effect evaluation indexes, builds a judgment matrix, derives the weight coefficient of each evaluation index, and employs the hierarchy based on the weight coefficient produced. To complete the assessment of the IoT-enabled interactive UI design effect, the analytical approach evaluates the relative value of the seven evaluation indicators by utilizing the discrete Hopfield neural network to develop the evaluation mathematical model. The simulation results reveal that the suggested method’s IoT-enabled interactive UI design effect evaluation accuracy is greater, while the evaluation time is shorter.

1. Introduction

Currently, the adoption of Internet of Things (IoT) technologies, which connect numerous objects to computer networks and offer value, has been widespread. In an IoT system, the user interface is how the system presents the information it generates to the interactive user interface (UI). As a result, it is not an exaggeration to suggest that the quality of the UI has a significant impact on the effectiveness of the IoT system. The IoT system’s user interface is realized as a graphical user interface (GUI) employing touch panel screens, for example. Furthermore, gadgets’ featuring buttons, switches, LEDs, and so on may be employed in various types of IoT systems. As a result, the IoT system’s UI should be developed to combine the usage of GUI with UI devices such as switches and buttons.

As IoT largely depends on the Internet that developed in the West during the second part of the twentieth century. The Internet ushered in a new era of human communication, allowing knowledge to be distributed across traditional political, economic, cultural, and geographic barriers, resulting in a qualitative improvement in the breadth, speed, and efficiency of information transmission. The Internet’s platform got increasingly complete in the 1990s, and the web interface became the initial vision of all netizens. With the Internet’s continued popularity and proliferation in this explosive period, it has become a crucial conduit for information distribution and the most common mode of information transmission [1]. The Internet is made up of thousands of websites, and each website is made up of several web pages. As a result, the web interface serves as the web page’s front end. For information distribution, the visual design of the web interface is especially crucial. In
comparison to the West, the visual design of the web interface in China is relatively behind and has not been generally acknowledged by the public.

At present, there are few Chinese websites with sophisticated interface designs and unique artistic creations. Based on the current development of China’s Internet, the visual design of China’s web interface is far from reaching. The Western level of art has not caused its due design and cultural influence [2]. Based on the above factors and the increasingly strong aesthetic needs of modern society with increasingly rich material life, it is believed that the research on the visual design of web interfaces has extraordinary theoretical and practical significance. The task of web interface visual design is to use basic elements such as text, graphics, color, animation, and audio to visualize information content to help viewers deepen their understanding of information and achieve the purpose of conveying information [3]. In other words, it must play a variety of diagnostic and interpretation functions for the information disseminated, while at the same time satisfying the aesthetic needs of the viewer group targeted by the website. Users and linked businesses place higher importance on the interactive and aesthetic aspects of the user interface. In addition, mobile games and tablet computers require UI designers to optimize them as a whole. In addition, from the perspective of traditional visual communication, UI design refers to the GUI such as the design of the interactive operation of the screen product and the visual effect of the interface, emphasizing the systematic design of the environment, the machine, and the human, which needs to be combined with ergonomics science, aesthetics, computer science, psychology, and market demand. For example, the well-known Huawei Honor series mobile phones and Apple’s smart products, iPad and iPhone, are widely loved by consumers. The reason why the products of these two companies are so popular is reflected in the outstanding software and hardware design. The fast and attractive UI interface design also piques consumers’ interest in purchasing. As a result, the impact of interactive UI design is assessed to enhance the quality of interactive UI interface design impacts. Many researchers have contributed to the creation of effective UI in this area. The contributions of these academics are detailed in Section 2.

Based on perceptual engineering, the early work of Zhu et al. [4] presents a technique for measuring the influence of e-commerce website product design and specifies product design goals and product design aspects by employing Internet technology to randomly redirect visiting visitors. The enhanced version collects data on user activity, does data statistics and analysis, and derives the evaluation result. The user takes part in the test without realizing it. The original and upgraded versions of the product are both available online at the same time and are influenced by a variety of external objective variables. The evaluation conclusions are more accurate and credible. The product design scheme combining an e-commerce APP and a hotel reservation APP verifies the validity and feasibility of the evaluation scheme. This method has certain reference significance for the perceptual design and design evaluation of Internet e-commerce websites. However, the design effect evaluation of this method takes a long period, causing low evaluation efficiency. Similarly, Li et al. [5] proposed a product design evaluation method under VR interactive technology. The user feedbacks the evaluation requirements to the system main controller through the human-computer interaction module, and the main controller transmits the formulated user requirements to the evaluation index system management subsystem. The subsystem first queries relevant demand information through the information query subsystem and then uses the three-tier classification evaluation model to establish and modify the product evaluation index system. It changes the evaluation index weights under the mandatory judgment method and the expert method. It sorts the evaluation indicators according to the index weights and comprehensively evaluates them. In addition, the analysis subsystem comprehensively evaluates the product design effect according to the sorted evaluation indicators. The viewer can view the evaluation effect in the evaluation result output module. After experimental analysis, it is found that the shortest time of the evaluated product design plan is 4.9 ms, and the minimum energy consumption is 0.498 kJ. The effect of human–computer interaction is good. The work of Li et al. [6] proposed a neural network-based interactive design evaluation method for dairy products. Aiming at the three indicators of interactive evaluation of dairy products, namely, “usability, education, entertainment” and its sub-indices, the ANP network analysis method is used to determine the weight of each index in the overall evaluation. After that, it establishes an evaluation model for the interactive design of baby products based on the RBF neural network and uses actual cases to verify its feasibility. The evaluation method has been verified in practice and its evaluation effect is objective and reasonable. It has a certain reference value for a more accurate evaluation of the interactive design of baby products. However, the above two methods have low accuracy in evaluating the effect of interactive UI design, resulting in a poor evaluation effect.

Because of the problems of the above methods, this study proposes IoT-enabled interactive UI design effect evaluation method based on discrete mathematical models, verifies the effectiveness of this method through simulation experiments, solves the problems in the traditional methods, and lays the foundation for interactive interface design.

The major contributions of this research work are listed below:

(i) This research suggests a discrete mathematical model for IoT-enabled interactive UI design impact assessment approach to address the concerns of low evaluation accuracy and long evaluation time in existing interactive UI design effect evaluation methods.

(ii) It first explains the structure of the IoT system for interactive design effect and IoT-enabled interactive UI design effect evaluation index system. After that, the evaluation and simulation of the mathematical model based on a discrete Hopfield neural network are thoroughly explained.
(iii) Secondly, it creates an IoT-enabled interactive UI design effect assessment index system using interactive UI design vision, hearing, and feeling.

(iv) Finally, it gets IoT-enabled interactive UI design effect evaluation indexes, builds a judgment matrix, derives the weight coefficient of each evaluation index, and employs the hierarchy based on the weight coefficient produced.

The rest of the sections of this study are organized in an organized manner as given below. The evaluation method of interactive IoT-enabled UI design effect based on the discrete mathematical model is presented in Section 2. Section 3 is based on the simulation and experimental analysis of the suggested method of IoT-enabled interactive UI design effect based on the discrete mathematical model. Finally, Section 3 highlights the conclusion of this study.

2. Evaluation Method of Interactive IoT-Enabled UI Design Effect Based on the Discrete Mathematical Model

2.1. Structure of IoT System for Interactive Design Effect. The Internet of Things system is made up of many functional parts. This study focuses primarily on the interactive IoT-enabled UI design effect of the functional component in charge of information display. Figure 1 depicts the organization of an IoT system, which includes a sensing component, an actuation component, a digital communications component, and an information processing component.

As shown in Figure 1, the sensing device is connected to a thing and is responsible for gathering information from the object. Similarly, the actuating component communicates with and controls the item. The data processing component analyses data from sensing devices to provide more valuable information, which is then transmitted to the actuation component through the data connection component. The sensor component, actuation component, and data transfer component are all implemented as embedded systems in several IoT networks.

On the contrary, the information processing component is also realized as an IT system. In an IoT system with this architecture, the information display function is primarily implemented as one of the embedded system’s functions. The information generated by the information processing component can be used by a system user with help of the information presentation function offered by the embedded system. As a result, we will enhance the design process in this research, focusing on the UI element of the embedded system built as the information presentation component of the IoT system for effectively evaluating the effect of interactive IoT-enabled UI design.

2.2. IoT-Enabled Interactive UI Design Effect Evaluation Index System. User interface (UI) design must not only fully reflect the interaction between the interface and the user but also meet the needs of different groups of users and carry out effective R&D and design according to the user’s perspective. Based on providing people with more convenient and high-quality services, the interaction and ease of use of UI design are comprehensively improved. The visual elements of interactive UI design include perception, hearing, and vision. Designers need to have an in-depth understanding of software functions and requirements, use information technology to conduct comprehensive analysis and research on related data, and quickly locate usage methods. The user environment and users carry out a series of design activities to fully satisfy the user needs of end users. In addition, it is necessary to fully consider the reading habits, usage rules, interest preferences, and other characteristics of different user groups and carry out in-depth thinking and innovation on the design form. In the concrete practice process, designers should cleverly use contemporary elements and innovative design concepts. Grasp the user’s visual thinking rules, scientifically use innovative technological methods to fine-process the preliminary design, and effectively optimize the design details to ensure that the transmission, communication, and exchange of information can be better completed [7].

Designers must thoroughly adhere to the principles of consistency, interactivity, and simplicity of use of interface visual design, grasp the link between interaction, objectives, design, and elements, and consider the user’s experience and emotions while creating specific designs. Users can create numerous interface design styles from which to pick or optimize the look of the interface design based on user input. Text is the most direct and effective visual element in interactive user interface design, as well as a significant means of information transfer and interaction in human-computer interaction [8]. In the set interface, avoid using conventional or unusual characters as much as possible, and instead use plain and undecorated text symbols. According to online survey data, interactive UI designers can establish the default font, font size, and format and put appropriate text guides or template instructions in the interface to help users to
customize settings based on their preferences. Panel design must be powerful in both aesthetics and usefulness not only to appeal to people’s aesthetics but also to correctly transmit vital information. When creating graphical visual elements such as buttons and icons, it is required to scientifically define the shape, color, composition, characteristics, functions, and names based on the interface theme and overall impact, as well as conduct interactive actions such as touch, click, and slide. [9] Optimization we may also add static pictures in BMP, PSD, PEG, PNG, GIF, and Web formats to the website, display them using compression methods, and account for brightness and color distortion, among other things, to boost the application difference in the post-design makeup procedure. When choosing an interface color, examine the usage impact of the color tone as well as the user’s comfort and optimize the color brightness, standard color application, color matching, and major color division. When developing the layout, you may take into account the user’s left-to-right, top-down surfing tendencies and concentrate on the commonly used application functionalities in a specific region, so the user can focus and operate it the first time. Hide certain seldom used functionalities so that users can view them based on their requirements, making the interface cleaner and more orderly [10].

As a result, this study builds an IoT-enabled interactive UI design effect evaluation index system using interactive UI design vision, hearing, and feeling to produce the interactive UI design effect evaluation index displayed in Table 1.

2.3. The Weight of Each Indicator Is Determined. We calculated the weight of each evaluation index after building the IoT-enabled interactive UI design effect evaluation index system and collected the interactive UI design effect evaluation index. When calculating the weight of each index, the weight coefficient of each evaluation index is acquired using the built judgment matrix, and the analytic hierarchy procedure is utilized to compute the relative relevance of the seven evaluation indexes based on the obtained weight coefficient [11]. We set the evaluation set’s scale from 1 to 9 and then create a judgment matrix based on the meaning provided by the set of assessments. The scale of the assessment set utilized is revealed in Table 2.

By examining the evaluation set in Table 2, we suppose that the same type of interactive UI design effect evaluation index is a criterion level, and compare a level n index \( U_{m1}, U_{m2}, \ldots, U_{mn} \). The influence of IoT-enabled interactive UI design effect evaluation index in another criterion layer is assumed to be \( O \). The two evaluation indexes such as \( U_i, U_j \) are taken each time, and \( a_{ij} \) is utilized to denote the proportion of the effect of \( U_i \) and \( U_j \) to \( O \), which forms a judgment matrix \( A \) given in the following equation:

\[
A = \begin{bmatrix}
a_{11} & a_{1n} \\
\vdots & \ddots & \vdots \\
a_{m1} & \cdots & a_{mn}
\end{bmatrix},
\]

where \( A = (a_{ij})_{mn} \), \( a_{ij} \geq 0 \), and \( a_{ij} = 1/a_{ji} \), \( i, j = 1, 2, \ldots, n \). At this time, the above equation is a positive and reciprocal matrix.

<table>
<thead>
<tr>
<th>Serial no.</th>
<th>Scale</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a )</td>
<td>One</td>
<td>This expression signifies that two elements are equally essential</td>
</tr>
<tr>
<td>( b )</td>
<td>Three</td>
<td>This indicates that one aspect is somewhat more essential than the other</td>
</tr>
<tr>
<td>( c )</td>
<td>Five</td>
<td>One aspect is more critical than the other</td>
</tr>
<tr>
<td>( d )</td>
<td>Seven</td>
<td>It indicates that when two things are compared, one is manifestly more essential than the other</td>
</tr>
<tr>
<td>( e )</td>
<td>Nine</td>
<td>It indicates that when two things are compared, one is more essential than the other</td>
</tr>
<tr>
<td>( f )</td>
<td>2, 4, 6, 8</td>
<td>The median value of the two adjacent judgments mentioned above</td>
</tr>
<tr>
<td>( g )</td>
<td>1, 1/2, \ldots, 1/9</td>
<td>The comparative judgment ratio</td>
</tr>
</tbody>
</table>

Table 1: IoT-enabled interactive UI design effect evaluation index system.

<table>
<thead>
<tr>
<th>First-level indicators</th>
<th>Secondary indicators</th>
<th>Third-level indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactive UI design effect ( U )</td>
<td>Visual ( U_1 )</td>
<td>Color ( U_{11} )</td>
</tr>
<tr>
<td>Hearing ( U_2 )</td>
<td>Brightness ( U_{12} )</td>
<td>Image ( U_{13} )</td>
</tr>
<tr>
<td>Feel ( U_3 )</td>
<td>Sound ( U_{23} )</td>
<td>Noise ( U_{22} )</td>
</tr>
<tr>
<td>Overall effect ( U_{31} )</td>
<td>Form ( U_{33} )</td>
<td></td>
</tr>
</tbody>
</table>

2.4. Evaluation and Simulation of the Mathematical Model Based on Discrete Hopfield Neural Network. A Hopfield network is a sort of spin glass network popularised by John Hopfield.

Table 2: Proportional scale evaluation set.

In a weighing technique, the coefficient related to observation is its weight. The decision makers assign a priority ranking to the multiojectives by selecting weighting coefficients. This results in a more general understanding of the utility function that represents the decision maker’s choice \( (s) \). According to the above equation, the weight coefficient is obtained in the following equation:

\[
A \omega = \lambda \omega,
\]

where \( \lambda \) represents the largest eigenvalue of \( A \) and \( \omega \) represents the eigenvector of \( \lambda \).

Combining (1) and (2), we get the index weight value [12]. According to the weight values obtained, the analytic hierarchy process is used to calculate the relative importance of the 7 evaluation indicators including color, brightness, image, sound, noise, shape, and overall effect. Hence, (3) represents the calculation formula:

\[
wi = \frac{c}{A \omega (U_{m1}, U_{m2}, U_{mn})}
\]

where \( c \) represents the degree of influence on the effect of IoT-enabled interactive UI design.
Hopfield in 1982, as described previously by Little in 1974, relying on Ernst Ising’s work with Wilhelm Lenz on the Ising model. Hopfield has made significant contributions to the artificial neural revolution, demonstrating that a modeled neural network shows crucial computational features. Hopfield networks may be utilized as associative memory to store and retrieve information, as well as to solve combinatorial optimization issues. Hopfield neural system is a fully associated feedback network, comprising continuous and discrete types. A Discrete Hopfield Neural Network (DHNN) is a single-layer neural network with binary input and output. Therefore, according to the relative importance of evaluation indicators, this study uses a discrete Hopfield neural network to construct IoT-enabled interactive UI design effects. Evaluation of mathematical models [13].

The input of the network is represented by \( I_1, I_2, ..., I_n \) and can be used as a threshold; on the contrary, the output is represented by \( V_1, V_2, ..., V_n \), and the relationship between input and output can be obtained as per equations (4) and (5):

\[
x_j(t) = \sum_{wij} V_j + I_j, \quad (4)
\]

\[
V_i(t + 1) = \text{sgn}(x_j(t)), \quad (5)
\]

where \( \text{sgn}(\cdot) \) is a symmetrical step function, and the output is +1 and −1. While, \( W \) represents the connection weight matrix of the network, and its element \( wij \) represents the connection weight of the \( j \)th neuron to the \( i \)th neuron [14].

The development of the Hopfield neural network state is a complicated nonlinear dynamic system. An “energy function” can be used to assess the system’s stability. When specific criteria are satisfied, the network’s energy gradually lowers until it reaches the system’s stable point. If the system’s stable point is thought of as a remembrance, the process of moving from the starting state to this steady point is the procedure of looking for the memory. Associative memory is the primary use of DHNN. Once the input vector \( I \) is used as a preliminary value, the system changes through feedback, and a vector \( V \) is obtained from the production of the system. Similarly, \( V \) is a steady memory associated with the development from the preliminary value \( I \). If we utilize it to resolve the supplier evaluation issue, we must first design \( W \) and \( I \) so that the sample of the memory pattern corresponds to the steady point of the system, which is equal to the training of the neural network procedure. The skilled memory model resembles the normal supplier evaluation rating, and the data to be assessed (i.e., the supplier to be rated) are then used as the new initial state. The network considers the starting state to be a novel rapid mode (i.e., the occurrence of certain distorted and noisy memory patterns) and recalls the memory pattern that is “closest” to it. This is the procedure of interlink memory [15].

The Hopfield network evaluation method is broken into two stages: memory and association. Because each assessment index has a varied weight, weight must be considered when assessing. A tougher task is expressing the weights of numerous indicators in discrete neural systems. In this research, a strategy of logically grouping neurons is employed to address this problem based on the weight of each evaluation indicator. Neurons in a similar group correspond to the same evaluation index. The superior the weight of the index, the number of neurons in the matching group, the more and the greater the effect on the evaluation outcome of the neural system. The specific method is as follows.

Supposing the overall amount of evaluation indicators is represented by \( m \), and the weights of each indicator are, respectively, \( wi, 1 < i < m \) after adjustment; then, there are \( 0 < wi < 1 \) and \( \sum_{i=1}^{m} wi = 1 \). Suppose the group corresponding to the weight \( wi \) is \( Gi \); then, the number of neurons \( ni \) contained in \( Gi \) is calculated in the following equation:

\[
n_i = RND(100 \times wi) \quad (6)
\]

where \( RND(\cdot) \) represents a rounding function that is calculated as per the standard of rounding, and the principle of maximum carry at the end is used for specific processing of \( n_i \) and the total is guaranteed to be 100. In the mode of memory, the neurons in the similar group take the same value; in the rapid mode (data to be evaluated), the neurons in the similar group also take the similar value, which is equal to the input data of the matching index of the group. Since these neurons in the same group have the same value in the procedure of memory and relationship, they have the “same” effect on the evaluation result. The bigger the weight of the index, the greater the number of neurons in its associated group, the stronger the force of “identity,” and the greater the influence on the neural network’s assessment outcomes. In this way, the role of weight is included in the evaluation outcome.

The total number of neurons in each level of the neural network is represented by \( N \), and the memory capacity of Hopfield is \((0.13\sim0.15)\ N\). When \( N \) is about 100, the corresponding memory capacity is 13–15. If the amount of samples in the memory mode is less than 13, then the Hopfield network designed according to this is reasonable and feasible, and the expression of the mathematical model for constructing an interactive UI design effect evaluation is given in the following equation:

\[
S = \frac{n_iN}{V_i(t + 1)}. \quad (7)
\]

3. Simulation and Experimental Analysis of the Suggested Method of IoT-Enabled Interactive UI Design Effect Based on the Discrete Mathematical Model

The user interface is the extent to which an interface assists a user in completing the activity for which it was designed. This usually refers to the extent to which errors are prevented and tasks are completed successfully, which is measured by the “rate of success” or “task completion percentage.” In this research, a simulation experiment analysis was done under the MatLab simulation platform to validate the efficiency of the IoT-enabled interactive UI
design effect evaluation method based on the discrete mathematical model in the actual usage of the apps. As the experimental material, we use IoT-enabled interactive UI design effect assessment indicators such as color, brightness, picture, sound, noise, shape, and overall effect. In addition, we perform an interactive UI design effect evaluation and randomly choose experimental samples from 7 indications to assess the usefulness of sample data. The sample size statistics of each indicator in the experiment are shown in Figure 2.

Figure 3 indicates that the correctness of the training samples and the correctness of the testing samples are quite comparable in all 30 classifiers (packet sensitivity type, packet content type, and interaction type). The accuracy rate is the classifier’s accuracy on the samples of training, whereas the accuracy testing is the classifier’s accuracy on the testing samples. Whereas if the correctness of the training samples is nearly identical to the correctness of the testing samples, there is no overfitting, otherwise, there is overfitting.

The IoT-enabled interactive UI design effect assessment approach is based on the discrete mathematical model proposed in this research, with the above effective experimental sample number as the experimental object. The product design assessment approach presented in [5] under VR interactive technology and in [6] proposed based on the evaluation method of interactive design of infant items based on neural network compares and evaluated the evaluation accuracy of interactive UI design. The comparison result is shown in Figure 4.

According to Figure 4, it can be seen that the interactive UI design effect evaluation accuracy of the interactive UI design effect evaluation method based on the discrete mathematical model proposed in this study can reach up to 100%, which is higher than the product design evaluation method under the VR interactive technology proposed in [5]. Li et al. [6] proposed the interactive UI design effect evaluation accuracy of the interactive design evaluation method based on the neural network of the baby products with high accuracy.

The discrete mathematical model put forward in this research serves as the foundation for the IoT-enabled interactive UI design effect evaluation approach, which is used to further validate the efficacy of the method. The product design evaluation approach under VR interactive technology suggested in [5, 6] is based on the neural network. The interactive design assessment approach for infant items is a comparative examination of the interactive UI design evaluation time. Figure 5 depicts the comparative result.

Analysis of Figure 5 shows that the evaluation time of IoT-enabled interactive UI design effect using the discrete mathematical model-based interactive UI design effect evaluation method proposed in this study is within 2 s. This is better than the product design evaluation method and product design evaluation method under VR interactive technology proposed in [5]. Li et al. [6] proposed a short evaluation time of interactive UI design effect based on neural network-based interactive design evaluation method for baby products.
4. Conclusions

Currently, the Internet, with the assistance of IoT, is rapidly changing the world. With the rapid development of network information, more and more people use this technology to facilitate themselves. It has contributed to the formation of the embryonic form of the network economy, especially since e-commerce has also entered people’s daily lives. Nowadays, shopping through e-commerce is a very common thing. With the emergence of a hundred schools of thought on e-commerce websites, under the premise of fierce competition, e-commerce, there are more and more website interface designs. At the same time, the extension of e-commerce continues to expand. As a result, assessing the impact of interactive UI design is critical. Based on these findings, this study suggested an IoT-enabled interactive UI design effect evaluation approach based on discrete mathematical models, validated its efficacy through simulation tests, overcame difficulties in existing methods, and provided the groundwork for interactive interface design. According to the simulation findings, the proposed method’s IoT-enabled interactive UI design effect evaluation accuracy is higher, while the evaluation time is lower.

Data Availability

The data used to support the findings of the study can be obtained from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare that there are no conflicts of interest in the publication of this paper.

References