Journal of Psychology and Social Health (JPsySH)
2021, Vol. 5, 1–7

eISSN: 2600-7819

# Development of Cognitive Training Game to Enhance Cognitive Process of Children with Learning Difficulty

## *Pembangunan Permainan Latihan Kognitif Berdasarkan Teknik Meta-Kognitif untuk Kanak-Kanak yang Mempunyai Masalah Pembelajaran*

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Received: 22 November 2021 / Accepted: 15 December 2021
*Dihantar: 22 November 2021 / Diterima: 15 Disember 2021*

*This paper discusses the development of cognitive training games based on meta-cognitive technique and to aid in enhancing cognitive processes among children with a learning difficulty (especially having problems paying attention and responding to stimuli accurately). The study was conducted on four (4) primary school students in the Bio-neurofeedback laboratory at the Faculty of Psychology and Education, Universiti Malaysia Sabah. The instruments used in this study include a cognitive training game, which consists of Neuro Game: Number and Neuro Game: Location to measure cognitive process and response accuracy to stimuli. The Mind Wave EEG Headsets measure the attention level of participants and computer to display the game and monitor participants' cognitive processes. The effectiveness of the cognitive training game is tested by comparing the mean score of attention and mean score of accuracy response to stimuli of participants at the initial five training sessions and a subsequent five training sessions. The pretest result shows no significant increment in participants' attention score and accurate response to stimuli score from the first five cognitive training sessions to the end of the session. These results are not as expected. However, the cognitive training game is believed to measure and improve children's cognitive process with further improvement with learning difficulty. One of the encouraging findings in the current study is the neuro game designed by the researchers can be used as an inventory to measure individual attention level and accuracy response to stimuli.*

*Keywords:* cognitive training, learning difficulty, attention level, accuracy response

*Kertas kerja ini membincangkan pembangunan permainan latihan kognitif berdasarkan teknik meta-kognitif dan untuk membantu dalam meningkatkan proses kognitif dalam kalangan kanak-kanak yang mempunyai masalah pembelajaran (terutamanya yang menghadapi masalah tumpuan dan masalah untuk bertindak balas terhadap rangsangan dengan tepat). Kajian telah dijalankan ke atas empat (4) orang pelajar sekolah rendah di makmal Bio-neurofeedback di Fakulti Psikologi dan Pendidikan, Universiti Malaysia Sabah. Instrumen yang digunakan dalam kajian ini termasuk permainan latihan kognitif, yang terdiri daripada Permainan Neuro: Nombor dan Permainan Neuro: Lokasi untuk mengukur proses kognitif dan ketepatan tindak balas terhadap rangsangan. Alat Mind Wave EEG digunakan untuk mengukur tahap perhatian peserta dan komputer pula untuk memaparkan permainan dan memantau proses kognitif peserta. Keberkesanan permainan latihan kognitif diuji dengan membandingkan skor min perhatian dan skor min tindak balas ketepatan kepada rangsangan peserta pada lima sesi latihan awal dan lima sesi latihan berikutnya. Keputusan praujian menunjukkan tiada peningkatan ketara dalam skor perhatian peserta dan tindak balas yang tepat terhadap skor rangsangan daripada lima sesi latihan kognitif pertama hingga akhir sesi. Keputusan ini tidak seperti yang diharapkan. Walau bagaimanapun, permainan latihan kognitif dipercayai dapat mengukur dan meningkatkan proses kognitif kanak-kanak dengan penambahbaikan selanjutnya dengan masalah pembelajaran. Salah satu penemuan yang menggalakkan dalam kajian ini ialah permainan neuro yang direka oleh penyelidik boleh digunakan sebagai inventori untuk mengukur tahap perhatian individu dan tindak balas ketepatan terhadap rangsangan.*

*Kata kunci: latihan kognitif, masalah pembelajaran, tahap perhatian, tindak balas ketepatan*

Generally, children who experience learning difficulties can be identified through three characteristics which include (i) lower performance level compared to peers in school, (ii) lower rate of learning, (iii) and difficulties in generalising what they learned from one context to a new situation. Brown and Campione (1990) claimed that children with learning issues could not gain flexible access to the knowledge or skills they had learned before. The skills learned is retained at the early stage of learning. However, learning difficulty may also be due to the children's meta-cognitive shortcoming and low self-regulatory (Brown, 1978; Brown & Ferrara, 1985; Brown, Palincsar & Armbruster, 1984).

Children with high meta-cognitive ability can plan strategies while conducting their tasks, be aware of the procedures for solving a problem effectively, review their achievement, and reflect and appreciate their success (Butler, 2002). On the contrary, children with low

  eISSN: 2600-7819

metacognitive skills may display deficiencies in their motive (avoid involvement in activities or quit readily), method (use ineffective strategies), result (setting an easy and less challenging goal) and source (not seeking help when needed) (Schunk & Ertmer, 2000).

Meta-cognition refers to the awareness of an individual about what is known and unknown. It is the individual's awareness and control over their cognitive processes and generates cognitive strategies to improve thinking and learning (Brown, 1987). Metacognitive technique refers to ways to increase awareness about the process of thinking and learning that occurs. When this awareness exists, individuals can control their thinking by planning, monitoring and reviewing what is learned. According to Pintrich (1999), students with high meta-cognition use cognitive and self-regulatory strategies to learn subjects in school. These students also possess a wide range of metacognitive knowledge specifically related to learning strategies and the learning processes in general (Pintrich et al., 2000). These students can also review their cognitive functions (Butler & Winnie, 1995) and modify their learning behaviour when they encounter changes due to demand from a situation or environment.

The meta-cognitive ability and generalisation skills are two essential aspects that can help to improve the academic achievement of children with learning issues (Brown, 1978; Brown & Ferrara, 1985; Brown et al., 1984; Schunk & Ertmer, 2000; Butler, 2002). Thus, in designing the intervention programs for this particular group of children, metacognition and self-regulation (self-regulatory) should be emphasised. Hence, the purpose of this study was to establish a cognitive training game that can help improve the self-regulation and meta-cognitive abilities of students with learning difficulties. The level of attention and accuracy of response to the stimuli among children with learning difficulties was the meta-cognitive aspect focused on in this study. In addition, this study also aims to carry out a pre-test on the effectiveness of cognitive training game to enhance the ability of metacognition (attention level and accuracy of response to stimuli) and self-regulated study of participants (assessed by the increase in the score of responding accuracy to stimuli from one training session to the next).

# Method

## Research Design

This study applied an experimental design to test the effectiveness of cognitive training games in improving meta-cognitive abilities and self-regulated survey of participants. The study was conducted in two phases: The first phase involved the development of cognitive training game based on meta-cognitive techniques, which include: (i) resource management strategies (ways to remember the number and location of the object), (ii) information process strategy (process information visually or using visual and verbal), and (iii) control activities (accuracy response to stimuli). The second phase was then carried out to pretest the effectiveness of the game (neuro game: object location and neuro game: number) in improving participants' attention level and accuracy response to stimuli.

## Participants

Four volunteer elementary school children in Kota Kinabalu, Sabah, aged between 10 and 12 years old, participated in this study with consent from their parents. Children who participated in this study are healthy. This study did not include children who have learning difficulties due to visual, hearing and motor disabilities, mental retardation, emotional disorders or environmental, cultural and economic deficiencies.

## Research Location

The study was conducted at the Bio-Neurofeedback Laboratory in the Faculty of Psychology and Education, University Malaysia Sabah.

## Instrument

The instruments used in this study consist of:

a) Cognitive training game contains neuro game: object location and neuro game: number designed by the researchers.
b) EEger Neurofeedback System, neurofeedback tools to measure the mental response (level of attention) through brain wave frequencies displayed in the computer monitor or laptop.
c) A Laptop or desktop computer (for the researcher to monitor the cognitive activity of the participants) and a laptop (for participants to play the neuro game).

# Data Analysis

The data were analysed by using IBM SPSS for Windows version 21.0. Non-parametric test of the Wilcoxon Signed-Rank is used to test the difference in the mean score of attention and mean score of accuracy response to stimuli of the participant's in the initial five training sessions and subsequent five training sessions. The purpose is to test the effectiveness of cognitive training games in improving participants' cognitive processes.

# Results and Discussions

## The Development of Cognitive training game based on Meta Cognitive Techniques

The designed cognitive training game consists of two cognitive activities: Neuro Game: Object Location and Neuro Game: Number. It is designed based on meta-cognition techniques. The cognitive training game is designed to train the participants to use resource management strategies and information processing strategies by stimulating their brain to process and remember the number and location of the object (stimuli) (refer to Figures 1 and 2 for the example of neuro game) which repeatedly displayed on the monitor of the computer.

## Apparatus

**Neuro Game: Number**. This exercise contains five number games programmed in Microsoft PowerPoint. In

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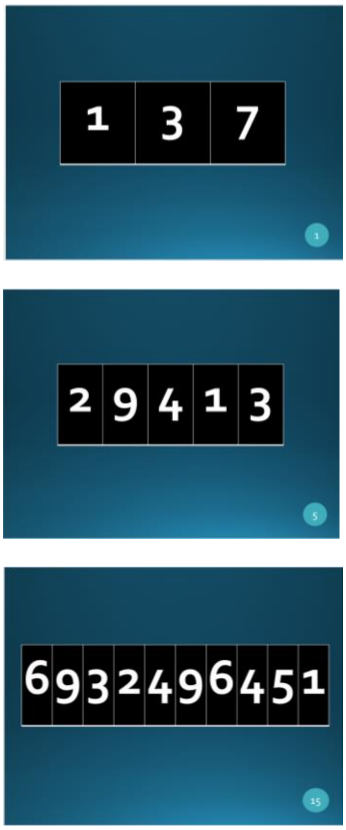
each of the number games, there are 16 sets of numbers arranged randomly from one (1) to nine (9) (the same digits are not repeated in the same set) and by the level of difficulty. This exercise begins by setting a unique number from a three-digit number (e.g., 3 5 8) to a memorable story of a set of ten-digit numbers (e.g., 8 6 3 4 2 1 9 5 7 0). The time of each set of numbers displayed on the computer screen has been determined according to the difficulty level (starting from 1 second for the low level up to 3 seconds for the high level of difficulty). Likewise, the time for the participant to respond to the stimuli has also been set between 1 and 3 seconds to answer each set of numbers depending on its level of difficulties (refer to Figure 1).

**Figure 1**

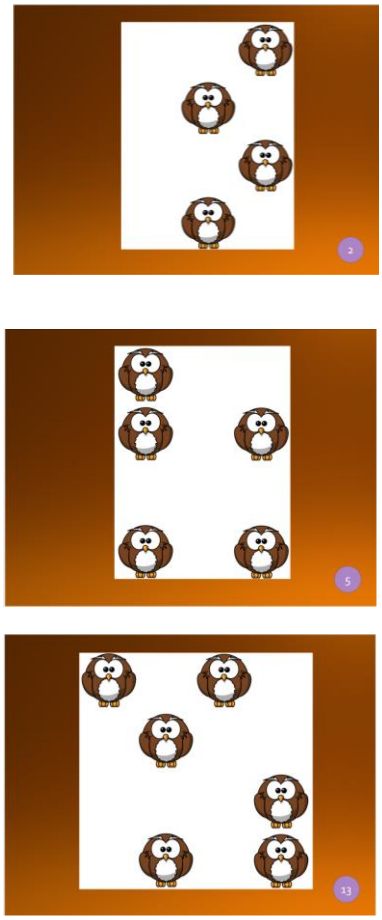
*Three Examples of Neuro Game: Number*




**Neuro Game: Object Location.** This training contains five games of object locations which also has been programmed in Microsoft PowerPoint. Each game also has 16 sets of location patterns that are randomly arranged. This exercise does not emphasise the level of difficulty. The time of each group of object location pattern displayed on the computer screen and the response time given has also been set. One second for each set of object locations pattern to show an on the computer screen and one second for the participants to mark the object location on the answer sheet provided (refer to Figure 2).

**Figure 2**

*Three Examples of Neuro Game: Object Location*



## The MindWave Mobile EEG Headsets

The MindWave Mobile EEG Headsets are tools used to measure and produce EEG power spectrum output (showing alpha, beta, etc.), NeuroSky eSense meters (measuring attention and meditation levels) and eye blinking recording. This device consists of a headset, ear clip and sensor arm. This device's reference electrodes and ground are channelled to the ear clips, and the EEG electrode is directed to the sensor arm. It should be placed on the forehead at the eye level of the participants (refer to picture 1 for the device The MindWave Mobile EEG Headsets and electrode positions). EEG data and scores for attention and meditation levels are recorded in Neuro View in The Research Tools. The data is then exported to Microsoft Excel or the IBM SPSS Statistics program to analyse the participants' attention level.

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***Figure* 3**

*The Mindwave Mobile EEG Headsets and Electrode Position*

**Administration and Scoring.**

In this study, a minimum of 20 cognitive training sessions is suggested for children with learning difficulties. In each training session, the participants were given one neuro game: number (containing 16 sets of numbers) and one neuro game: object location (also containing 16 groups of object locations pattern). Each cognitive training session takes approximately 25 minutes. The participants will be given a neuro game: number training first, followed by a neuro game: object location.

Participants are asked to memorise the number and location of the object displayed on the computer screen as suggested by the researcher. For example, the participants may memorise the stimuli visually or, using both visual and verbal stimuli (see and read silently), memorise the displayed number as a whole or by grouping the numbers. As for the neuro game: object location, participants can also remember visual stimuli and imagery (look and then draw the object's location by imagining it in the head or memorising according to the place patterns). Participants also can use their strategy to remember the number and the object location in their way. Participants then write their answers in the answer sheet while the computer screen shows "ANSWER". In each training session, the participants will be given one trial per game before the actual training is carried out and before the score is recorded.

The score of accuracy response to stimuli obtained is calculated by the correct answers given by the participants in the neuro game: number and neuro game: object location. The higher the score obtained by the participants, the higher the accuracy of responding to stimuli among the participants. Attention level scores are derived from EEG data and scores recorded in Neuro View in The Research Tools. The measure score is the average score of attention in each cognitive training session.

**The Effectiveness of Cognitive Training Game in Enhancing the Attention Level and Accuracy Response to Stimuli of The Participants**

The effectiveness of cognitive training games in enhancing the attention level and accuracy response to stimuli of the participants is tested by comparing the mean score of the attention and mean score of accuracy response to stimuli of the participants in the initial five training sessions and subsequent five training sessions. The effectiveness of cognitive exercises is proven if the mean score of the attention and mean score of accuracy response to stimuli increases significantly from the first five training sessions to the subsequent five training sessions. Due to the small sample size, data analysis was performed with a non-parametric Wilcoxon Signed Rank Test. The results of the study are shown in Table 1.

The result in Table 1 shows that there is no significant difference between the mean score of attention gained by the participants in the first five cognitive training sessions 1 to 5 (*M*= 45.92, *SD*= 2.94) and the mean score of attention obtained by them in sessions 6 to 10 (*M*= 47.58, *SD*= 4.48) ($z$ = -730, p>.05). The findings also showed that there is no significant difference in participants' attention level after they had attended cognitive training sessions 6 to 10 and after they had attended training sessions 11 to 15 (*M*= 47.81, *SD*= 2.43) (z = .365, p>.05). The same results were obtained for the next training session, where all the participants did not show any significant improvement in their attention scores from the first training session to the 20th training session. The result showed the pattern of the attention score obtained by the participant within 20 training sessions is unstable and fluctuate.

The Signed-Rank Test also indicated no significant difference between the attention score obtained by participants in the initial cognitive training sessions and subsequent cognitive training sessions based on neuro game: number (refer to Table 2). This finding is parallel to the results on cognitive training neuro game: object location.

The Wilcoxon Signed-Rank Test used to test the difference mean score of accuracy response to stimuli indicated that there was no significant difference between participants' mean score of accuracy response to stimuli in the initial cognitive training sessions and their mean score in the later cognitive training sessions neither based on neuro game: object location nor neuro game: number (refer Tables 3 and 4). Although the results are insignificant, the findings showed that participants' attention scores improved from one training session to the next.

Table 1
*The Wilcoxon Signed-Rank Test on Attention Score of Participants based on Neuro Game: Object Location*

| Session comparison | N | Mean | *SD* | *Z* | Sig. |
|---|---|---|---|---|---|
| Session 1 – 5 | 4 | 45.92 | 2.94 | .730 | .465 |
| Session 6 – 10 | 4 | 47.58 | 4.48 | | |
| | | | | | |
| Session 6 – 10 | 4 | 47.58 | 4.48 | .365 | .715 |
| Session 11 - 15 | 4 | 47.81 | 2.43 | | |
| | | | | | |
| Session 11 - 15 | 4 | 47.81 | 2.43 | .365 | .715 |
| Session 16 - 20 | 4 | 47.48 | 1.35 | | |

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| | | | | | |
|---|---|---|---|---|---|
| Session 1 – 5 | 4 | 45.92 | 2.94 | .730 | .465 |
| Session 16 - 20 | 4 | 47.48 | 1.35 | | |
| | | | | | |
| Session 6 – 10 | 4 | 47.58 | 4.48 | .365 | .715 |
| Session 16 - 20 | 4 | 47.48 | 1.35 | | |

Table 2

*The Wilcoxon Signed-Rank Test on Attention Score of Participants based on Neuro Game: Number*

| Session Comparison | N | Mean | *S.D* | *Z* | *Sig.* |
|---|---|---|---|---|---|
| Session 1 – 5 | 4 | 55.42 | 1.97 | .01 | .98 |
| Session 6 – 10 | 4 | 57.71 | 7.59 | | |
| | | | | | |
| Session 6 – 10 | 4 | 57.71 | 7.59 | 1.46 | .144 |
| Session 11 - 15 | 4 | 51.57 | 3.29 | | |
| | | | | | |
| Session 11 - 15 | 4 | 51.57 | 3.29 | 1.46 | .144 |
| Session 16 - 20 | 4 | 54.88 | 1.43 | | |
| | | | | | |
| Session 1 – 5 | 4 | 55.42 | 1.97 | 1.46 | .144 |
| Session 16 - 20 | 4 | 54.88 | 1.43 | | |
| | | | | | |
| Session 6 – 10 | 4 | 57.71 | 7.59 | .365 | .715 |
| Session 16 - 20 | 4 | 54.88 | 1.43 | | |

Table 3

*The Wilcoxon Signed-Rank Test on Accuracy Response to Stimuli Score of Participants based on Neuro Game: Object Location*

| Session Comparison | N | Mean | *S.D* | *Z* | *Sig.* |
|---|---|---|---|---|---|
| Session 1 – 5 | 4 | 7.81 | 4.08 | 1.10 | .273 |
| Session 6 – 10 | 4 | 9.63 | 2.50 | | |
| | | | | | |
| Session 6 – 10 | 4 | 9.63 | 2.50 | 1.46 | .144 |
| Session 11 - 15 | 4 | 10.56 | 1.78 | | |
| | | | | | |
| Session 11 - 15 | 4 | 10.56 | 1.78 | .921 | .357 |
| Session 16 - 20 | 4 | 10.09 | 2.15 | | |
| | | | | | |
| Session 1 – 5 | 4 | 7.81 | 4.08 | 1.47 | .141 |
| Session 16 - 20 | 4 | 10.09 | 2.15 | | |
| | | | | | |
| Session 6 – 10 | 4 | 9.63 | 2.50 | 1.10 | .273 |
| Session 16 - 20 | 4 | 10.09 | 2.15 | | |

Table 4

*The Wilcoxon Signed-Rank Test on Accuracy Response to Stimuli Score of Participants based on Neuro Game: Number*

| Session Comparison | N | Mean | *S.D* | *Z* | *Sig.* |
|---|---|---|---|---|---|
| Session 1 – 5 | 4 | 7.56 | 2.32 | 1.51 | .131 |
| Session 6 – 10 | 4 | 8.06 | 2.38 | | |
| | | | | | |
| Session 6 – 10 | 4 | 8.06 | 2.38 | .365 | .715 |
| Session 11 - 15 | 4 | 8.25 | 3.14 | | |
| | | | | | |
| Session 11 - 15 | 4 | 8.25 | 3.14 | 1.10 | .273 |
| Session 16 - 20 | 4 | 8.63 | 2.67 | | |
| | | | | | |
| Session 1 – 5 | 4 | 7.56 | 2.32 | 1.83 | .068 |
| Session 16 - 20 | 4 | 8.63 | 2.67 | | |
| | | | | | |
| Session 6 – 10 | 4 | 8.06 | 2.38 | 1.29 | .197 |
| Session 16 - 20 | 4 | 8.63 | 2.67 | | |

Although the results of this cognitive training are not expected at the pre-test stage, it is still believed that the cognitive training based on neuro game: object location and neuro game: number can enhance participants' cognitive process. This is evident from the increased scores gained by participants in the initial training session to the next cognitive training session. It is also believed that through ongoing cognitive training, the participants will learn the strategies and modify their information processing and resource management strategies to more effective strategies and ultimately help them improve their attention level and responsiveness to stimuli. Additionally, the findings may be influenced by the small sample size, the number of training sessions, the test administration procedure, and the neuro game's design.

Based on the pre-test results, it is assumed that the sample size needs to be increased and the number of cognitive training sessions either based on neuro game: object location or neuro game: number should also be expanded to probably at least 30 sessions, especially for the children with learning difficulty. Cognitive training should be carried out consistently and conducted at least twice a week in administrative procedures. The psychological condition (e.g. emotion, mood) and physical condition (e.g. fatigue) of participants during cognitive training should also be given attention. Cognitive training itself should also be improved. Rewards and music can be added to the original neuro game (object location and number) to encourage positive behaviour and reduce boredom. Different neuro games that can stimulate cognitive processes and resource management, such as neuro games in stories, puzzles, and short video clips, can also be added to the initial cognitive training.

One of the exciting findings in this study is the neuro game designed by the researchers can be used as an inventory to measure the level of attention and accuracy response to stimuli. It can be used to differentiate individual abilities in these two aspects. From that, the measure of the outcome of this inventory can help develop an intervention program for children with problems in attention and in responding accurately to stimuli.

## Conclusion

The researchers of the current study had developed two cognitive training games based on metacognitive techniques. The neuro game (object location and number) aims to improve children's cognitive and learning processes with learning difficulties. Neuro game: object location and neuro game: number train participants to use the information processing strategies and resource management strategy to enhance attention level and accuracy response to stimuli. In the pre-test of this study, 20 sessions of cognitive training based on neuro game: object location and neuro game: number were given to four volunteer primary school students. The pre-test aims to test the effectiveness of this cognitive training game in enhancing the cognitive and learning process (i.e., the participants' attention level and accuracy response to stimuli). Although the research findings are not as expected, the cognitive training games are believed to measure and enhance the cognitive process of children. Still, further improvement on the design of the games, design of the study, and the procedures of administration of the training are required

## Acknowledgements

This research project is supported by the Innovation Scheme Grants (Project: SGI157-2021) under Universiti Malaysia Sabah. We would also like to express our appreciation to the participants involved in this study.

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eISSN: 2600-7819

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