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Development of Brain Balancing System for Left and Right Hemispheres

Karen Chua, Zheng You Lim*, Kok Swee Sim and Shing Chiang Tan

Abstract— This paper presents the development of the Brain Balancing System Windows Application (BBSWA) to improve both the left and right hemispheres of the brain. The BBSWA includes the brain training games such as spot the difference, piano, block view, word building, word scrambler, sudoku, left-hand control, memory card, flash card, crossword, math logic, and mnemonics. In this research, the Stroop test and brain dominance test are employed to measure the balancing level between the two hemispheres of the brain. The results show that the BBSWA developed in this research is able to improve the balancing level between the left and right hemispheres of the brain. This research proves the theory of brain balancing and brain balancing can be achieved through appropriate brain training. The largest improvement achieved is that the percentage of dominance between the two brain hemispheres is reduced by 18.18%. The smallest improvement achieved was that the difference between the two brain hemispheres was reduced by 9.08%.

Keywords— Brain, Dominance, Left, Right, Hemisphere, Training, Education, Software, Application.

I. INTRODUCTION

The most complex organ in the human body is the brain. The brain can be divided into the right and left hemispheres. The brain is the important organ that in

charge of learning, sensing, body controlling, and memory [1]. The left and right hemispheres are connected by the corpus callosum, which is located in the middle of the left and right hemispheres. [2] Corpus callosum allows for the information from the left hemisphere to flow to the right hemisphere and vice versa. The functions of the left hemisphere are different from the functions of the right hemisphere [3]. The left half movements of the body are controlled by the right hemisphere. Vice versa, the right half movements of the body are controlled by the left hemisphere [4]. In addition, both hemispheres of the brain associate with different kinds of thinking. The left brain is majoring in rational, verbal, analytical, and factual thinking. The right brain is majoring in emotional, non-verbal, and creative thinking [5]. Most people tend to dominantly use one hemisphere of the brain. This explains why some people are talented in art but weak in mathematical calculation, while some people are good at logical thinking but not creative thinking [6]. However, studies show that the potential of the brain can be maximized by fully utilize both sides of the hemisphere, and this state is known as brain-balanced or whole-brain thinking [7]. The advantage of a whole-brain thinker is that the person has rapid learning ability [8] as well as higher thinking agility and diversity [9]. Hence, in this way, the whole brain

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thinker will be able to fully unleash the potential of their brain and have a high possibility of achieving utmost attainments in their life [10]. Some of the famous persons who are known as whole brain thinkers are Leonardo Da Vinci, Albert Einstein, and Thomas Edison.

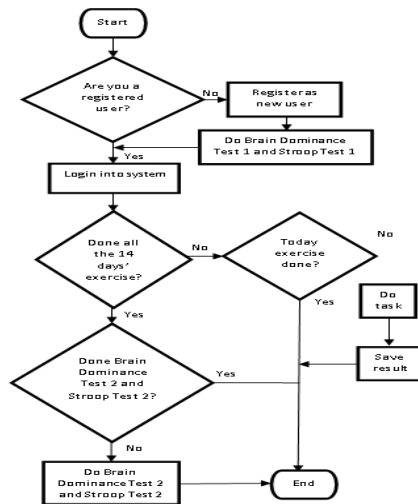


FIGURE 1. General flow chart of system.

Hence, this research aims to develop series of brain training games in the Brain Balancing System Windows Application (BBSWA). In addition, it is aimed to enhance the weaker hemisphere of the brain, meanwhile retaining the capability of the stronger hemisphere of the brain in order to achieve the brain balancing state.

II. METHODOLOGY

This section explains the development of the Brain Balancing System Windows Application (BBSWA), brain training games, training procedure, and assessment tools.

A. Brain Balancing System Windows Application (BBSWA)

The BBSWA is developed with several features: user login and register system, brain training games (will be further explained in Section II(B)), and brain dominance test (will be further explained in Section II(D)). Figure 1 shows the general flow chart of BBSWA.

A new user is required to register a username and password before starting the Brain Dominance Test 1 and Stroop Test 1. The reason that Brain Dominance Test 1 and Stroop Test 1 are performed before brain training games is to compare the activity of the left and right brain before and after the participants undergo brain training games. After registration, the participant will be directed to a login form to access the Brain Balancing System Windows Application. The participation of participant for that particular day will be checked before the exercise of the day starts. The exercises are referred to the brain training games designed in the system. If the participant has already participated in the exercises for the day, the system will

end with a message to notify the participant to join in again the next day as the current day's exercises have been done. On the other hand, if the participant has not yet participated in the exercises for the day, he will be directed to the exercises. The exercises are commissioned according to the result of Brain Dominance Test 1. The amount of the left-brain development type exercise is more than the amount of the right-brain development type of exercise if the participant's left-brain capability is weaker. After undergoing the exercises for the day, the system will save the results and exits from the system. After 14 days of the training, the subject is required to undergo the Brain Dominance Test 2 and Stroop Test 2. This is to assess the subject's improvement of brain balancing level after the series of training.

The login and register system in BBSWA are developed to allow multi-user and to serve the privacy information security purpose. With this feature, multiple users can access the system anywhere with their login credentials. This feature also prevents the participants' information and results from being viewable by the other participants.

For the user login feature, an excel file consisting of all the users' data is stored in Google Drive. The excel file acts as a database and stores all the users' results. The excel file can be retrieved from Google Drive when the system administrator wishes to read data from or write data into the excel file. Once the excel file is updated with the latest data, the excel file will be uploaded into Google Drive. The purpose of locating the excel file in Google Drive is to allow the participant accessing to his/her latest data from another PC as long as the PC is installed with the Brain Balancing System Windows Application. The Brain Balancing System Windows Application is connected to Google Drive using Google APIs. The Google APIs is an application programming interface (APIs) that allows a third-party application to communicate with any Google services such as Google Drive. Google Drive is online storage space. Authorization and authentication of a third-party application to access Google Drive is done by Google APIs using the OAuth 2.0 protocol [11]. To begin the communication between the Google Drive and Brain Balancing System Windows Application, OAuth 2.0 client credentials from the Google APIs Console are required. The client credentials consist of a Client ID and a Client Secret. The functions of client credentials are to generate an authorization token and prove the identity between client and service provider.

Object Linking, Embedding, and Database (OLEDB) provider is used in the Brain Balancing System Windows Application to write data into and read data from the excel file that consists of all the users' data. OLEDB is also known as Object Linking and Embedding Database. OLEDB is an application programming interface (API) designed by Microsoft. The function of API is to allow two or more systems to communicate and transmit data. OLEDB provider acts as a bridge and it is used to communicate between the Brain Balancing System

Windows Application and the excel file. Besides, the OLEDB provider is required to communicate between the system with the excel file, Access Database Engine is also required in order to complete the communication between the system and the excel file [12]. The Access Database Engine is used to facilitate data transfer between Microsoft Office files and any application other than Microsoft Office application [12].

B. Brain Training Games

The brain training games developed in the Brain Balancing System Windows Application are Piano, Left Hand Control, Sudoku, Memory Card, Flash Card, Block View, Spot the Difference, Math Logic, Word Building, Word Scrambler, Crossword, and Mnemonics. Every brain training game is implemented to improve either the left or right hemisphere of the brain or to enhance both sides of the brain.

The first brain training game in Brain Balancing System Window Application is Piano. Playing piano can improve the balancing between the two hemispheres of the brain as playing the piano can train hand and eye coordination, improve dexterity, sharpen motor skills and improve focus [13]. Both sides of the hand and eye control are required when playing the piano. Hence, playing a musical instrument such as the piano can improve brain activity in the left and right brain. Besides that, playing the piano can also develop the right side of the brain. This is because the right brain is used to process music.

Next, the Left-Hand Control game is designed to improve the activity of the right hemisphere of the brain [14]. The game rule of the Left-Hand Control is that the participants are required to use their left hand to control the mouse and click on the square to turn red. The game aims to increase the activity of the right brain hemisphere by using the left hand.

Sudoku is a popular logic-based puzzle game. The objective of the Sudoku puzzle game is to fill in the 9 x 9 grid with digits from 1 to 9. The 9 x 9 grid is formed of nine identical 3 x 3 grids. The participants are required to fill in the number from 1 to 9 in the grid without any repetition in any row, any column, and any 3x3 grid. The Sudoku game is developed in the Brain Balancing System Windows Application to enhance left brain development. The participants' concentration and logical processing will be improved throughout the Sudoku brain game [15].

The Memory Card game is a memory-based brain training. Memory game is very useful in improving the neural pathways [16]. Through the memory game, new neural connections will be formed in the brain. The Memory Card game can enhance the function of the brain and raise memory capacity and ability. In this game, three levels are designed with different difficulties. The higher the level is, the greater the number of cards is required to be memorized by the participants in a limited time.

Next, the Flash Card game is developed to improve eye coordination, brain processing, and concentration. The participants are required to fully focus on the game in order to achieve the best result [17]. Faster eye coordination can be trained through the game because the participants are required to memorize 5 different flash cards consisting of different shapes and colors. Each card will only be shown for 1 second. There are also three levels designed for the flash card game. In the first level of the game, the participants are required to concentrate on the shape printed on the flash card. In the second level of the flash card game, the participants are required to look for the shape stated in the question and memorize the color of the stated shape. The third level of the flash card game requires the participants not to only focus on the color and shape, but also the number written in the predefined shape and color. The brain processing, concentration, and eye coordination can be improved when the game is designed to push the participants' limits.

Block View game is a visual-based brain game. Visual-based brain games can be used for developing the right hemisphere of the brain. Creative thinking and imagination skills can be enhanced through playing the Block View game. Three levels are designed for the Block View game. The first level is Block View from a Point as shown in Figure 2, the second level is Block Forming as shown in Figure 3 and the third level is a moving block as shown in Figure 4.

Spot the Difference is a brain training game that requires visual information processing [18]. During visual information processing, the movement of eyes, visual attention, visual awareness, and visual memory processing of the participants are trained. Eye movement is required by the participants to compare the images shown in the question. After going through a few Spot the Difference games, the participants' visual information processing ability could be improved.

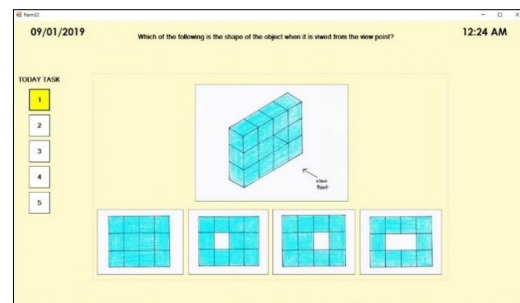


FIGURE 2. The layout of Block View from a Point.

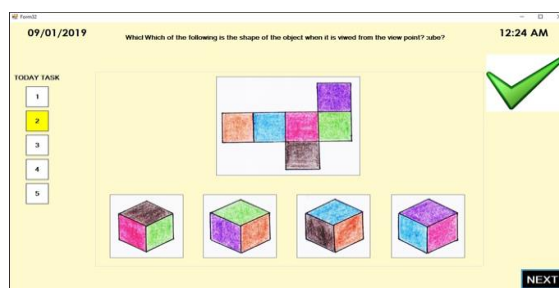


FIGURE 3. The layout of Block Forming.

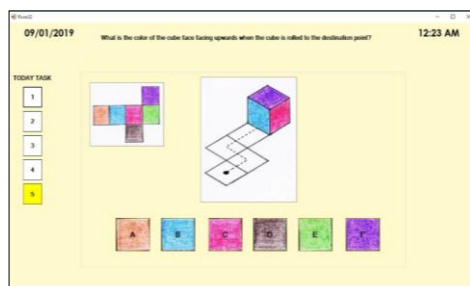


FIGURE 4. The layout of Move the Block.

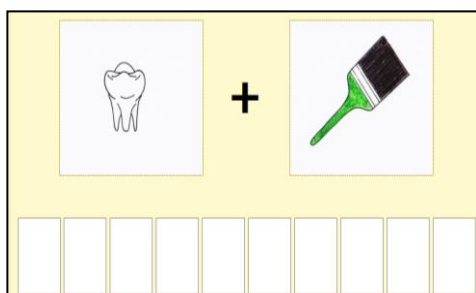


FIGURE 5. The layout of Word Building Game.

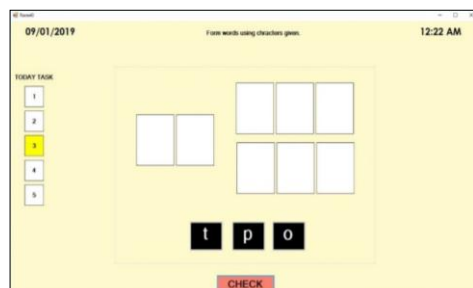


FIGURE 6. The layout of Word Scrambler Game.

Left brain thinkers usually have stronger math and logic skill. Hence, we develop a Math Logic game in order to improve the left-brain activity of the brain. Ten different questions are created in the Math Logic brain training game. The questions are mainly related to mathematic and require the participants to think logically or calculate logically in order to obtain the correct answers to the questions. Math Logic game can also help the participants to develop problem-solving skills.

Word Building is a brain training game where the participants are required to form a word by referring to the two pictures presented in the question. The Word Building game is a very useful word game that can be

used to help the participants in learning spellings, think logically, and enhance their imagination skills. The developed application is shown in Figure 5. Imagination ability will be improved during the game when the participants are required to use their imagination to link both pictures together to form a word.

Word Scrambler is a word game that can improve the left brain's processing speed. Besides, the word scrambler game can also improve the participants' working memory as the game requires the participants to recall the vocabulary learned. In addition, the word scrambler also trains the processing speed of the eyes. This is because the participants are required to form more than one word by using the given characters without repeating the characters in a word. Therefore, the participants need to have a fast eye and brain processing speed in order to get the answers in a short period. Figure 6 shows the example of the Word Scrambler game.

Crossword game is a type of puzzle game that helps the participants to enhance the development on the left hemisphere of the brain. The participants are required to think about the character to fill into the crossword puzzle by understanding the word-based clue or image-based clue given in the question. Two types of crosswords game are designed in this application. The first type of the crossword puzzle game is Fruit Crossword and the second type of crossword puzzle is Month Crossword.

Mnemonic is a very useful memory game that makes memorizing information easier [19]. The acrostic is a type of mnemonics. It is a type of memory strategy that creates a complete sentence or a series of words, in which the first character of each word stands for the order of words to be remembered. Mnemonic increases the ability of the participants to remember difficult or unfamiliar information easily. Throughout the Mnemonics game, the left hemisphere of the brain is enhanced as the games include language, logical thinking, and mathematic. Three types of modes are designed for the Mnemonic game. The first mode is the order of operations in algebra. Parenthesis, Exponents, Multiplication, Division, Addition, and Subtraction are the operations in algebra. The sentence "Passing Exams May Be Difficult at School" is formed by referring to the first letter of the order of the operations in the algebra. The second mode is to memorize the order of the planets in the solar system. The order of the planets in the solar system from the sun is Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The sentence "My Very Educated Mother Just Served Us Noodles" is formed in order to memorize the order of planets in the solar system. The third mode is to memorize the order of the resistor color code. The resistor colors consist of black, brown, red, orange, yellow, green, blue, violet, grey, and white. "Better Be Right or Your Great Big Vocation Goes Wrong" is the

sentence formed according to the first letter of each resistor color code. Imagination and creativity of the sentences are the most important aspects of the mnemonic. A creative sentence can help the participants to easily remember and the memory will last in the mind for longer.

C. Assessment Tools

There are two assessment tools employed to assess the performance of the subject's brain: Brain Dominance Test and Stroop Test.

Two different sets of brain dominance tests are designed in the Brain Balancing System Windows Application. Each set consists of 22 questions. The first set is required to be completed by the subject in the beginning before proceeds to the brain training session. The second brain dominance test will take part after the participants complete all the designed brain training. During the test, the participants are required to choose between the two options given in the question. Each option represents either the cognitive style of the right brain or the cognitive style of the left brain. The difference between the left and right brain dominance percentages will be calculated for each participant according to the option that they choose [20]. The performance of the subject is justified by comparing the result of the second test set to the result of the first test set. If the difference between the left and right brain percentage is decreased, this shows that the balance between the left and right hemisphere of the brain is improved after the participants participated in the brain training games. The improvement can be shown by the reduction in the percentage difference between the left and right brain hemispheres.

Next, another assessment tool is the Stroop Test. The Stroop test is performed by using a list of words represented in different colors that may not match with the actual color's name as shown in Figure 7. The participants are required to respond to the color instead of the word. Stroop test is carried out to test the cohesiveness of the left-brain hemisphere and right brain hemisphere. If a person is said to have a better balance between the left and right brain, the person can efficiently and precisely respond to the Stroop test. When there is a distraction to the game which contradicts the game's instructions, the ability of the two brains to work together will be put to the test [21]. The performance is assessed based on the correctness and time taken for each response. This test is also carried out before and after the brain training.

After the participant has completed all the exercises, the participant will be tested with a second set of Brain Dominance Set (Brain Dominance Test 2) and Stroop Test (Stroop Test 2). A form of the participant's result will be presented to show the activity of the left and right brain before and after undergoing all the exercises. From the results, we can observe whether the balance between the two brains is improving or not.

D. Subjects and Training Procedure

There is a total of 23 participants (14 males, 9 females) participated in the brain balancing training by using the developed Brain Balancing System Windows Application. All the subjects have an IQ score above 85 points.

As mentioned in Section II(C), the subject is required to complete the first set of Brain Dominance Test (Brain Dominance Test 1) and Stroop test (Stroop Test 1). Based on the results of Brain Dominance Test 1, the participants are assigned to one of the 5 different categories according to their result. In order to improve the left and right balancing, the brain training games are commissioned according to the result of Brain Dominance Test 1. If the participant is weak in the left-brain capabilities, more exercises will be assigned to focus on left-brain development and vice versa. Questions are set in each game. The amount of questions for left and right brain development is distributed as shown in Table 1.

The participants are required to go through all the brain training game exercises that are designed for 2 weeks continuously. In this system, a total of 5 brain exercises should be completed every day. Each session of exercise will take 15 minutes at most to complete.

BLACK	BLUE	YELLOW	RED
BLACK	BLUE	YELLOW	GREEN
BLACK	BLUE	RED	GREEN
BLACK	YELLOW	RED	GREEN
BLUE	YELLOW	RED	GREEN

FIGURE 7. The example of words for Stroop Test.

TABLE 1. The amount of the left and right brain development exercise for each category.

Category	Percentage (%)		Amount of question	
	Left (L)	Right (R)	Left	Right
1	$L \leq 20$	$80 < R \leq 100$	63	7
2	$20 < L \leq 40$	$60 < R \leq 80$	49	21
3	$40 < L \leq 60$	$40 < R \leq 60$	35	35
4	$60 < L \leq 80$	$20 < R \leq 40$	21	49
5	$80 < L \leq 100$	$R \leq 20$	7	63

III. RESULTS

To assess the reliability of the developed BBSWA, it can be determined by comparing the results before and after the brain training. The results of Brain Dominance Test 1 and Brain Dominance Test 2 are illustrated in the bar charts in Figure 8 and Figure 9.

The participants are categorized based on the results referring to Table 1. Category 3 is considered the people with balanced brain, which is the aim of the developed BBSWA system. Categories 1 and 2 are right-brain dominant and category 4 and 5 are left-brain dominant. According to the bar chart shown in Figure 8, most of the participants before the training are categorized in category 4. A total of 11 participants out of 23 participants is categorized in category 4 and occupied 60 to 80 percent of left-brain dominance. This result proves that the traditional education system indeed mainly focuses on the left brain's cognitive development. According to Figure 9, after the brain training sessions, the number of left-brain dominant (category 4 and category 5) and right brain dominant (category 1 and category 2) decreased after undergo brain training using BBSWA. According to the matrix table shown in Table 2, the left brain dominance subject in category 1 transited to category 3, and the right brain dominance subject in category 5 transited to category 4 after undergoing brain training. 3 subjects from category 2 and 4 subjects from category 4 transited to category 3 after the brain training. The number of subjects in category 3 remains in the same category after undergoing the brain balancing training. In total, the number of participants in category 3 shows an increase from 6 people to 13 people after the participants participated in the brain training games as shown in Figure 9. Category 3 is the category that consists of the most balanced between the left hemisphere and the right hemisphere of the brain. This shows that the brain training games designed in the Brain Balancing System Windows Application can improve the respective hemisphere of the brain to achieve brain balancing. Besides, the brain training games in this application will also help the people to maintain the brain balanced state for those are already achieved brain balanced in the beginning before the training.

Stroop Test is also used to observe the changes of participants after using the BBSWA. The first attempt of the Stroop Test is to record the ability of the participant's left and right brain hemisphere to work together before the participants participate in the brain training session. The second attempt of the Stroop Test is to record the ability of the participant's left and right brain hemisphere to work together after the participants completed the brain training session. The average completion time taken for the Stroop Test 1 and Stroop Test 2 for each subject is computed in Figure 10.

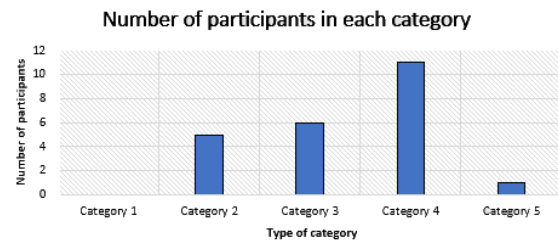


FIGURE 8. The number of participants in each category for Brain Dominance Test 1.

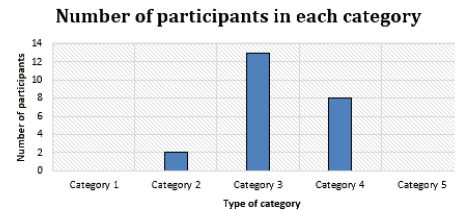


FIGURE 9. The number of participants in each category for Brain Dominance Test 2.

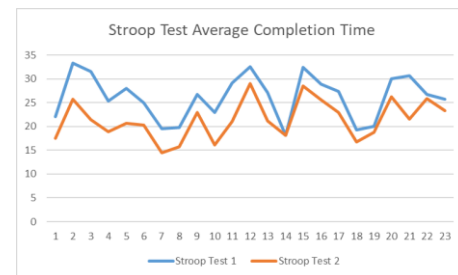


FIGURE 10. Average completion time taken for the Stroop Test 1 and Stroop Test 2 for each subject.

TABLE 2. Matrix table of transited category after brain training.

Category		Brain Dominance Test 2 (After)				
		1	2	3	4	5
Brain Dominance Test 1 (Before)	1	0	0	1	0	0
	2	0	2	3	0	0
	3	0	0	5	0	0
	4	0	0	4	7	0
	5	0	0	0	1	0

According to the result as illustrated in Figure 10, all the subjects have improved with a shorter completion time in Stroop Test 2 compared to the completion time in Stroop Test 1. For Stroop Test 1, the average completion time is 26.18 seconds. Whereas, the average completion time for Stroop test 2 is 21.42 seconds. This is due to the participants have a higher ability of the left and the right brain to work together, achieving the state of brain balanced after undergoing the brain training in BBSWA. As a result of a better balance between the left and the right brain, the participants are able to respond to the Stroop Test efficiently and accurately.

Hence, these results of Brain Dominance Tests and Stroop Tests prove that the brain training games designed in the Brain Balancing System Windows

Application are able to improve the balance between the left and the right brain hemisphere.

IV. CONCLUSION

According to the Brain Dominance Test, the number of participants categorized in most balance category which is category 3 shows an increase from 6 participants to 13 participants. According to the Stroop Test, the average time taken by the participants to respond to each question in the Stroop Test 2 is shorter than the average response time taken by each participant to respond to each question in the Stroop Test 1. The results show that after undergoing the brain pieces of training in BBSWA, the ability of the left and right brain to work together has improved as the participants are able to respond to Stroop Test 2 more efficiently and accurately without much distraction from the dominant side of the brain. In a nutshell, the brain training games designed in the BBSWA has shown to improve the balance between the left and right hemisphere of the brain. Imbalance energy may occur if a person only uses one of their brain hemispheres excessively. Our brain can achieve limitless potential when our left-brain hemisphere and right-brain hemisphere interact in a balanced condition to a level that is unprecedented, and it is known as whole-brain thinking.

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AUTHOR CONTRIBUTIONS

Karen Chua: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Zheng You Lim: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Shing Chiang Tan: Conceptualization, Data Curation, Methodology, Validation, Writing – Original Draft Preparation;

Kok Swee Sim: Project Administration, Supervision, Writing – Review & Editing.

CONFLICT OF INTERESTS

No conflict of interests were disclosed.

ETHICS STATEMENTS

Our publication ethics follow The Committee of Publication Ethics (COPE) guideline. <https://publicationethics.org/>

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