EFFECTIVENESS OF TENDINGPETS APPLICATION ON WORKING MEMORY AMONG ADOLESCENT IN PHRAE PROVINCE, THAILAND : A QUASI-EXPERIMENTAL STUDY

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ประสิทธิผลของเทนดิง พี.อี.ที. แอปพลิเคชั่นต่อสมรรถนะความจำเพื่อใช้งานในกลุ่มวัยรุ่น จังหวัดแพร่ ประเทศไทย: การวิจัยกึ่งทดลองแบบมีกลุ่มควบคุม

น.ส.พิชสุดา เดชบุญ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาสาธารณสุขศาสตรดุษฎีบัณฑิต
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Thesis Title	EFFECTIVENESS OF TENDINGPETS APPLICATION ON WORKING MEMORY AMONG ADOLESCENT IN PHRAE PROVINCE, THAILAND : A QUASI-EXPERIMENTAL STUDY
By	Miss Phitchasuda Detboon
Field of Study	Public Health
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พิชสุดา เดชบุญ : ประสิทธิผลของเทนดิง พี.อี.ที. แอปพลิเคชั่นต่อสมรรถนะความจำเพื่อใช้งานในกลุ่มวัยรุ่น จังหวัดแพร่ ประเทศไทย: การวิจัยกึ่งทดลองแบบมีกลุ่มควบคุม. (EFFECTIVENESS OF TENDINGPETS APPLICATION ON WORKING MEMORY AMONG ADOLESCENT IN PHRAE PROVINCE, THAILAND : A QUASI-EXPERIMENTAL STUDY) อ.ที่ปรึกษาหลัก : ศ. ดร.จิตรลดา อารีย์สันติชัย

บทนำ สมรรถนะความจำเพื่อใช้งาน เป็นสมรรถนะและความสามารถของการทำงานของสมองที่เกี่ยวข้องกับการจำและประมวลผลข้อมูลที่เข้ามาชั่วคราวในขณะทำงานหรือแก้ปัญหา ซึ่งสมรรถนะนี้เป็นสมรรถนะสำคัญต่อวัยรุ่นและมีความเกี่ยวข้องกับความสำเร็จในการเรียนวิชาคณิตศาสตร์ ภาษาอังกฤษและพฤติกรรมเสี่ยงทางสุขภาพ การวิจัยกึ่งทดลองแบบมีกลุ่มควบคุมนี้ มุ่งสำรวจประสิทธิผลของแอปพลิเคชัน "TendingPETs" ในการเสริมสร้างสมรรถนะความจำเพื่อใช้งานและผลกระทบต่อการประสิทธิผลทางการศึกษา และพฤติกรรมเสี่ยงในกลุ่มวัยรุ่นจำนวน 99 คน ในจังหวัดแพร่ ประเทศไทย โดยแบ่งออกเป็นกลุ่มทดลอง 50 คน ซึ่งจะได้ใช้แอปพลิเคชัน "TendingPETs" ร่วมกับการเรียนในห้องเรียนตามปกติ จำนวน 2 เดือน และกลุ่มเปรียบเทียบ จำนวน 49 คน ที่เข้าเรียนในห้องเรียนตามปกติ จำนวน 2 เดือน และกลุ่มตัวอย่างทั้งหมดจะถูกติดตามผลของความยั่งยืนของกิจกรรมเป็นเวลา 4 เดือน ผลลัพธ์ทั้งหมดการวิจัยตั้งแต่ระยะก่อนการทดลอง, หลังการทดลอง (2 เดือน) และระยะติดตามผล (6 เดือน) ถูกนำมาวิเคราะห์ทางสถิติโดยใช้ repeated measures ANOVA

ผลการวิจัย พบว่า คะแนนค่าเฉลี่ยความจำในการทำงานและคะแนนในรายวิชาคณิตศาสตร์ ภาษาอังกฤษในกลุ่มทดลองเพิ่มขึ้นหลังจากการทดลองและระยะติดตามผลอย่างมีนัยสำคัญทางสถิติ ($p< 0.001$) รวมไปถึงมีผลกระทบทำให้เกิดความเปลี่ยนแปลงต่อพฤติกรรมเสี่ยง โดยแสดงให้เห็นว่ามีการลดการบริโภคแอลกอฮอล์ในระยะของการติดตามผลอย่างมีนัยสำคัญทางสถิติ ($p< 0.05$) แต่ไม่มีพบการเปลี่ยนแปลงในการลดการบริโภคยาสูบในกลุ่มเด็กวัยรุ่นทั้งสองกลุ่ม ($p>0.05$)

ดังนั้น ผลการวิจัยนี้อาจจะแสดงให้เห็นว่า แอปพลิเคชัน "TendingPETs" ทำให้เกิดการเปลี่ยนแปลงในทางบวกต่อสมรรถนะความจำเพื่อใช้งาน และความสำเร็จในการเรียนวิชาคณิตศาสตร์ ภาษาอังกฤษ ดังนั้นแอปพลิเคชัน "TendingPETs" น่าจะเป็นเครื่องมือมีค่าในการส่งเสริมความสุขของวัยรุ่น แต่อย่างไรก็ตาม งานวิจัยในอนาคตควรสำรวจผลกระทบที่ยาวนานของแอปพลิเคชันนี้ และรวมไปถึงการให้ความสำคัญกับแปรควบคุมที่อาจมีผลต่อผลลัพธ์ โดยเฉพาะการพฤติกรรมเสี่ยง และในแง่ของการนำไปใช้ อาจจะพัฒนาต่อยอดหรือปรับปรุงข้อจำกัดของแอปพลิเคชันให้ใช้งานได้ในสภาพแวดล้อมของโรงเรียนและครอบครัว การศึกษาเปรียบเทียบและการวิเคราะห์ระยะยาวจะให้ข้อมูลที่มีค่าเพิ่มเติมในการพัฒนากลยุทธ์ด้านสาธารณสุข

สาขาวิชา	สาธารณสุขศาสตร์	ลายมือชื่อนิสิต .....
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Phitchasuda Detboon : EFFECTIVENESS OF TENDINGPETS APPLICATION ON WORKING MEMORY AMONG ADOLESCENT IN PHRAE PROVINCE, THAILAND : A QUASI-EXPERIMENTAL STUDY. Advisor: Prof. CHITLADA AREESANTICHAI, Ph.D.

Working memory performance refers to the capacity and ability of the brain to temporarily remember and process incoming information while working or solving problems. This competency is crucial for teenagers and is linked to success in learning mathematics, English language, and health-related behaviors. This quasi-experimental research, conducted with a controlled group, aims to explore the effectiveness of the "TendingPETs" application in enhancing working memory capacity and its impact on educational effectiveness and risky behavior among 99 teenagers in Phrae Province, Thailand. The participants were divided into an experimental group of 50 individuals who used the "TendingPETs" application alongside regular classroom studies for two months, and a comparison group of 49 individuals who attended school in a normal classroom for the same duration. All participants were followed up to assess the sustainability of the activities for four months. The research results, comprising pre-experiment, post-experiment (2 months), and follow-up (6 months) data, were analyzed using repeated measures ANOVA.

The research findings revealed that the average working memory scores and scores in mathematics and English subjects significantly increased in the experimental group after the experiment and during the follow-up period ($p < 0.001$). Furthermore, the study demonstrated an impact on changes in risk-taking behavior, with a statistically significant reduction in alcohol consumption during the follow-up period ($p < 0.05$). However, there was no change in the reduction of tobacco consumption in either group of adolescents ($p > 0.05$).

Therefore, the results of this study suggest that the "TendingPETs" application induces positive changes in working memory performance and contributes to success in studying mathematics and English. Consequently, the "TendingPETs" application could be a valuable tool in promoting teen happiness. However, future research should explore the long-lasting effects of this application and consider control variables that may influence the results, particularly in terms of risky behavior. Additionally, the application's limitations may be further developed or improved for use in school and family environments. Comparative studies and long-term analyses will provide additional valuable information for developing public health strategies.

Field of Study:	Public Health	Student's Signature .....
Academic Year:	2023	Advisor's Signature .....

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Phitchasuda Detboon

TABLE OF CONTENTS

Page

LIST OF TABLE

Page

LIST OF FIGURE

Page

CHAPTER 1
INTRODUCTION

1.1 Background

Intelligence quotient (IQ) and emotional quotient (EQ) have traditionally been considered crucial factors for success in various aspects of life. However, contemporary evidence from the twenty-first century underscores the significance of executive function (EF) as an even more influential determinant of success in work and life.

Executive function (EF) encompasses a set of cognitive abilities regulated by the prefrontal cortex (PFC). Key components of EF include attention, inhibitory control, cognitive flexibility, activity initiation, working memory, planning, reasoning, problem-solving, and performance monitoring (1). These cognitive abilities are pivotal for academic success, cognitive development, social and psychological growth, as well as overall mental and physical well-being. Importantly, executive functions are not innate but can be cultivated and refined. Research suggests that they continue to develop from early childhood through late adolescence. Among the core elements of executive function, working memory, inhibitory control, and cognitive flexibility are often considered paramount (2, 3, 4).

Working memory is the ability to remember and hold information in memory that is necessary to help integrate information to solve problems or complex decision-making. Working memory, in particular, plays a vital role in the cognitive and social development of adolescents. Strong working memory positively impacts scholastic abilities, such as arithmetic and reading, and is a robust predictor of success in these domains (5, 6). Additionally, robust working memory has been associated with reduced engagement in risk behaviors during adolescence, such as alcohol consumption, driving accidents, and risky sexual behavior (7, 8). Conversely, weak working memory has been linked to difficulties in retaining information, making it challenging for adolescents to engage effectively in tasks such as note-taking during classes (9). Impulsivity is another behavior often associated with weak working memory, which can lead to actions without thoughtful consideration (10). Furthermore, poor working memory has been correlated with substance use in adolescents (11, 12, 13, 14).

There are several approaches to strengthen working memory in adolescents, including educational methods (e.g., visual image memory techniques, retrieval practice), common strategies (e.g., chunking, grouping), and physical activities. Additionally, research suggests that gaming can have a positive impact on executive functions and short-term memory. During gaming, the release of dopamine, a neurotransmitter vital for learning and working memory, has been observed to enhance learning outcomes, visuospatial skills, and memory (15, 16, 17, 18, 19).

In the context of Thailand, research pertaining to working memory among adolescents remains notably deficient, despite its intrinsic relevance to both academic performance and overall health. The decline in academic achievements, particularly evident in subjects like mathematics and English among 9th-grade students in recent years, underscores the urgency of investigating the state of working memory within the Thai adolescent demographic. Data derived from reports by the National Institute of Educational Testing Service reveal a discernible downward trend in the Ordinary National Educational Test scores from 2015 to 2017. Specifically, there is a decline in the overall mean scores for Mathematics (32.40, 29.31, and 26.30) and English (30.54, 31.80, and 30.45) during this period (20). Furthermore, it is imperative to recognize the interplay between weak working memory and substance use among Thai adolescents, thereby accentuating the imperative nature of fostering and enhancing working memory skills within this cohort. The prevalence of alcohol consumption among adolescents aged 15-19 in 2017 stood at 13.6%, with the Northern region recording the highest proportion of adolescent drinkers (21). This issue is further underscored by data from the Department of Public Health, revealing that approximately 250,000 new individuals engage in alcohol consumption in Thailand annually, with an alarming age of initiation noted at 13-15 years (69.0%) and 16-17 years (30.2%) (22). Furthermore, a survey conducted by the Child and Adolescent Mental Health Rajanagarindra Institute in 2016 illuminated a concerning aspect: 5.8% of adolescents aged 13-17 exhibited tobacco abuse, with 2.4% among them being identified as having developed tobacco dependence. These observations collectively underscore the pivotal role of working memory in the lives of Thai adolescents and the urgency of fostering its development (21).

It is noteworthy, however, that research in the realm of working memory in Thailand has predominantly focused on preschool children. Prior studies, such as the works

of Artsiri C and Vanno V in 2018, which explored the application of storytelling to enhance working memory in preschool children (23), Tamaekong A in 2019, which implemented group activities to promote basic executive skills (24), and Siwilas T and Wisessathorn W in 2020, which utilized board games to augment visuospatial working memory in preschool children (25), have all primarily concentrated on this younger demographic. Consequently, there exists a conspicuous dearth of research initiatives concentrating on the augmentation of working memory among Thai adolescents. Moreover, limited studies have ventured into the domain of employing video games as a means to enhance working memory among this specific age group.

Within the context of Phrae province, the concept of working memory remains a relatively novel area of study. To date, research endeavors related to working memory within Phrae province have remained rather limited. Notably, a prior survey conducted in 2018 centered on behavioral issues and learning disabilities associated with weak working memory among 7-year-old children. This survey uncovered that approximately 20.2% of these children exhibited a susceptibility to learning disabilities, with an additional 3.03% displaying indicators of slow learning. However, it is imperative to emphasize that there is an evident dearth of data concerning the status of working memory among adolescents within Phrae province. Conversely, data pertaining to the academic performance of 9th-grade students in Phrae province is available. An analysis of reports from the National Institute of Educational Testing Service highlights a consistent decline in the Ordinary National Educational Test scores from 2017 to 2019, with specific regard to subjects such as Mathematics and English. The overall mean scores for Phrae province students in Mathematics (31.05, 33.68, and 29.56) and English (31.68, 29.87, and 34.15) during this timeframe mirror the trends observed in students across Thailand as a whole (26). Furthermore, the intersection between weak working memory and various health-related issues among adolescents in Phrae province merits consideration. A 2016 Phrae data report identified significant concerns within the adolescent population, including teenage pregnancy, engagement in sexual risk behaviors, and alcohol use (27). This aligns with the findings of Yanuch Y and Yodkhamolsart S (2016), who noted the prevalence of alcohol use as a significant issue among adolescents in the region. Notably, when assessing alcohol consumption patterns by gender, it was observed that male adolescents demonstrated a higher

propensity for alcohol consumption, with a preference for indulging in festival or party communities (28).

While the topic of working memory is indeed an intriguing one within the context of Phrae province, it is essential to acknowledge the inadequacy of studies focusing on working memory among adolescents. Additionally, there exists a conspicuous absence of prior interventions utilizing gaming applications to enhance working memory among adolescents in Phrae province. Consequently, the forthcoming study will endeavor to bridge this gap by implementing the 'TendingPETs' application and assessing its impact on working memory among adolescents within Phrae province, Thailand.

1.2 Research question

Does the TendingPETs application affect working memory among adolescents in Phrae province, Thailand?

1.3 Objective

1.3.1 General Objective

To assess the effectiveness of TendingPETs application on working memory among adolescents in Phrae province, Thailand.

1.3.2 Specific Objective

1) To compare changing of working memory of adolescents before and after receiving a TendingPETs application within a group (intervention group and comparison group).

2) To compare changing of working memory of adolescents before and after receiving a TendingPETs application between intervention group and comparison group.

3) To compare changing of academic performance of adolescents before and after receiving a TendingPETs application within a group (intervention group and comparison group).

4) To compare changing of academic performance of adolescents before and after receiving a TendingPETs application between intervention group and comparison group.

5) To compare changing of risk behaviors of adolescents before and after receiving a TendingPETs application within a group (intervention group and comparison group).

6) To compare changing of risk behaviors of adolescents before and after receiving a TendingPETs application between intervention group and comparison group.

1.4 Research hypothesis

1.4.1 TendingPETs application effect on working memory among adolescent in Phrae province, Thailand.

1.4.2 TendingPETs application effect on academic performance among adolescent in Phrae province, Thailand.

1.4.3 TendingPETs application effect on risk behaviors among adolescent in Phrae province, Thailand.

1.5 Conceptual framework

This proposal study applied Social Cognitive Theory to develop conceptual framework. Detail of conceptual framework in this study shown in Figure 1.

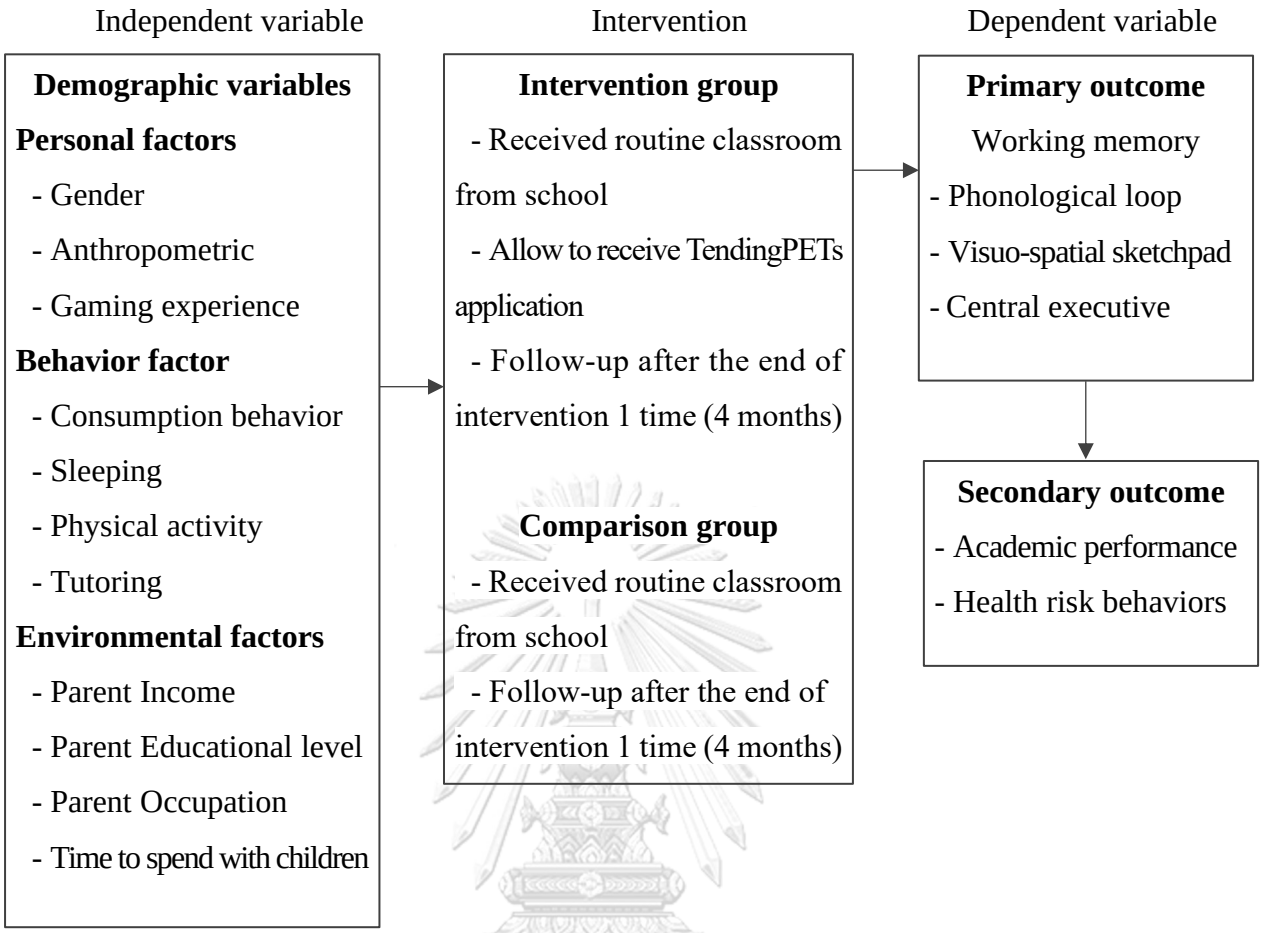


Figure 1.1 Conceptual Framework

1.6 Operation definition

1.6.1 Working Memory (WM) refers to the ability to store and manipulate information in memory, ranging from specific stimuli to complex decision-making. Working memory consists of four components: the central executive, episodic buffer, phonological loop, and visuospatial sketchpad.

1.6.1.1 Phonological Loop is responsible for storing and temporarily retaining vocal or subvocal information through the phonological store and articulatory rehearsal process.

1.6.1.2 Visuospatial Sketchpad is responsible for the temporary storage and manipulation of visuospatial information and mental images.

1.6.1.3 Central Executive functions as the controller, directing attention and information to both the phonological loop and visuospatial sketchpad. It also manages cognitive tasks such as mental arithmetic.

In this study, working memory will be measured using the Lucid Recall test developed by St Clair-Thompson H. L.

1.6.2 Academic Performance refers to the ability of adolescents to apply knowledge and skills to describe, answer, and solve problems across various academic subjects. Academic performance in this study will focus on Mathematics and English performance.

1.6.2.1 Mathematics Performance relates to an adolescent's ability to apply knowledge and skills to describe, answer, and solve problems in the field of Mathematics, specifically under the 9th-grade curriculum. Mathematics performance will be assessed using the Programme for International Student Assessment developed by the Organization for Economic Co-operation and Development (OECD).

1.6.2.2 English Performance pertains to an adolescent's ability to apply knowledge and skills to describe, answer, and solve problems in the field of English, specifically under the 9th-grade curriculum. English performance will be assessed using an English test administered by the Office of the Basic Education Commission.

1.6.3 Risk Behaviors refers to any activity undertaken by individuals with a frequency or intensity that increases the risk of disease, injury, or negative outcomes. In this study, researcher focuses on alcohol use and tsobacco use.

1.6.3.1 Alcohol use refers to the consumption of beverages containing ethyl alcohol.

1.6.3.2 Tobacco use involves the inhalation of smoke from burning tobacco, including cigarettes, pipes, and cigars.

For the assessment of risk behavior among adolescents in this study, the ASSIST tool will be employed.

1.6.4 Adolescents refers to individuals who are 15 years old and attend public schools in Phrae province, Thailand.

1.6.5 Anthropometric Measures encompass a series of measurements used to assess body composition, including muscle, bone, and adipose tissue. The core anthropometric elements measured in this study include height, weight, and body mass index (BMI).

1.6.6 Consumption Behavior relates to the habits that adolescents choose and the supplements they consume or intake into their bodies.

1.6.7 Sleep refers to the natural state of inactivity during which consciousness is effectively suspended. In this study, sleep is measured in terms of hours of sleep.

1.6.8 Physical Activity covers any bodily movement generated by skeletal muscles and may include activities such as walking, cycling, sports, and active forms of recreation. In this study, physical activity will be measured based on timing and types of physical activities.

1.6.9 Tutoring pertains to additional educational sessions attended by adolescents beyond regular school classes. In this study, tutoring is focused on subjects and the number of tutoring hours.

1.6.10 Gaming Experience encompasses activities related to playing games, whether online or offline and across various devices. In this study, researcher attention is directed toward the type of game played and the time spent gaming over a 6-month period.

1.6.11 TendingPETs Application refers to a 2D graphics game application designed for smartphones, rooted in the key concept of Game-Based Learning as described by Plass JL et al (2015). This application comprises five modes: domain character info, daily quests playing, mini-game quests, knowledge reading mode, and duet mode. The application's content is aligned with the central standard curriculum for the 9th grade. Additionally, the Entertainment Software Rating Board (ESRB) has rated this game application with an "E" rating, indicating suitability for all age groups.

CHAPTER 2
LITERATURE REVIEW

The effectiveness of TendingPETs application on working memory among teenagers aged 15 in Phrae province, Thailand: A quasi-experimental study was investigated in this study. So, the following are the findings of the literature review that are related to working memory:

2.1 Executive functions

2.2 Working memory skill

2.3 Games

2.4 Adolescent development

2.5 Health Behavior Theory

2.6 Literature review about game application on working memory among adolescent

2.1 Executive functions

2.1.1 Definition of executive functions

Hughes C and Ensor R (29) define executive functions as the set of process that govern goal-directed acts and flexible, adaptive responses to changes in the environment.

Diamond A (30) defines executive functions as a family of top-down mental process needed when going on automatic or relying on instinct or intuition would be ill-advised, insufficient, or impossible.

Traverso T et al (31) define executive functions as a set of cognitive abilities that allow individuals to control thoughts and actions in the face of new or complex situations.

Zelazo P D et al (32) define executive functions as the attention-regulation skills that make it possibles to sustain attention, keep goals and information in mind, refrain from responding immediately, resist distraction, tolerate frustration, consider the

consequences of different behaviours, reflect on past experiences, and plan for the future.

From reviewing can be summarized definition of executive function as a set of cognitive ability that play important role to help individuals control thoughts and behaviours for make a goal more or less likely to happen.

2.1.2 Where are executive functions controlled ?

Brain is an important organ that is responsible for controlling all functions of the human body. There are different lobes of the brain, containing 4 lobes such as frontal lobes, parietal lobes, temporal lobes and occipital lobes, and each lobe also recognizes and responds differently. In part of executive functions, as we know executive functions refer to mental processes and self-directed action. So, it has been controlled by the prefrontal cortex (PFC).

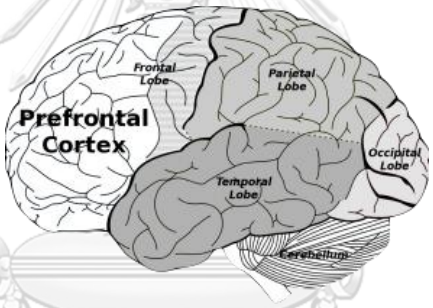


Figure 2.1 Four major lobes of brain: frontal, temporal, parietal and occipital (Sandra Bond Chapman, 2013)

Prefrontal cortex is an area of the cerebral cortex which covers the front part of the frontal lobe. In general the prefrontal cortex is divided into 3 basic parts, including dorsolateral prefrontal cortex, anterior cingulate cortex and orbitofrontal cortex.

1. Dorsolateral prefrontal cortex (DLPFC)

This part is located in the lateral part of Brodmann's area (BA) 9 and 46 . It's important for memory that contributes to processing of information and linked to ability to maintain and shift information, working recall, planning and also important for working memory.

2. Anterior cingulate cortex (ACC)

Anterior cingulate cortex lies in Brodmann's area 24, 25, 32, and 33. These parts have a unique role in cognitive and emotion. The activity of the anterior cingulate cortex has been related to decision-making, inhibition, inappropriate response, attention and motivation.

3. Orbitofrontal cortex (OFC)

This part associated with Brodmann's is 10,11 and 47 (33). This OFC is involved in impulse control, socially appropriate behaviors, adaptive and goal-directed behavior (34).

According to the role of each part of the prefrontal cortex, they are implicated in a variety of complex cognitive behaviors and also contribute to executive function.

How linked between prefrontal cortex and executive function?

Prefrontal cortex is sensitive to variation in levels of neurotransmitters present in the synapse, most specifically the catecholamines, dopamine, and norepinephrine. That is, activity in neurons that underlie EF is high when levels of these neurotransmitters increase moderately from baseline (32).

2.1.3 Key element of Executive functions

Executive function comprises a variety of skills including inhibition (inhibitory control), working memory, cognitive flexibility, attention, initiation, planning and organizing, reasoning, problem solving and monitoring.

2.1.3.1 Working memory is the ability to temporarily hold and manipulate information in an accessible state and put it to use in complex cognitive tasks. Therefore, working memory is necessary for successfully remembering, making sense of new or complex information, linguistic information, whether read or heard (35).

2.1.3.2 Inhibition or inhibitory control is the ability to control behavior, control attention and control emotions so as to ignore distraction and resist temptations, inappropriate habits, and to think before acting.

2.1.3.3 Cognitive flexibility is the ability to flexible thinking that allows humans to switch action and focus from one task to another, make complex thinking possible and flexible to adapt or adjust to changes in the situation or environment.

2.1.3.4 Attention is the ability to direct, select and concentrate on a target, event or task for a period of time without interruption or either external or internal stimuli.

2.1.3.5 Initiation is the ability to start doing something. It requires a lot of brain power for think ahead what needs to be done, making plan or find the way about how to start doing it and putting plan into implement.

2.1.3.6 Planning and organizing is the ability to think and list all of the steps or strategies about how to do a task and arranging and sequence necessary actions to achieve the goal.

2.1.3.7 Reasoning is the ability to think about something in a logical way, in order to make a decision or judgment.

2.1.3.8 Problem solving is the ability to find the cause of a problem, identify, analyze and choose an alternative method or solution for solving a difficult or unexpected event or situation or problems.

2.1.3.9 Monitoring or self-monitoring is the ability to observe and conduct behavior and performance in relation to a goal. Also, it includes the ability to control self-presentation, expression behavior to others or in social situations.

That's all 9 skills of executive function that underlie the prefrontal cortex. Due to the prefrontal cortex maturing slowly and being fully developed until mid-twenties, executive function also spends many years for development gradually (36).

2.1.4 Time for build executive function

As development of executive function is involved with the biological process of brain maturation (37). So, executive function also takes a long time to develop that spans time from infant until late adolescence.

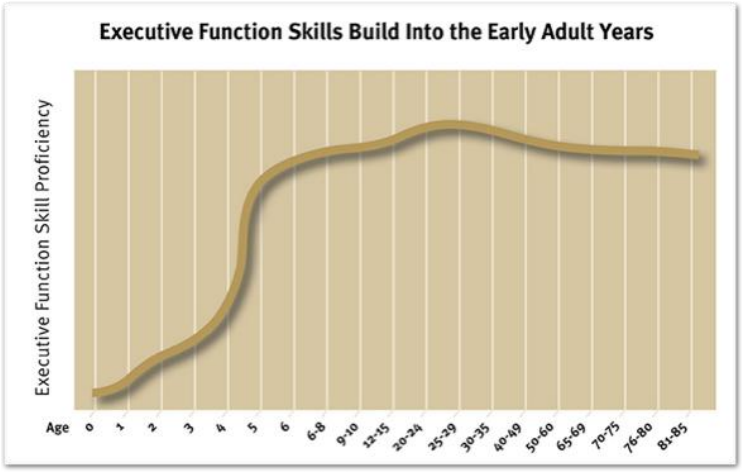


Figure 2.2 Period time of executive function development (Center on the Developing Child, 2012)

Since age-related improvements and differentiation of functions through neural specialization. Thus, preschool periods represent a time of great cognitive, behavior (38), language, motor skill and also psychological abilities growth, those development may be related with executive function. That means preschool children have been identified as a sensitive time for emergence and develop these skills. There are many researches such as Isquith P K et al (39) ,Carlson SM (40), Traverso L et al (31), Fuhs M W and Day J D (41) that support the rapid maturity in executive function occurring during preschool period.

However, a study of executive function showed that cognitive flexibility, response inhibition, and working memory, that core executive function, develop through late childhood and into adolescence (42, 43). Higher level executive functions that have more complex functions seem to mature in adolescence or early adulthood (44). Therefore, not only preschool children but adolescents need to promote executive function as well. Supporting evidence by Diamond A revealed that executive functions in childhood and adolescent is a predictor of life outcome (30).

2.1.5 How is executive function important for adolescents?

Several researches have focused on the role executive function in adolescents and found that executive function plays an important role in academic performance, social functioning, and adolescent's behavior.

2.1.5.1 Adolescent with strong executive function

When adolescent success in executive function development, adolescents will be great at successful school completion, control behaviors needed for accomplishing tasks and maintaining goal-directed activities.

2.1.5.2 Adolescent with weak executive function

On the other hand, adolescents who have poor executive function may have a problem such as sleep problems, emotional dysregulation, hyperactivity-inattention problems, learning in a highly structured classroom and lack of persistence to complete tasks or goals. Furthermore, poor executive function has been linked with negative outcomes such as attentional deficit and can lead to risk-taking behaviors and substance abuse.

2.2 Working memory

2.2.1 What is working memory?

Baddeley A (45) defines working memory as the cognitive system used to store and manipulate the information necessary to carry out cognitive tasks.

Purpura D J and Ganley C M (46) define working memory as an individual's ability to hold information in memory while simultaneously processing other information.

Gade M et al (47) define working memory as ability of information formerly learnt as well as the integration of this information to resolve problems encountered during cognitive performance.

Kirova A M et al (48) define working memory as a system that underpins cognitive activities ranging from attention allocation to specific stimuli to complex decision-making.

From reviewing, researchers summarized the definition of working memory as the ability to remember and hold information in memory that is necessary to help integrate information to solve problems or complex decision-making. In this study, researchers defined the definition of working memory as the ability to store and manipulate information in memory for a specific stimulus to complex decision-making.

2.2.2 Component of working memory

According to the multi-component working memory by Baddeley and Hitch in 1974, working memory component was divided into 3 components as phonological loop, visuospatial sketchpad and central executive. Generally, all three components have limited capacity to manipulate and hold information for a short term period.

However, there are important systems that affect cognitive processes such as solving problems, decision-making and reasoning, these three are separate responsibilities. The detail of each component is following:

2.2.2.1 Phonological loop (PL)

The first component is the phonological loop. This component is called slave systems which involve short term store and maintaining information by vocal or subvocal rehearsal (49). This component was including 2 subcomponents as follow:

1) Phonological store

Phonological store located in left cerebral hemisphere, evidence from neuroimaging (50). It serves to temporarily preserve sound that people heard rapidly (around two seconds) before sound disappears.

2) Articulatory rehearsal mechanism

The second subcomponent is the articulatory rehearsal mechanism, located in Broca's area. This subcomponent takes responsibility for repetition of verbal information as soon people hear its and related with prevent information in phonological
loops that very quickly decay.

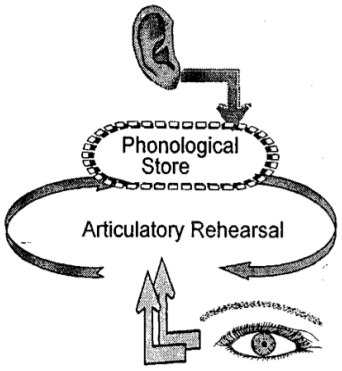


Figure 2.3 A diagram of phonological loop derived from Baddeley (1986) (Logie R H, 1995)

There are several phenomena that involve phonological stores that make people more cleary about phonological stores and articulatory rehearsal mechanisms.

- The phonological similarity effect

The first phenomena is the phonological similarity effect. This phenomena reflects that phonological store processes rely on changing from letter stimuli to voice code by subvocalization. If people cannot read or repeat words, the phonological store process will disappear quickly. In addition, if people remember a set of letter or word that accent similarity or sounding items overlap, accuracy of retention will be decrease.

- The word length effect

The word length effect is a key factor for articulatory rehearsal mechanism interference. In detail, if people must memorize several words and cannot repeat words in mind that affect to forget words rapidly.

- Suppression effect

This phenomena involves articulatory suppression. This phenomena suppresses phonological loop, especially the articulatory rehearsal mechanism, by disturbing the process of transformation from word to voice coding in phonological stores or people speaking words that are not related with letter or sentence should be recognized.

2.2.2.2 Visuo-Spatial Scratch Pad (VSSP)

Visuo-Spatial Scratch Pad also called slave systems like phonological loops. Generally, This component has a subdivision including visual cache (store information) and inner scribe (spatial relations). It has a key role for temporary storage and manipulating visuospatial information and mental images. Also, it can be recorded into nonverbal or visual forms (51). But, it has a limited capacity based on spatial characteristics.

2.2.2.3 Central executive (CE)

The third component is central executive, which is the most complex component of working memory. It is a master controller which focuses attention and directs information to two slave systems. Baddeley assumed central executive have four potential roles : attentional focus on stimuli or activity at that time, divided attention to

all activities or tasks when people have to perform more than one task at the same time, change or shift attention from currently activity to other activity, and integrate between working memory and long term memory. However, the definition and model of central executive from Baddeley is unclearly and need more evidence to support as well. So, other researchers try to learn and find the best model for describing this component.

Central executive model from Miyake et al (2000) is popular and is supported by physiological psychology to explain the central executive. Miyake et al assumed central executive is responsible for 3 important roles: inhibition irrelevant stimuli, shifting attention that reflex to flexibility think and updating data that reflex to capacity which is regularly and properly coding and updating data (52).

These all are the components of working memory regarded as the multi-component working memory 1974 version. But in A.D. 2000, Baddeley added a new system of working memory called Episodic buffer (EB).

2.2.2.4 Episodic buffer (EB)

New component's name is episodic buffer. This component is assumed to be a limited capacity temporary storage system (53) that holds integrated episodes or chunks in a multidimensional code (49). Because information that allows episodic buffers are a variety of types whether it be a verbal, visual, color, shape, or movement. So, when episodic buffers accept and hold information, if data has similarity, episodic buffers will manipulate data by chunking. But, due to the capacity of the episodic buffer being limited, it might store a data set of only 4 sets (52).

2.2.3 Relevant Theories in the Context of Working Memory

In the realm of cognitive psychology and behavioral sciences, several theories hold particular relevance when considering the dynamics of working memory. These theories contribute to a comprehensive understanding of how working memory operates and its implications for decision-making and behavior. Among the prominent theories in this domain are Verbal Short-Term Memory (STM), and the Dual Coding Theory.

2.2.3.1 Verbal Short-Term Memory (STM)

Verbal Short-Term Memory (STM) is a cognitive construct that pertains to the transient retention and manipulation of verbal content, encompassing spoken words or numerical information, for a brief timeframe. It assumes a pivotal role in

diverse cognitive functions, including the comprehension of language, problem-solving, and the process of learning.

Key discoveries and facets of the theory regarding Verbal Short-Term Memory encompass:

1) Constrained Capacity: STM exhibits a limited capacity, enabling it to contain only a modest volume of information for a short interval, classically estimated at approximately 7 items, with a margin of variation of plus or minus 2. This notion derives from the renowned research conducted by George A. Miller.

2) Temporal Limits: Information housed in STM endures a relatively transient existence. It dissipates rapidly unless subjected to rehearsal or transferred into long-term memory. The typical duration associated with STM is believed to range from 15 to 30 seconds.

3) Repetition Strategies: One common technique employed to sustain information within STM is maintenance rehearsal. This process involves the repetition or mental reiteration of the information, thereby prolonging the persistence of items within STM.

4) Chunking Strategies: Individuals can augment the functional capacity of STM through the method of chunking. Chunking involves the grouping of individual pieces of data into more meaningful and coherent units. As an illustration, rather than attempting to remember a random sequence of letters, one might find it more manageable to remember a meaningful word or acronym formed from those letters.

5) Serial Position Effect: STM is subject to an empirical phenomenon known as the serial position effect. This effect signifies the inclination to recall items situated at the outset of a list (referred to as the primacy effect) and those located at the conclusion (recognized as the recency effect) more effectively than items positioned in the middle. The effect implies that items at the beginning of a list undergo greater rehearsal and potential incorporation into long-term memory, while items at the end persist within STM.

6) Delineation from Long-Term Memory: STM can be demarcated from long-term memory (LTM) based on distinctions pertaining to capacity, duration, and the nature of the content held. LTM is adept at accommodating

extensive information over protracted periods, potentially indefinitely, in contrast to the limited and transient characteristics of STM.

7) Neurobiological Foundation: STM is correlated with specific cerebral regions, notably the prefrontal cortex and parietal cortex. Damage to these regions can impair verbal STM functioning.

Verbal Short-Term Memory serves as a fundamental cognitive construct, integral to our capacity to momentarily retain and manipulate verbal information. Its constraints in terms of capacity and temporal persistence are prominent features, and approaches such as rehearsal and chunking can optimize its efficacy. The comprehension of STM is of paramount significance across multiple domains, encompassing psychology, neuroscience, and education, as it imparts valuable insights into the processing and retention of verbal content in our daily cognitive endeavors.

2.2.3.2 Dual Coding Theory

Dual Coding Theory, developed by Allan Paivio in the 1970s, explores how our minds store and manage information. It proposes two interconnected cognitive systems: one for processing words and language-based data, the other for handling visual and non-verbal information.

Key Principles:

1) Verbal and Non-Verbal Systems: Humans have distinct mental subsystems for language-based and visual information processing.

2) Dual Representation: Information is stored in memory using both verbal and non-verbal codes. For instance, we remember "apple" not only as a word but also as an mental image.

3) Enhanced Memory: Combining verbal and visual elements makes information more memorable and easier to recall due to dual pathways for retrieval.

4) Practical Applications: Dual Coding Theory has practical uses in education and psychology. Educators use it to enhance learning by combining text with visuals.

5) Concrete vs. Abstract Information: Concrete concepts (e.g., "dog") are easier to remember than abstract ones (e.g., "justice").

6) Imagery and Mnemonics: Mental imagery and mnemonics aid memory by creating vivid associations with verbal information.

7) Cross-Modal Facilitation: Processing information in one modality can facilitate understanding and recall of information in another modality.

Dual Coding Theory underscores the value of combining verbal and visual elements in information processing and memory. It has practical applications in education and enhances memory by leveraging dual representation.

In summary, the researcher has skillfully harnessed the fundamental principles from both Verbal Short-Term Memory (STM) and Dual Coding Theory to shape the game elements and processes within the TendingPETs application. This application is purposefully designed to present players with challenges that revolve around the retention and manipulation of information, achieved by seamlessly blending verbal and visual components. The ultimate goal is to create an immersive and unforgettable experience that directly contributes to the enhancement of working memory skills. By strategically incorporating techniques like repetition, chunking, and other cognitive strategies, the game offers an effective method for fortifying working memory capacities.

2.2.4 Time for build working memory skill

As we know, working memory skill is linked with the frontal lobe. In part of time for development of working memory skill, some studies reported that capacity of working memory skill develops from infants until middle childhood, supported by Casey BJ et al (54) and Klingberg T et al (55). Likewise, studies of Dempster FN (56) and Lenroot RK and Giedd, YN (57) reported frontal and parietal gray matter volume peaking between 10 and 14 years of age, since working memory skill was also better able to develop in this period as well. Additionally, some studies found the greatest period for working memory capacity increasing occurs before mid-adolescence (58).

From the above literature it seems that the appropriate time for developing working memory is infants until middle childhood. Also, adolescence represents a time of dynamic cognitive development. Hence, researchers will recruit adolescents who are 15 years old to participate in this study.

2.2.5 Why is working memory important?

As mentioned above, working memory involves holding, storing and manipulating verbal and visual information. It is important for learning and doing everyday tasks and underpins many thinking processes.

2.2.4.1 Adolescent with strong working memory

From data of Canadian Association for Neuroscience presented adolescence is associated with the maturation of cognitive functions, such as working memory, decision-making, and impulsivity control. So, working memory plays an important role in development in general and many of the skills that adolescents use to learn, read or pay attention. Strong working memory can positively impact scholastic ability such as arithmetic and reading (5). Also there are much stronger predictors of success in reading, spelling and mathematics (6). Beside strong working memory related to academic performance. Moreover, strong working memory was associated with risk behavior prevention in adolescence such as alcohol, driving accidents and sexual behavior. Great working memory can predict reduced involvement in sexual risk taking (7). Supported evidence by Khurana A et al (2012) the finding of study showed early sexual initiation were entirely mediated by working memory and impulsivity (8).

2.2.4.2 Adolescent with weak working memory

On the other hand, weak working memory is associated with difficulty remembering information, regarding a report by Melbourne child psychology (9) revealed that adolescents who have a problem with working memory may have difficulty struggling with notes in class because they can only remember short information at the time. Also, weak working memory was associated with impulsivity behavior in accordance with Khurana A et al. (10) shown working memory was associated with imbalance indicators of acting without thinking.

In part of health problems and working memory, poor working memory is correlated with substance use in accordance with Khurana A et al. (10) resulted in adolescents whose weak working memory had more risk for substance use because they have problems on impulsivity control. According to Sweeney MM et al (2018) found working memory impairment was associated with adolescent cannabis use (11). In particular, weak working memory associated with prediction of alcohol use in adolescents (12) in

accordance with Grenard SL et al (2008) (13) and Peeters M et al (2012) (14) presented deficits in working memory have been associated with increased alcohol use.

2.2.6 Assessment of working memory

2.2.5.1 The Alloway Working Memory Assessment (AWMA2)

The Alloway Working Memory Assessment (AWMA-2), revision from AWMA (2007) developed by Alloway T P, is an automatic online assessment of working memory and all tests are presented on screen. This tool use with individuals and appropriate for children who 5-year-old to older who 69 year old that have 3 versions:

1) Screener: this version consists of 2 working memory tests that are suitable for screening people who suspect working memory difficulties. The Screener test takes approximately 5 to 7 minutes.

2) Short form: this version consists of 4 working memory tests that are suitable for screening people who are suspected to have working memory difficulties. But it has a limitation that cannot be a specific area of difficulties. This test takes approximately 10 to 15 minutes.

3) Long form: this version consists of 8 working memory tests that are suitable for confirmation of significant working memory problems. This test takes approximately 30 minutes.

Tests of AWMA-2 are as follows:

1) Verbal short term memory: test by digit recall and letter recall.

2) Verbal working memory: test by backwards digit recall and processing letter recall.

3) Visuospatial short term memory: test by dot matrix and block recall.

4) Visuospatial working memory: test by Mr X and backwards dot matrix.

For AWMA-2 scoring, when completed individual assessment, computer will automatic process scoring and show result on screen. Scores are standardized to a mean of 100 and a standard deviation of 15 for each age band.

Percentiles represent the percentage of individuals in the same age band who obtained this score or less.

2.2.5.2 Working memory test battery for children (WMTB-C)

Working memory test battery for children, developed by Pickering SJ and Gathercole S E in 2001, is an assessment tool of working memory for children aged 5 years old to teens (15 years old). WMTB-C is used to measure three composites:

1) Central executive subtests: This component test by
    1.1 Listening recall
    1.2 Counting recall
    1.3 Backward digit recall
2) Phonological loop subtests: This component test by
    2.1 Digit recall
    2.2 Word list matching
    2.3 Word list recall
    2.4 Non-word list recall
3) Visuo-spatial sketchpad: This component test by
    3.1 Block recall
    3.2 Mazes memory

For scoring, each memory task score was calculated. The absolute score was calculated as the sum of all correctly recalled stimuli in perfectly recalled lists. The proportion correct score was calculated as the average proportional recall for each trial, and the proportions for all the trials were then average. Finally, a single WM score was calculated for each scoring method by averaging the Z scores.

2.2.5.3 NEPSY-II (memory for designs and narrative memory subtests)

NEPSY-II is an assessment of neuropsychological development in children who are 3 to 16 years old. This tool consist of 6 domains, details of six domains are as follows:

Table 2.1 Details of NEPSY-II measurement

Domain	Description	Subsets name	Ages
Attention and executive function	measure how well a child can plan, organize, change, and control behavior	Animal sorting	7 to16
		Auditory attention and response set	5 to16
		clocks	7 to16
		design fluency	5 to12
		inhibition	5 to16
		statue	3 to16
Language	measure how well a child understands and uses words and sentences to communicate with others	Body part naming and identification	3 to 4
		Comprehension of instructions	3 to 16
		Orometer sequences	3 to 12
		Phonological processing	3 to 16
		Repetition of nonsense words	5 to 12
		Speeded naming	3 to 16
		Word generation	3 to 16
Memory and learning	measure how a child takes in, stores, and remembers information	List memory (Immediate and delayed)	7 to 12
		Memory for designs (Immediate and delayed)	3 to 16
		Memory for faces	5 to 16
		Memory for names	5 to 16
		Narrative memory	3 to 16
		Sentence Repetition	3 to 6
		Word list interference	7 to 16
Sensorimotor	measure how well a child can control hand movements	Fingertip tapping	5 to 16
		Imitating hand positions	3 to 12
		Manual motor sequences	3 to 12
		Visuomotor precision	3 to 12

Table 2.1 Details of NEPSY-II measurement (Cont.)

Domain	Description	Subsets name	Ages
Social perception	measure how well a child understands other people's feelings and thought	Affect recognition	3 to 16
		Theory of mind	3 to 16
Visuospatial processing	measure how well a child sees and arranges visual information	Arrows	5 to 16
		Block construction	3 to 16
		Design copying	3 to 16
		Geometric puzzles	3 to 16
		Picture puzzles	7 to 16
		Route finding	5 to 12

For core assessment, preschool children take 45 minutes to test and school ages take 1 hour. In part of comprehensive assessment, preschool children take 90 minutes to test and school ages take 2-3 hours. In part of NEPSY-II score, authors recommended use classification table for report score, as shown below:

Table 2.2 Scoring and interpretation of NEPSY-II

Standard score	Scaled score	percentile rank	NEPSY-II scaled score	NEPSY-II percentile rank	Classification label
> 129	>15	>98%	13-19	> 75	Above expected
121-129	15	92-98			
111-120	13-14	76-91			
90-110	8-12	25-75	8-12	26-75	At expected
80-89	6-7	9-24	6-7	11-25	Slightly below expected
70-79	4-5	2-8	4-5	3-10	Below expected
<70	0-3	below 2	1-3	below 2	well below expected

2.2.5.4 Lucid recall

Lucid recall, developed by St Clair-Thompson HL. in 2013, is a fully automated assessment tool of working memory for children aged 7 years old to 16 years old. Lucid recall is used to measure three composites: central executive, phonological loop, and visuospatial sketchpad.

1) Central executive subtests

This component tests by counting recall. Counting recall test involves carrying out a sequence of between two and six independent counting tasks whilst simultaneously remembering the results of each count in the same order

2) Phonological loop subtests

This component test by word recall. Word recall is a computerized test in which a child hears sequences of words through the computer speakers/ headphones. They are then required to recall the words in the same order in which they were presented. There are then a maximum of six test items at each list length (of 2–6 words).

3) Visuo-spatial sketchpad

This component is tested by pattern recall. Pattern recall is computerized test which a child sees a matrix pattern of filled (black) and unfilled (white) squares on the computer screen. When the pattern disappears they are presented with a blank matrix and required to fill squares in the same order that the child sees.

Test duration of Lucid recall takes 20-30 minutes. Lucid recall results cover standard scores, confidence interval, centile scores, age equivalents, memory span, and average time. Standard scores are provided in 6-month age bands from 7 to 16. Standard scores have a mean (average) 100 and a standard deviation of 15, distributed in a normal curve.

Score range 85 – 115 is regarded as the ‘normal’ or ‘average’ range. A score of less than 70 means very low scores and more than 130 means very high scores.

Table 2.3 Standard score and percentile score of Lucid recall test

Standard score	percentile score	Standard score	percentile score
70	2	110	75
80	9	115	84
85	16	120	91
90	25	130	98
100	50		

In this study, research selected Lucid recall for measurement of working memory in adolescents. Because this tool is appropriate for children who are 7 years old to16 years old. Also, this tool already tests sensitivity and reliability.

2.3 Games

It is common knowledge that games are structured kinds of play. Games are typically made for the purpose of entertainment or enjoyment. However, researchers have discovered that games are linked to cognition. As a result, games are utilized as teaching aids or to stimulate the brain. Furthermore, some of the games studied have been linked to improved working memory.

2.3.1 Definition of game

Costikyan G (59) defines game as a form of art in which participants, termed players, make decisions in order to manage resources through game tokens in the pursuit of a goal.

Kelley D (60) defines game as a form of recreation constituted by a set of rules that specify an object to be attained and the permissible means of attaining it.

Researcher summarized the definition of game as one of a person's activity, that is, a form of recreation through participating in a scenario and set of rules through game tokens in pursuit of a goal, after reading the term. Researchers classified a game in this study as one of a person's activities that is usually conducted for amusement, practicing some skill by participating in a setting and set of rules via fake-world vehicles.

2.3.2 Types of game

Nowadays, there are many varieties of games and each type of game has different characteristics and underlying objectives. The following are list of types games:

2.3.2.1 Massively Multiplayer Online (MMO)

Massively Multiplayer Online (MMO), also known as MMOG, is an online video game which is capable of a large number of players participating via a large-area of internet network at the same time. Common features of Massively Multiplayer Online are players using a network and cooperating or interacting with other players on the same server. Most of the tasks in MMOG need multiplayers to support each other to handle or clear the tasks in game.

2.3.2.2 Role playing game (RPG)

Role playing game, abbreviated RPG, is a genre of game in which the player assumes the roles of a character undertaking a long scenario or quest in a fictional setting to reach the final outcome of the game. Also, most of the activities in RPGs are a series story and tasks. So, the outcome of the game depends on what player is chosen.

There are many kinds of RPG such as action RPG, sandbox RPG and tactical RPG. Examples of RPGs which are famous are Final fantasy, Star wars, Lunar: silver star story complete, Pokemon Red and Blue.

2.3.2.3 Massively Multiplayer Online-Role playing game (MMORPG)

MMORPG are an online game that combines massively multiplayer online and role playing games. Features of MMORPG are typically represented by large, sophisticated and evolving virtual worlds set in (61), many players participate in the game through active interaction with other characters and take longer periods to play than other games. MMORPG are popular and enjoyable leisure activities. Hence, there are an increasing number of gamers worldwide.

Examples of popular MMORPG are World of Warcraft, The Elder Scrolls Online, Black Desert Online, Guild Wars 2, Old School Runescape.

2.3.2.4 Simulations

Simulation is a series of instructional designs in which players are provided with various activities from real-world situations in the form of a game.

Examples of famous simulation games are The Sims, Firefighting Simulator, Construction Simulator Pro 2017.

2.3.2.5 Adventure

Adventure game is a game of the feature characterized by puzzles or investigations in which players are given choices to solve the situation or tasks in game. Examples of the best simulation games are The Walking Dead, Minecraft, Far cry4, and Fallout 4.

2.3.2.6 Sports

Sport game is a game genre that simulates the practice of imagined sports. Examples of sports game list are Archery, Badminton, Boxing, Cricket.

2.3.2.7 Educational

Education games are designed for educational purposes, teach certain subjects or learn some skills that are related to education. Examples of educational game lists are Pandemic, Colorfy: coloring art game, Vocabulary spelling city, Health and physical education.

2.3.3 Advantages and disadvantages of playing game

Games are an integral element of practically every adolescent's life. Aside from being entertaining and leisure activities, games can be a tremendous potential benefit for adolescents if they play within the time constraints.

According to a study by Griffiths M (62) presented that the game had many positive impacts. For instance:

1)Video games can help children develop some basic skills such as language skills, mathematics and reading skills, and social skills.

2) Video games linked with brain wave biofeedback.

3) Some games have been used to enhance adolescents' perceived self-efficacy.

4) Video games have been used to improve children's health care (i.e. improve self-care skills, medical compliance).

5) Video games have benefits on education as they help children learn about subjects.

Study of Granic I et al (63) summarized the benefits of playing games on 4 domains; cognitive, motivations, emotional and social.

1) Benefit of playing game on cognitive domain

Playing games was associated with cognitive function promotion. Supported evidence, study of Green CS and Bavelier D showed playing games, especially action games, can enhance broader categories of executive function, task-switching, multi-tasking, and visual short-term memory tasks (64). Study of Parisod H et al summarized advantages of digital games that playing games can promote cognitive skills and understanding of abstract concepts (65). Also, games can promote memory, understanding and conceptual dimension, this finding was supported by von Wangenheim CG et al (66).

Furthermore, games seem to be associated with developing problem solving skills (especially puzzle game genre) (67), enhanced creativity capacities and spatial skill. In accordance with study of the American Psychological Association shown that playing games enhance spatial resolution in visual processing.

2) Benefit of playing game on motivations domain

Games seem to be linked with the ability of self-efficacy, self-confidence and self-effort. Each game has a scenario and goal of the game, hence games can provide player effort to goal, especially if characteristics of games are RPG or MMORPG. Supported by study Vlachopoulos D and Makri A presented that games have effects on student engagement and learning motivation (68).

3) Benefit of playing game on emotional domain

Apart from fun, relaxing and reducing stress, playing games can provide more than that. They are linked with emotional and mental health. In accordance with study of the American Psychological Association shown that playing games enhance spatial resolution in visual processing. Also, study of McGonigal J suggested positive emotions were associated with playing games (69).

4) Benefit of playing game on social domain

Games are one of the largest social activity communities. So, games were linked with social domain, because adolescents who played have collaborative and interactive experiences. Playing games are helpful in organizing groups, prosocial skills, support and helping behavior since most digital games or online games need

cooperation between players, especially RPG, MMORPG that are popular in the online game genre at present. Supported by study of Parisod H et al revealed that games can create connections with other players and players can get peer support through games (65).

Furthermore, according to the literature review, aside from the previously mentioned cognitive, motivational, emotional, and social domains, playing games has a significant impact on education. Several studies have found that games can improve educational results or academic performance. Clark DB et al presented digital games impacted on learning result in a comprehensive review (70). Similarly, Backlund P and Hendrix M (71) and Badea M (72) found that games had an impact on learning performance. Furthermore, the usage of games for health advantages is growing. Physical exercise can be encouraged through gaming. Many studies have effectively employed game applications to increase physical activity. Schoeppe S et al (2006) provided evidence from a systematic study that application-based therapies improve physical activity (73).

In addition, game genres, particularly educational games, are occasionally utilized to enhance health education (74) and health-related information. A systematic evaluation conducted by Primack BA et al discovered that video games have the potential to promote health education (75). According to a study conducted by Maheswari UN et al, gaming had an impact on children's oral health-related knowledge (76). According to a study, there are numerous advantages to gaming for adolescents. The American Academy of Pediatrics recommends that teenagers limit their screen usage to 30 to 60 minutes per day on school days and no more than 2 hours per day on non-school days.

Adolescents who spend a lot of time or all of their time playing games, on the other hand, can have negative repercussions. First, excessive or uncontrolled game playing during adolescence might develop to game addiction. Following that, playing games may expose you to a hazardous gaming atmosphere or conduct. Players may engage in social engagement through trash talk, cyberbullying, or cheating. Griffiths M.'s study described game limitations where immersion gaming may lead to excessive use or game addiction and probable exposure to harmful environment (62). Furthermore, gaming may raise the risk of health issues such as increased sedentary

behavior, sleep disorders, vision, and muscular-skeletal problems. Supported by the study of Ayeni Bara I found health problems (i.e. visual, muscular-skeletal and obesity) were associated with long-time playing games (77).

To summarize, game playing has a number of advantages; each game has a unique set of advantages that vary depending on the genre of game. Proper gaming time has been shown to reduce depression, promote cognitive function and executive function, improve interaction experiences, planning skill, and motivation domain. Spending too much time playing games, on the other hand, can have negative implications such as game addiction, increased chance of being exposed to a toxic gaming environment, and health concerns.

2.3.4 How do game effect on working memory?

There are many ways to improve working memory in adolescents, including teaching (for example, teaching over-learn materials, using visual image memory strategies, and providing retrieval practice), common strategies (for example, chunking, grouping), and physical activity (stimulate brain-derived neurotrophic factor (BNDF)).

So far, we've learned that gaming can be used for amusement, fun, and relaxation. However, some studies have revealed that gaming has an impact on executive processes and short-term memory. Some evidences exhibited during playing game hormone specifically Dopamine or also known as feel-good hormone. Dopamine, a neurotransmitter that is an important component of the brain system and, along with learning and working memory, was released while players played the game, and it altered learning result, visuospatial skills, and memory. According to a study by Koepp M et al, the neurotransmitter dopamine may be implicated in learning, and dopamine is released while playing video games. (78). Similarly, Eichenbaum A et al found that when people play video games, their brains generate an abundance of neurochemicals (such as dopamine), which is associated with improved learning and brain plasticity (79). Another study, Moisala M et al (16), discovered that everyday game playing was connected with enhanced working memory functioning.

Thus, in this study, researchers will develop game apps to improve working memory in adolescents by integrating two types of games (simulation and educational game).

2.3.5 Game-Based Learning

In this study, researchers used Game-Based Learning that was defined by the definition and element of the game by Plass JL et al (80) to conducting game application.

This model revealed the basis of game design elements that facilitate learning by fostering learners, cognitive, motivational, affective, and sociocultural foundations.

2.3.5.1 Elements of game design

Elements of game design are the basic and vital of every game. Plass JL et al study presented fundamental elements of game consisting of game mechanics, visual aesthetics, narratives, musical score, and related content and skill.

1) Game mechanics: this element refers to the action or sets of activities that the player repeats throughout the game; these activities can focus on learning mechanics or assessment mechanics, or both. The mechanics of the TendingPETs application in this study include when players log into the game and then select the mode that the player wishes to play to complete the task. Each mode has a goal and appropriate options. If a player successfully chooses or answers, they will receive good feedback and a high score. (For example, in daily quests, players must select food and feed pets. If a player chooses a favorite or excellent food for a pet, the pet will respond positively.

2) Visual aesthetics: this element relates to the game's attractiveness or pleasing appearance, which includes the general look and sense of the game as well as the game characters. The visual design dictates how game mechanics' tools and functions are seen, how cues are represented, and how feedback is delivered (80). Furthermore, visual aesthetics represented the player's attractiveness. If the images of a game are appealing, it might entice the player to play and make the game more enjoyable. Researchers in this project create aesthetic and gaming art designs of TendingPETs applications in 2D graphics.

The researcher created game artwork that included all visual aspects such as characters, objects, backgrounds, and texts using animation principles design, color psychology, and color of tone that was appropriate for the age of the participants. Furthermore, all of the visual and artwork design in this game is based on the E rating of the

entertainment software rating board (ESRB), which means that the visual and language in the game are not violent or damaging to the user and that anyone can play it.

3) Narrative Design: The storyline of a game is progressed by features such as cutscenes, in-game actions, dialogues, and voice-overs. It gives context for learning by integrating game rules, characters, tasks, events, and incentives (80). Researchers in this work use narrative design through cutscenes to inform rules of play and all materials in knowledge reading mode.

4) Incentive System: A game's incentive system is the motivational aspects that the player will receive while playing the game. It is the goal of game incentive systems to motivate players to continue their efforts and provide feedback. These rewards can be of an intrinsic character, such as a power-up that grants the player special powers in the game, or of an external nature, such as granting stars or points. In this study, researchers used game incentives in part as pet character awards, which grant extra pet powers or titles when the user completes the condition or reaches the game's goal.

Furthermore, by participating in all mini-games, players will earn game rewards. When they complete a mini game, they will receive special game awards such as intelligence points, items for caring for pets, or whatever the characteristics of the mini game require.

5) Musical score: these elements provide background sounds that are often used to direct the player’s attention to specific important events or moments in the game (80). In this study, researchers will use silent beat music to create the feeling of a game like having more fun, relaxing, exciting and make the player feel in the mood to play the game.

6) Content and skills: content and skills is the subject matter content and skills that the game is designed to teach. This element is supposed to determine the learning mechanics to be used, the visual design to be adopted, the narrative design, the incentive system design, and the musical score (80). In this study, content and skills part designs for teaching knowledge and skills. So, all of the contents are conducted under the central standard curriculum of 9th grade students.

Summary, researcher harnessed the principles of Game-Based Learning and incorporated key game design elements to develop a game application. These elements,

such as game mechanics, visual aesthetics, narrative design, incentive systems, musical scores, and content and skills, were used strategically to create an engaging and educational experience for the players. The game application's design focused on enhancing learning, motivation, and engagement by seamlessly integrating these game elements. This approach aimed to provide an effective and enjoyable platform for teaching and learning aligned with the 9th-grade curriculum.

2.4 Adolescent development

It rapidly varies during adolescence, and each stage of adolescence has different growth and development. Understanding teenage growth and development is therefore critical. Understanding how to help children nurture in the proper manner or method will assist adolescents in developing a robust development.

2.4.1 Age and stage of adolescent

2.4.1.1 Stage of adolescent by American Academy of Child and Adolescent's

American Academy of Child and Adolescent's recognized stage of adolescent as 3 stages. The following are stage of adolescent:

1) Early adolescent: refer to children who age between 11 to 13 year old
2) Middle adolescent: refer to children who age between 14 to 18 year old
3) Late adolescent: refer to children who age between 19 to 21 year old

Table 2.4 Stage of adolescent by American Academy of Child and Adolescent's

Early adolescent	Middle adolescent	Late adolescent
1) frequent changes in mood 2) struggle with sense of identity 3) increased influence of peer Group 4) desire for independence	1) intense self-involvement, changing between high expectations and poor self-concept 2) continued adjustment to changing body, worries about being normal 3) feelings of love and passion	1) increased emotional stability 2) increased concern for others 3) social and cultural traditions regain some of their importance

2.4.1.2 Stage of adolescent by WHO

The WHO classified adolescence into three stages. Adolescence normally begins between the ages of 10 and 19 years. Here are the stages of adolescence:

1) Early adolescent: refer to children who age between 10 to 15 year old

2) Middle adolescent: refer to children who age between 14 to 17 year old

3) Late adolescent: refer to children who age between 16 to 19 year old

2.4.1.3 Stage of adolescent by Bureau of Reproductive Health , Thailand

Bureau of Reproductive Health divided stage of adolescent as 3 stages. It stars at 10 to 19 years old. Stage of adolescent are the following:

1) Early adolescent: refer to children who age between 10 to 14 year old

2) Middle adolescent: refer to children who age between 15 to 16 year old

3) Late adolescent : refer to children who age between 17 to 19 year old

In this study, research interested in early to middle adolescent (15 years old) in Phrae province.

2.4.2 Domain of adolescent development

Adolescent development is a process of changing characteristic and behavior with directly pattern. There are three domains of adolescent development: physical development, cognitive development, social-emotional development.

2.4.2.1 Physical development refer to bodily and biological changes that undergo as they age, also including fine and gross motor development

* Data from: American Academy of Child and Adolescent (2008), WHO (2010).

How to support adolescent physical development

Adolescent health depends on physical growth. As a result, it is critical in assisting adolescent physical growth as they mature. According to data from the Center for Parent and Teen Communication, nutrition, exercise, and sleep are of the utmost significance for promoting rapid physical growth during adolescence.

2.4.2.2 Cognitive development refer to mental or intellectual abilities that related with mental process. It is involved with learning, thinking abstractly, reasoning skill, and problem-solving skill.

* Data from: American Academy of Child and Adolescent (2008), WHO (2010).

How to support adolescent cognitive development

Cognitive growth is vital in judgment, reasoning, planning, and dealing with complexity. The Center for Parent and Teen Communication pioneered the path for supporting cognitive development by encouraging teenage ideas and independent thinking, as well as engaging in discussions or asking adolescent to seek solutions to problems.

2.4.2.3 Social-emotional development refer to ability of emotional expression, manage feeling in different situation, learning how to interact with other person, and ability to self help or self care in daily life that including morally and ethically.

* Data from: American Academy of Child and Adolescent (2008), WHO (2010).

How to support adolescent social-emotional development

Social and emotional development have a consequence on long-term decisions, values, and morals. There are many ways to support social-emotional development, such as implementing small groups in school for social skill development, parents encouraging adolescent to join any community (i.e. school, community group, sports team), discussing with adolescent about puberty change and supporting their interest by providing opportunities for activities.

To summarize, adolescence is one of the most quickly changing stages of human development. Puberty, cognitive development, and social-emotional development are three essential categories of development during this period. As a result, discovering how to support teenage growth can assist adolescent development, which can lead to effective health and cognitive performance.

2.4.3 Risk behaviors among adolescent

Adolescence, as we all know, is a time of intense personal development and increased independence. As a result of this, adolescents are more likely to be exposed to risk factors that might lead to risky conduct.

2.4.3.1 Sexual risk behavior

Adolescence is a time of change and growth for core gender, gender role, and sexual orientation. So, teenagers are drawn to sexual activities and casual sexual relationships. In any case, adolescents are at a significant risk of being exposed to sexually explicit media, which may contribute to risky sexual behaviors. Sexually transmitted infections (STI) and unplanned pregnancy can occur if adolescents are unaware of safe sex behavior, such as whether or not to use condoms or any contraceptive, and have several sex partners.

2.4.3.2 Substance abuse

Substance is any material whether solid, powder, liquid, or gas that possesses physical properties. For example of substance such as illegal drugs, prescription drugs. Substance abuse, also known as drug abuse, is the pattern of harmful or wrong way to use any and it's can impacts physical and mental health. In addition, substance abuse effects associated with crimes, morbidity, and burden of disease.

2.4.3.3 Alcohol use

Alcohol use refers to the use of beverages containing ethyl alcohol. Typically, individuals consume alcohol to celebrate, relax, or socialize. Adolescents are the most likely to drink alcohol. Adolescents who drink excessively put their health at risk, including short-term health risks (injury, violence, alcohol poisoning, risky sexual behavior such as unprotected sex, multiple partners) and long-term health risks (chronic disease such as cancer of the liver and colon, immune system weakness, mental health problem, or social problem).

In Thailand, a 2017 alcohol drinking study found that adolescents aged 15-19 years old had a 13.6% prevalence of drinking alcohol, with the North area having the greatest proportion of adolescent drinkers (81). Furthermore, a survey conducted by the Department of Public Health found that around 250,000 new drinkers were listed in Thailand each year, with the average age of first alcohol consumption being 13-15 years old (69.0%), followed by 16-17 years old (30.2%) (82).

2.4.3.4 Smoking

Smoking is the act of inhaling the smoke produced by burning tobacco, which includes cigarettes, pipes, and cigars. Smoking increases the risk of diseases and health problems such as stroke and coronary heart disease, damages blood vessels, threatens eyesight, and causes skin to dry out and lose elasticity. Furthermore, smoking can cause cancer in practically every part of the body, including the mouth and throat, kidney and renal pelvis, liver, stomach, and lung.

According to the Child and adolescent mental health rajanagarindra institute survey in 2016, 5.8% of adolescents aged 13-17 years old abused tobacco and 2.4% relying on it in Thailand. likewise, the Action on Smoking and Health Foundation Thailand observed that 37.2% of 8th grade children had low levels of harmful chemicals in tobacco and were easily accessible for purchasing tobacco.

As previously mentioned, there is a notable increase in risky behaviors among Thai adolescents, particularly concerning alcohol use and smoking habits. Notably, the average age of initial alcohol consumption and smoking initiation has been decreasing annually. Moreover, it is widely recognized that smoking is detrimental to health, irrespective of age. There is compelling evidence indicating that the commencement of alcohol use or smoking before the age of 21 may rapidly progress into habituation and

addiction. Therefore, this study will primarily focus on strategies for the prevention of alcohol consumption and smoking among adolescents.

2.5 Health Behavior Theory

Health Behavior Theory plays a crucial role in understanding and describing the change in working memory and its impact on risk behavior among adolescents. Specifically, the Transtheoretical Model (TTM), the Health Belief Model (HBM) and theory of planner behavior can be applied to illuminate this relationship:

2.5.1 Transtheoretical Model (TTM)

The TTM consists of five stages of change: precontemplation, contemplation, preparation, action, and maintenance.

2.5.1.1 Precontemplation

In this stage, individuals are unaware of a need for change and may not recognize the relationship between working memory and risk behavior. They are not considering taking any action to address this issue.

2.5.1.2 Contemplation

In the contemplation stage, individuals begin to recognize the importance of working memory in making informed decisions regarding risk behaviors. They acknowledge that there is room for improvement but have not yet committed to taking specific actions.

2.5.1.3 Preparation

During this stage, individuals are preparing to take action. They may be researching strategies, seeking information, or making plans to improve their working memory in the context of risk behavior.

2.5.14 Action

The action stage signifies a commitment to behavioral change. Individuals in this stage are actively implementing strategies to enhance their working memory, such as participating in cognitive training programs.

2.5.1.5 Maintenance

The maintenance stage follows the action stage and involves maintaining the changes made. Individuals are working to sustain improved working

memory over the long term and continue to make informed decisions regarding risk behaviors.

Understanding these stages within the Transtheoretical Model provides a framework for designing interventions tailored to adolescents at different points in their journey of working memory enhancement and risk behavior reduction. It also underscores the importance of recognizing where individuals are in this process when developing and implementing strategies to facilitate behavioral change.

2.5.2 The Health Belief Model (HBM)

Here was the Health Belief Model (HBM) by providing a more detailed on its key components.

2.5.2.1 Perceived Susceptibility:

This component focuses on how adolescents perceive their vulnerability to negative consequences related to poor working memory. It involves their understanding of the link between working memory and the ability to make informed decisions, particularly in the context of risk behaviors.

2.5.2.2 Perceived Benefits and Barriers:

This aspect involves adolescents' consideration of the advantages of enhancing their working memory compared to the perceived obstacles or barriers they may encounter in the process.

2.5.2.3 Cues to Action:

In the HBM, cues to action are influential triggers that encourage individuals to take action for the betterment of their health or well-being. These cues can come in various forms, including educational interventions, awareness campaigns, or access to cognitive training programs.

In essence, the Health Belief Model (HBM) provides a framework for understanding how adolescents perceive the importance of working memory in relation to risk behaviors. It underscores the significance of perceiving susceptibility to negative consequences, evaluating the benefits and barriers of working memory enhancement, and recognizing the role of cues to action in encouraging adolescents to take steps to improve their working memory. This comprehensive understanding of HBM can guide the design of effective interventions aimed at enhancing working memory and reducing risk behaviors among adolescents.

2.5.3 Theory of planner behavior

This theoretical framework, rooted in psychology and health behavior studies, unravels the motivational tapestry that drives adolescents' intentions and actions. At its core, the TPB unveils the significance of attitudes, subjective norms, and perceived behavioral control in shaping the path adolescents tread towards enhanced working memory and, consequently, informed decisions regarding risk behaviors.

2.5.3.1 Attitudes

In the context of the TPB, attitudes refer to the cognitive evaluations adolescents make regarding the significance of enhancing their working memory. Adolescents' attitudes are instrumental in shaping their intentions and behaviors related to working memory improvement.

2.5.3.2 Subjective Norms

Subjective norms involve the influence of peer norms, social pressures, and the approval of significant individuals or groups in the lives of adolescents. This influence can be both direct and indirect.

2.5.3.3 Perceived Behavioral Control

This component pertains to the extent to which adolescents believe they have control over enhancing their working memory. It involves their perception of available resources and their perceived ability to engage effectively in activities such as cognitive training.

In essence, the Theory of Planned Behavior (TPB) provides valuable insights into the motivational factors that underlie adolescents' decisions concerning working memory improvement and its subsequent impact on risk behaviors. The interplay between attitudes, subjective norms, and perceived behavioral control collectively shapes their intentions and actions. Understanding these components helps in the design of interventions and strategies that encourage adolescents to actively engage in working memory enhancement, thereby positively influencing their risk behavior decisions.

In summary, Incorporating the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB) provides a robust framework for comprehending adolescent behavior within the context of working memory enhancement and risk behavior prevention.

The HBM focuses on adolescents' perception of their susceptibility to negative consequences related to poor working memory, the benefits of enhancing it, and the barriers they may encounter. It emphasizes the role of cues to action as triggers for improving working memory. This understanding guides the design of interventions aimed at enhancing working memory and reducing risk behaviors among adolescents. On the other hand, the TPB delves into the motivational factors influencing adolescents' intentions and actions concerning working memory enhancement. Attitudes, subjective norms, and perceived behavioral control collectively shape their decisions in this regard.

So, this knowledge served as a foundation for designing interventions and content sequences within the knowledge mode of the TendingPETs application that encourage adolescents to actively engage in working memory enhancement, thus positively influencing their risk behavior decisions.

2.6 Literature review

2.6.1 Literature review about effectiveness of video game on enhance working memory skill among adolescent

As a result, digital technologies play an important part in daily life. As a result, gaming on smartphone apps has created new chances for adolescents to develop their working memory skills. The following are the most common memory training features: CogniFit Brain Fitness, Fit Brains Trainer, and Lumosity are a few examples.

Researchers were also interested in gaming-based ways to supporting working memory and cognitive domain. Several studies have effectively employed smartphone applications to improve working memory. These are reviews of the literature on video games for improving working memory in adolescents. Researchers examined journals from a range of databases, including Pubmed, SCOPUS, Sagepub, and BMJ. Each study's details and findings are summarized below:

Colzato LS et al (2013) (17) studied action video gaming and cognitive control in experienced video game players (VGPs) compared with little to no video game experience players (NVGPs). Results presented participants who had experienced video gaming were faster and more accurate in the monitoring and updating of working memory than little to no video game experience players.

Oei AC and Patterson MD (2013) (83) studied a multiple game training for enhance cognitive among 75 undergraduates in Singapore. Participants were randomly separated to 5 groups and received different game training (hidden-object, memory matrix, match-3, action and The Sims). Finding presented video game maybe related with cognitive and executive functions improvement and different game enhance different aspects of cognition.

Stanmore E et al (2017) (84) studied meta-analysis about effect of video game on cognitive functioning in adolescent. This study recruited randomized controlled trials researches and was used to extract data for found association of video game with 2 outcomes as global cognitive and individual cognitive domains. Results shown video game significant effect on attention and visuospatial skills.

Boendermaker WJ et al (2018) (85) studied using serious game on training working memory among 84 high school adolescents in Netherlands. Participants were assigned in 3 groups with 3 conditions; gamified WMC training, the standard condition and the placebo condition. Results presented gaming was related with motivation to train and also effected of time on working memory performance.

Liu S et al (2019) (86) studied effects of video gaming on working memory performance among 27 young adult in German. Participants were compared working memory performance when they did 3 activates as eyes-open resting, listening to music and playing Angry Bird game app. Result shown video gaming during may affect working memory performance.

Choi E et al (2020) (87) reviewed commercial video games and cognitive functions that seek association between commercial video games and cognitive training. Results, video games were positive associated with cognitive functions but it was limited to the task or performance requiring the same cognitive functions.

Hamidi F et al (2020) (88) investigated the effectiveness of computer game interventions in enhancing attention and working memory in children with Attention Deficit Hyperactivity Disorder (ADHD) from second to sixth-grade students in Najafabad City, Iran. The intervention consisted of 18 sessions, with each session lasting 20 minutes, exclusively for the experimental group. The findings revealed that the computer game interventions led to notable improvements in spatial visual attention and working memory (p-value<0.05).

Mirmahdi R (2020) (89) conducted a study to investigate the influence of computer games on the working memory and spatial visual perception of students afflicted with specific learning disorders pertaining to reading, writing, and mathematics. The research was carried out at a girls' primary school located in Tehran. The findings of the study revealed that these computer games had a favorable impact on the participants' working memory and spatial visual perception.

2.6.2 Literature review about association between working memory and academic performance, and preventive risk behavior among adolescent

Marie-Maude Dubuc et al (2020) (90) investigated the relationship between interference control, working memory, and academic performance in 187 male and female high school students. The results revealed that female students generally outperformed male students in academic subjects like science and language during the study. However, no significant gender differences were observed in interference control or working memory. Additionally, working memory had weak associations with academic performance and limited predictive ability over a three-year period.

Studer-Lueth B et al (2022) (91) investigated the effects of working memory (WM) training on cognitive and academic performance in 86 typically developing 8–12-year-old children in a school setting. Participants completed a 6-week WM training program using n-back and complex span tasks or a control training with perceptual-matching tasks within their regular school environment. Results showed the WM training group exhibited increased WM and math performance compared to the control group. Additionally, there were trends towards improved vocabulary and overall enhancements in fluid intelligence and reading after both types of training.

Nengpeng Zhan et al (2022) (92) study focused on understanding how these cognitive functions are influenced by grade level, academic performance, and gender. The study involved 283 students, including 144 boys and 139 girls, aged 6 to 13 years from the Experimental Primary School Affiliated with Shanghai Jiao Tong University in Shanghai, China. The study found that both attention and working memory performance improved as students progressed through higher grades in primary school. Additionally, students with better academic achievement demonstrated superior performance in working memory tasks.

Larsen H et al (2014) (93) investigated cognitive biases related to smoking in adolescents from the US and the Netherlands, and how these biases are associated with smoking behavior. Results showed stronger attentional bias and weaker inhibition skills were associated with higher nicotine dependence, and weaker working memory was linked to increased daily cigarette use. In conclusion, attentional bias, inhibition skills, and working memory play crucial roles in explaining smoking behavior among adolescents.

Tahaney KD and Palfai TP (2018) (94) investigated association between working memory moderates and perceived norms and heavy episodic drinking among 98 college students who reported one or more instances of drinking in the past month. It was revealed that working memory serves as a protective factor. Individuals with higher working memory capabilities were less susceptible to the influence of social norms on alcohol use.

Padovano HT and Miranda R (2021) (95) aimed to investigate alcohol craving in adolescents during daily life and the roles of working memory and biological sex. The findings indicated that alcohol craving was influenced by stress, peer presence, and alcohol cues. Working memory, although not directly linked to craving, acted as a buffer against stress-induced craving, primarily in males, who generally experienced higher craving than females.

2.6.3 Literature review about parenting factors

The following are some parenting factors that related with working memory among adolescents:

Study	Subjects	Factors	Result
Castillo R et al (2011) (96)	2,162 Spanish adolescents	*Independent variables :* Parental educational Parental occupational levels Socioeconomic factor *Outcome:* working memory	Educational and occupational levels of adolescents parent were positively associated with all specific cognitive abilities and the overall score (p<001 to .04).
Society for Research in Child Development (2014) (97)	300 children (10- through 13-year-olds)	*Independent variables:* education level *Outcome:* working memory	The education of parents was associated to children's performance on working memory tasks.
Zhang H et al (2020) (98)	11,875 children (9 to 11 years)	*Independent variables :* Socioeconomic status, parental psychopathology, social environment *Outcome:* Child psychopathology, behavior, and cognitive function	Greater socioeconomic status was associated with greater child general cognition and Executive Function.

CHAPTER 3
RESEARCH METHODOLOGY

In this study, the effectiveness of TendingPETs application on working memory among adolescents in Phrae province, Thailand, the researcher presented the following details about the methodology:

3.1 Research design

3.2 Study duration

3.3 Population and sample size

3.4 Sampling method

3.5 Procedure and material

3.6 Measurement

3.7 Data collection

3.8 Data analysis

3.9 Ethical consideration

3.1 Research design

This study adopted a quasi-experimental design, specifically employing the Two-Group Pretest-Posttest Experimental approach. The primary objective was to investigate the effectiveness of the TendingPETs application in enhancing working memory among 15-year-old adolescents residing in Phrae province, Thailand.

3.2 Study duration

The quasi-experimental study spanned from February 2022 to August 2022, encompassing a total duration of six months. This period was divided into two phases: a two-month intervention phase and a subsequent four-month follow-up phase.

3.3 Population and sample size

The study focused exclusively on public schools within Phrae province. The target population comprised 15-year-old students attending these public schools.

3.3.1 Sample size calculation

Sample size determination utilized the G-power program with a confidence level of 95% (Type I error = 0.05) and statistical power (1-α) set at 80%.

Drawing from Brain training game boosts executive functions, working memory and processing speed in young adults: A randomized controlled trial of Boendermaker et al. (91), which reported an effect size of 0.58 for similar interventions.

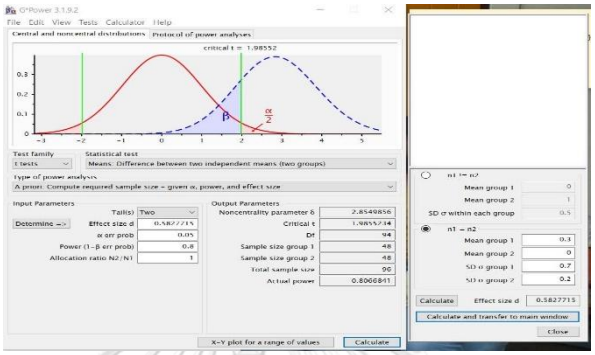


Figure 3.1 A G-power algorithm utilized for calculating the sample size for this study.

The calculated sample size was initially set at 96 participants. To account for potential data collection errors and attrition, the sample size was adjusted by 10%. Consequently, the final sample size for the study consisted of 106 participants, divided evenly into an intervention group (53 participants) and a comparison group (53 participants).

3.3.2 Adolescent inclusion and exclusion criteria

3.3.2.1 Inclusion criteria

1) Adolescents aged 15 years.

2) Adolescents who attended at least one year of public school in Phrae province.

3) Adolescents possessing smartphones and internet access.

4) Adolescents whose parents consented to their participation and provided informed permission.

5) Adolescents not enrolled in Math and English tutorial classes.

3.3.2.2 Exclusion criteria

1) Adolescents affiliated with sports clubs.

2) Adolescents engaged in regular physical activity (60 minutes per day of moderate to vigorous intensity).

3) Adolescents with vision, hearing, or physical mobility impairments.

4) Adolescents participating in E-sports.

5) Adolescents allowed to participate but failing to complete over 10% of their gaming assignments.

3.4 Sampling method

Participants were recruited using a multi-stage sampling approach, detailed as follows:

3.4.1 First stage: Zone selection

Phrae province was partitioned into two distinct zones, each encompassing multiple administrative districts. In accordance with the 2020 Phrae summary report, Zone 1 was found to encompass 10 secondary schools with a collective count of 270 classrooms. In contrast, Zone 2 contained 6 secondary schools and 143 classrooms, as substantiated by data sourced from the Phrae provincial operation center.

The selection of Zone 1 was predicated upon specific criteria, notably the presence of the highest count of secondary schools and classrooms. Data details are presented below:

Table 3.1 Number of secondary schools in Phrae province by zone area

Zone	District	Number of secondary school	Number of classroom
1	Muang phrae	6	160
	Song	2	79
	Nongmuangkhai	1	12
	Rong kwang	1	19
	Summary	10	270
2	Denchai	1	38
	Long	1	29
	Wang chin	2	37
	Sungmen	2	39
	Summary	6	143

3.4.2 Second stage: Selection of district

In Zone 1, the selection process involved identifying the district with the highest enrollment of secondary school students and junior high school students. According to data extracted from the 2020 Phrae summary report, Muang Phrae district was found to fulfill these criteria.

Specifically, this district was observed to have the highest count of secondary schools, totaling six, and the greatest number of junior high school students, with a total enrollment of 2,720 students.

Table 3.2 The count of secondary schools in Phrae province categorized by geographical zones

Zone	District	Number of secondary school	Number of junior high school student
1	Muang phrae	6	2,720
	Song	2	1,675
	Nongmuangkhai	1	160
	Rong kwang	1	261
	Summary	10	4,816

3.4.3 Third stage: Recruitment of school

Muang Phrae district was home to six secondary schools, including Nareerat School Phrae, Piriyalai School Phrae, Muangphrae School, Thinopatwittaya, Huai Ma Wittayakhom School, and Thakham Wittayakhom School.

Students from middle school and above (schools with more than 121 students) adhering to a standard curriculum were included in the study. Using simple random sampling, one school was designated as the intervention group, while another served as the comparison group.

3.4.3 Fourth stage: Recruitment of participants

Participants were selected based on the specified inclusion and exclusion criteria.

Sampling method

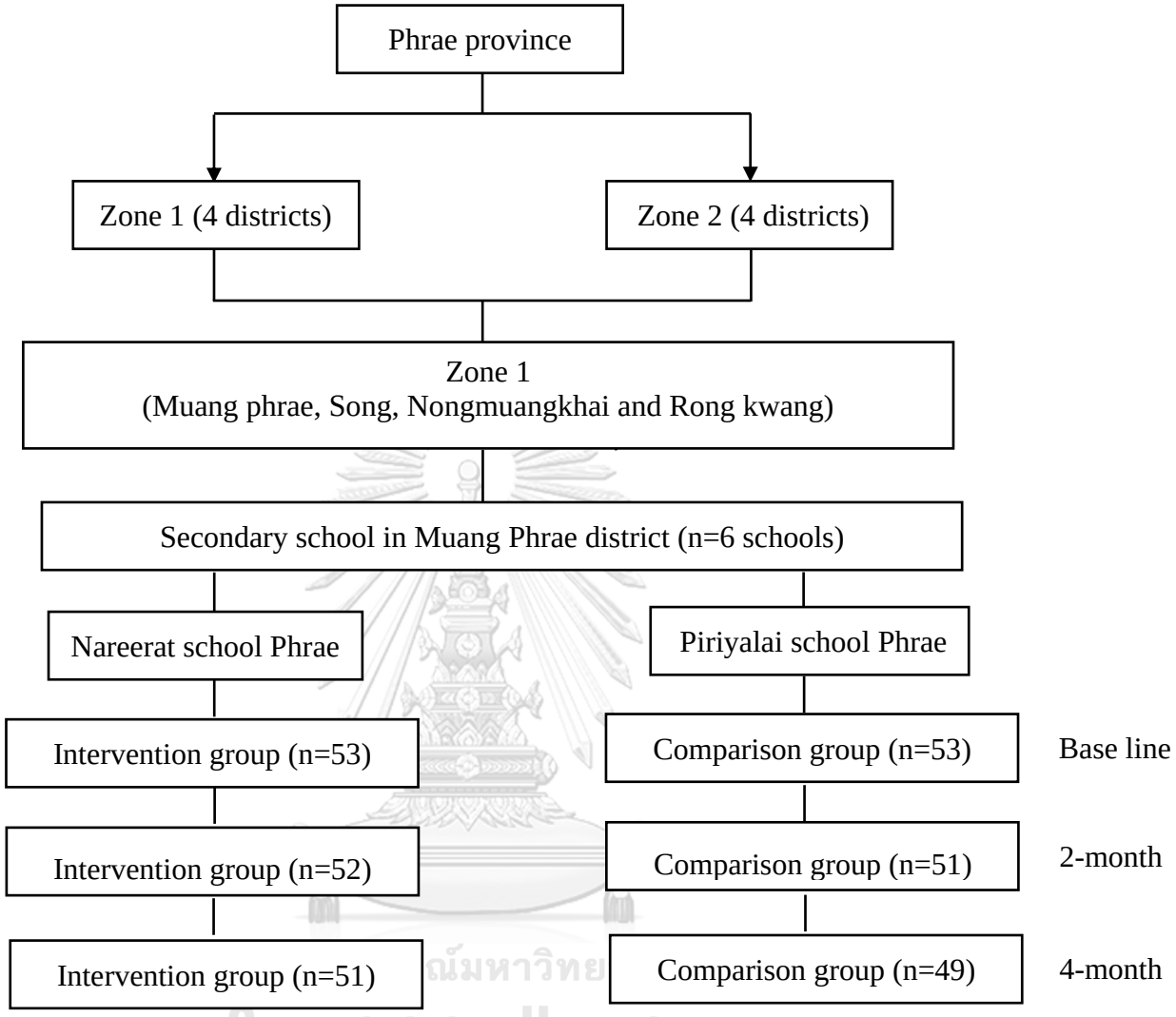


Figure 3.2 Sampling method

3.5 Procedure

Participants in the intervention group were provided access to the TendingPETs application, which allowed them to engage in interactive activities at their discretion. In contrast, the comparison group did not receive access to the TendingPETs application during the study period.

Data collection encompassed assessments of working memory, academic performance, and risk behaviors at three distinct time points: baseline (0 months), post-intervention (2 months), and a follow-up at four months. Working memory assessments were conducted using lucid recall techniques administered by child psychologists.

Secondary outcomes included academic achievement, measured via the PISA mathematics and English test specifications, as well as evaluations of risk behaviors such as alcohol consumption and smoking, assessed through the ASSIST questionnaire.

3.5.1 TendingPETs application mechanism

The intervention involved providing adolescents in the intervention group access to the 'TendingPETs application' for a duration of eight weeks. This application is a 2D graphic game with an Entertainment Software Rating Board (ESRB) rating of 'E' (suitable for everyone). Its design and implementation are rooted in the key concept of Game-Based Learning, as proposed by Plass JL et al., aligning with established principles of educational game development.

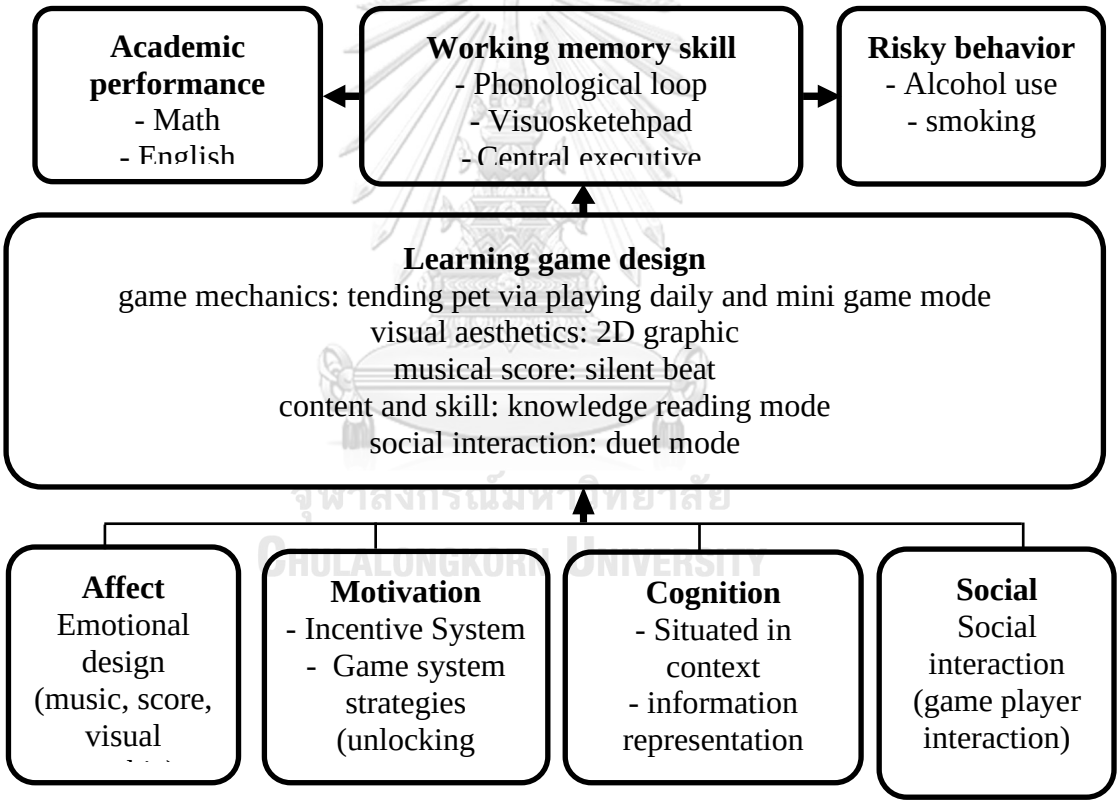


Figure 3.3 framework of TendingPETs application applied

3.5.1.1 TendingPETs application overview

The TendingPETs game mechanics are structured around the premise that players are entrusted with the care and nurturing of a virtual pet, with the objective of

fostering the pet's intellectual growth through a range of interactive functions and mini-games.

TendingPETs comprises four primary modes: Main Character Information, Daily Quests, Mini Game Missions, and Knowledge Reading. It is worth noting that the application allows players to engage with it at their convenience; however, certain modes, such as Mini Game Quests, impose time constraints.

1) **Mode 1: Main Character Information**

In this mode, players access the pet's profile, offering insights into various aspects of the virtual pet, including its visual attributes (type, color, clothing, and dwelling), current level, title, and abilities across physical, mental, and intellectual domains.

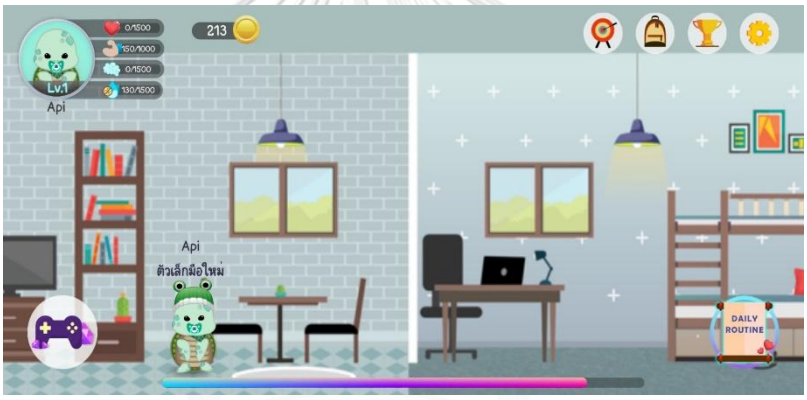


Figure 3.4 Main screen of TendingPETs application

2) Mode 2: Daily quests playing

Every day, players engage in a series of four essential activities designed to nurture and enhance the well-being of their virtual pets as part of their daily objectives. These activities are integral to the holistic care of the digital companions:

Task 1 Feeding: Players exercise discretion in choosing and providing nourishment to their pets from a diverse menu of available foods. Each food item consumed carries unique effects, primarily impacting the physical aspect of the pet. Additionally, certain foods exert influence over the pet's mental and intelligence attributes, thereby contributing to a comprehensive evaluation of its health.

Task 2 Learning Missions: These missions are versatile and can

be undertaken at the player's convenience. Inextricably linked to the knowledge reading mode and mini-games, this quest category bolsters the player's knowledge base. The knowledge accrued from these missions proves invaluable, as it directly informs their ability to respond to questions posed in various mini-games, thereby influencing their performance.

Task 3 Entertainment: This quest category centers on recreational activities with the pets, fostering a bond between player and digital companion. Significantly tied to the mental well-being of the pet, the activity's efficacy hinges on the pet's mental score. If the pet's mental condition falls below a designated threshold, it may not engage enthusiastically in any activity. Furthermore, for every decrement of 30 mental points, the player experiences the depletion of 1 energy bar, a vital resource utilized for participating in mini-games.

Task 4 Cleaning: A crucial facet of pet care entails the upkeep and hygiene of both the pet itself and its living quarters. The cleaning quest activities encompass grooming and maintaining the pet's habitat, ensuring that it remains a clean and pleasant environment for the pet's optimal well-being.

Figure 3.5 Daily quests

3) Mode 3: Mini game quests

Mini-game quests consist of five games, each designed to target specific cognitive functions:

1st Mini Game: The First Egg for Newbie: This game focuses on

improving math skills. Players are presented with two math quizzes and must complete them within a time limit. The quizzes are generated randomly

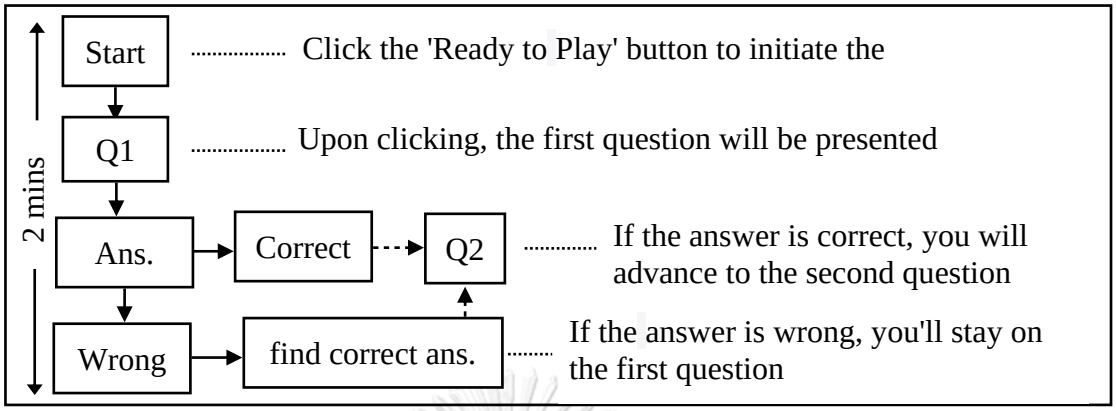


Figure 3.6 The first egg for newbie game mechanics

2nd mini game: Endless

This mini-game is strategically designed to target and enhance visuospatial performance, a critical cognitive skill. Players are engaged in a dynamic challenge that directly impacts their visuospatial sketchpad. The game begins with a single word displayed on the screen, demanding rapid recognition and typing skills. As the game progresses, the complexity and difficulty level gradually increase. This progression uniquely exercises the player's visuospatial sketchpad, as they must not only recall and reproduce the current word but also retain and reproduce all previously presented words.

The gameplay unfolds as follows: When the first word, for instance, "Cocaine," is presented, the player is tasked with typing "Cocaine." Subsequently, as the second word, "Methadone," surfaces, the player's response must encompass both the previous word, "Cocaine," and the current one, "Methadone." Upon successful completion of the challenge, the system generates a comprehensive summary of the player's responses. Notably, this compilation may encompass words such as "Cocaine," "Methadone," and "Morphine," all categorized under Schedule 2 substances.

This description offers an academic perspective on the game's mechanics, emphasizing its role in enhancing visuospatial memory through the repetition of sequentially presented words.

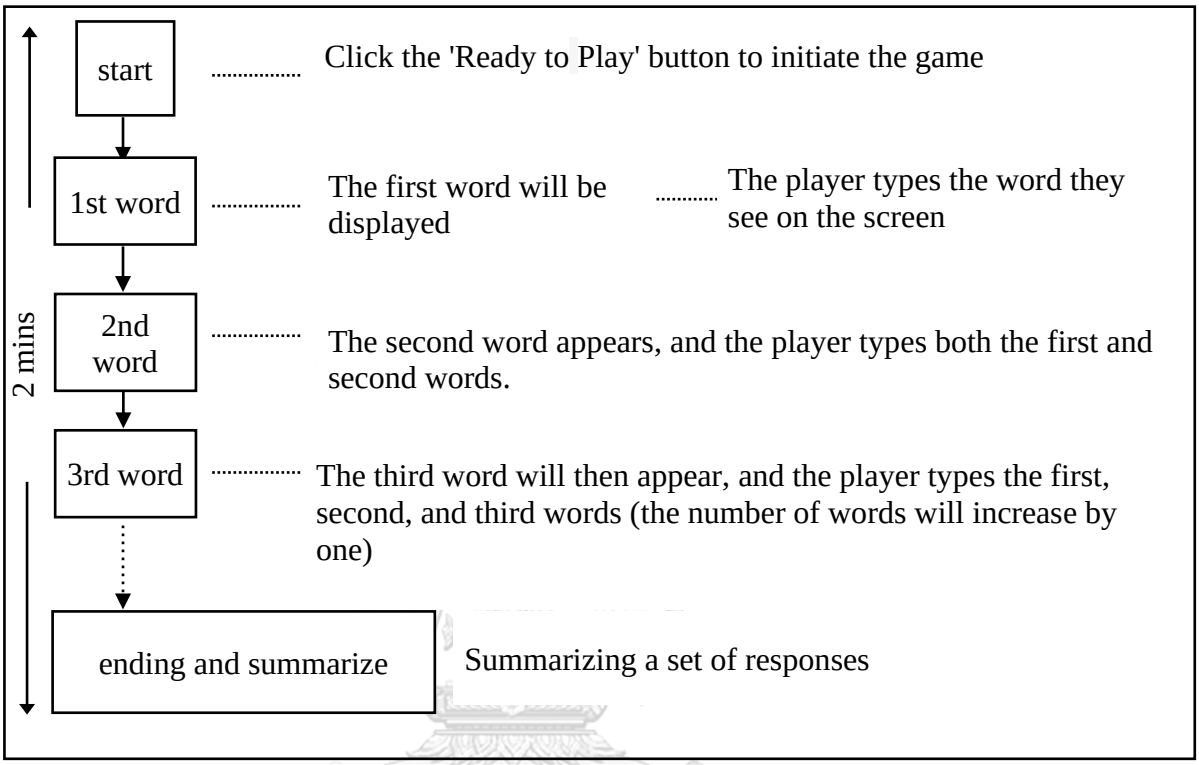


Figure 3.7 Endless game mechanics

Figure 3.8 Guideline screen of Endless

Figure 3.9 Example of Endless screen

3rd mini game: Over and over

The "Over and Over" mini-game has been intricately designed to finely tune and elevate phonological loop performance, a foundational element within the domain of working memory. This game immerses players in an auditory challenge, demanding their adeptness in processing spoken commands and seamlessly matching them with corresponding visual representations.

The essence of this exercise is a direct and rigorous targeting of the phonological loop, fostering rapid processing of auditory information while establishing robust associations with visual cues.

As participants navigate through the various levels of the game, the challenge progressively intensifies. This deliberate escalation serves a distinct purpose — to compel players to continually extend the boundaries of their phonological loop capacity. Each ascending level introduces an array of intricate auditory commands, enriching the cognitive demands and necessitating heightened phonological memory and recall proficiencies. This iterative process serves as an efficacious training platform for fortifying the phonological loop, ultimately elevating overall working memory performance.

This description offers an academic perspective on the game's mechanics, underscoring its pivotal role in enhancing the phonological loop, a crucial component of working memory.

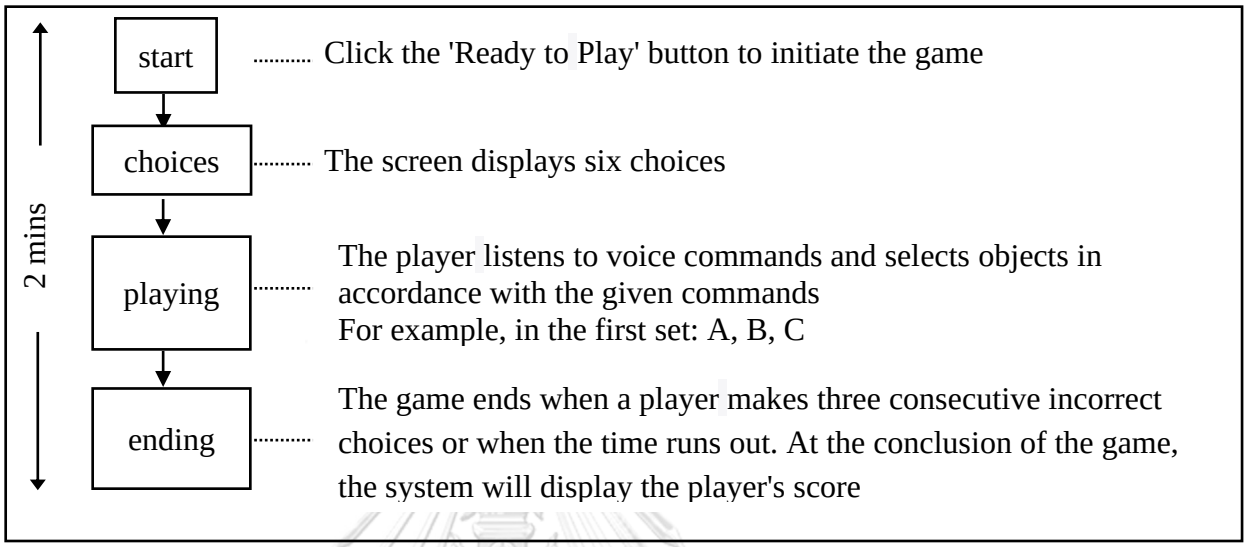


Figure 3.10 Over and Over game mechanics

Figure 3.11 Over and Over game screen

4th mini game: What's answer?

This particular mini-game is meticulously designed to facilitate the improvement of visuospatial sketchpad performance and risk behaviors—a fundamental cognitive domain. Within this game, participants are presented with a straightforward yet effective challenge, aimed at refining their visuospatial sketchpad abilities.

The mechanics of the fourth mini-game are elegantly simple: players are tasked with reading a series of quizzes and selecting the correct answers within a predefined time constraint. Notably, the quizzes themselves are thoughtfully selected at random to ensure a varied cognitive challenge.

This academic description underscores the specific focus of the mini-game on enhancing visuospatial sketchpad performance, and risk behaviors.

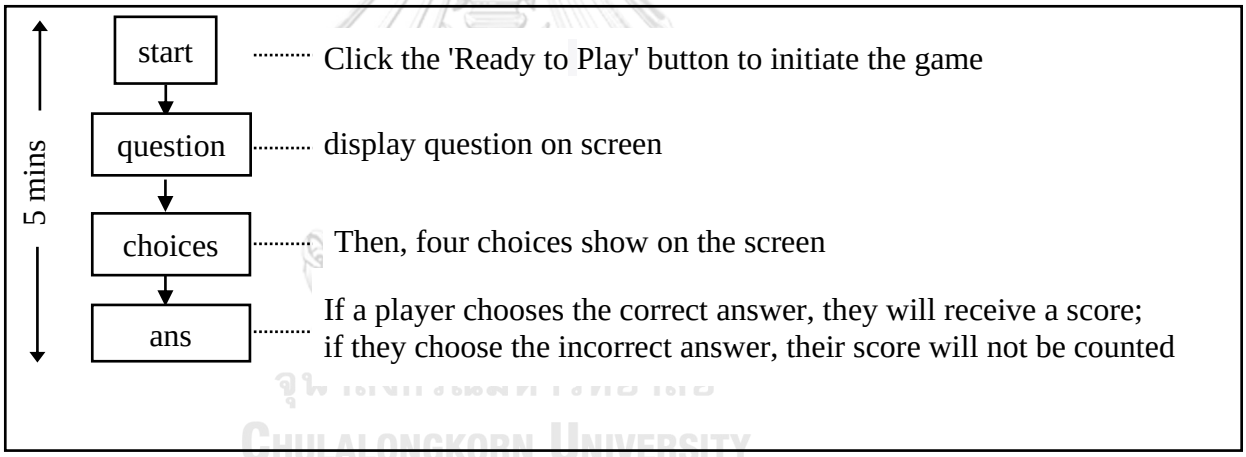


Figure 3.12 What's answer game mechanics

Figure 3.13 What's answer game screen

5th mini game: Last boss

Within this application, the final boss mini-game stands as the pinnacle of cognitive challenge, seamlessly integrating various educational facets encompassing mathematics, English, and knowledge pertaining to alcohol and cigarettes. Players are presented with a multifaceted task: identifying correct answers within the game, all harmoniously synchronized with a musical backdrop. This synchronization culminates in a progression from relatively straightforward questions or commands to progressively intricate ones.

This holistic approach extends conventional cognitive testing, serving as an opportunity for players to consolidate their proficiency in mathematics and English. Additionally, it reinforces their comprehension of the associated risks linked to alcohol and cigarettes. Consequently, the final boss mini-game offers a comprehensive cognitive enhancement experience, contributing to the players' overall cognitive development.

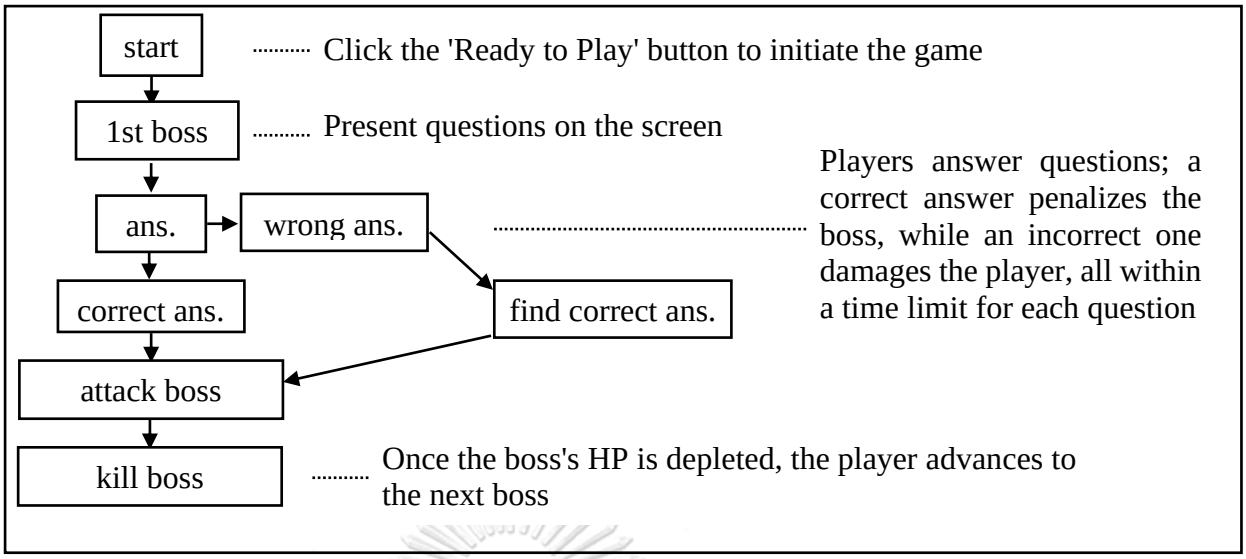


Figure 3.14 Last boss game mechanics

Figure 3.15 Last boss game screen

4) Mode 4: Knowledge reading mode

Within the application, the Knowledge Reading Mode stands as a pivotal repository of information, accessible through the Pet House screen's Library Room. This mode serves as the fundamental wellspring from which all quiz content within the mini-games originates. As such, players are strongly encouraged to immerse themselves in this mode's wealth of information prior to embarking on mini-game adventures, as it offers continuous access to all pertinent content.

The Knowledge Reading Mode features four categorized sections: Mathematics, English, Health Education, and Information on Alcohol and Cigarettes, providing structured learning. These principles enhance the learning

experience.

Table 3.3 The principles of knowledge reading mode

Subject	Topic	
Math	Number and Operation	Geometry and Measurements
	Statistics	data analysis and probability
English	Conversation	Grammar and Vocabulary
	Reading Comprehension	Error Recognition
Health education	Physical health	Risk behavior
Alcohol and tobacco	Basic knowledge of alcohol and tobacco	Alcohol and your organs
	Alcohol and the adolescent brain	Alcohol use and chronic disease
	Tobacco and your organs	Tobacco and the adolescent brain
	Tobacco use and chronic disease	

Figure 3.16 English knowledge reading mode screen

5) Mode 5: Duet mode

The principal aim of this mode is to foster social interaction among players, elevating their overall gaming experience. Initially, a competitive feature was implemented, wherein players engaged in question-answering contests, with the victor earning a distinctive reward. Additionally, participants possess the

capability to exchange emoticons or brief messages to facilitate communication.

To access and participate in this mode, players must achieve a pet level of at least level 4.

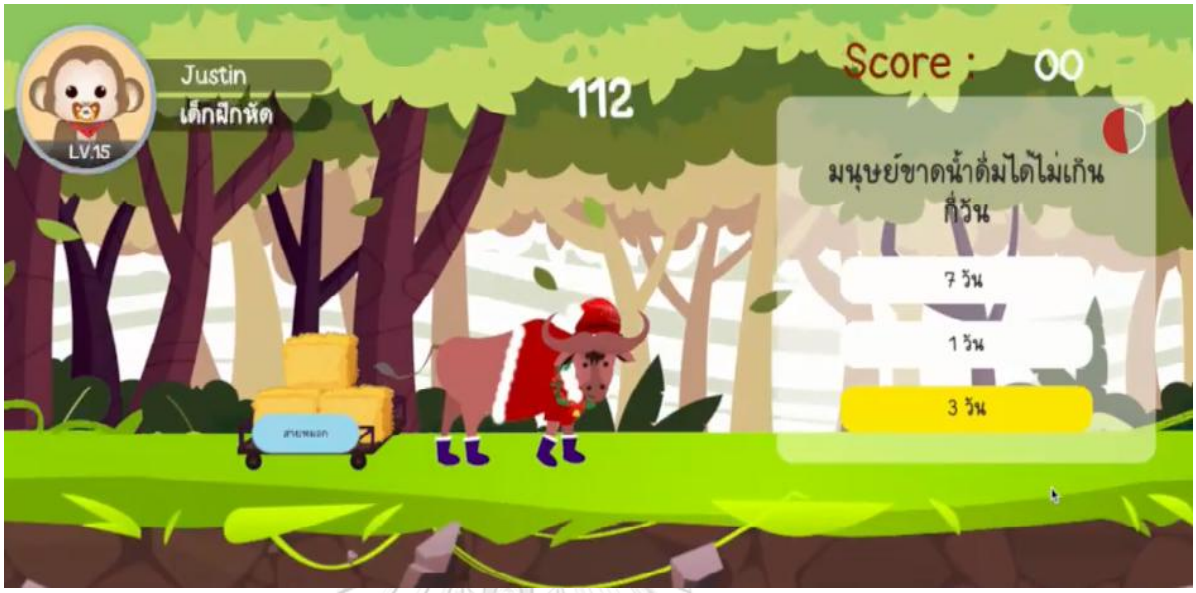


Figure 3.17 Example of duet mode screen

The table below provides a concise summary of the details pertaining to the TendingPETs application:

Table 3.4 Detail of TendingPETs application

Mode	Activities
Main character info	Main Character Info Mode provides users with detailed insights into their individual pets, encompassing the following key components: 1. Pet Name: Within this mode, players exercise their creativity by assigning unique names to their pets. 2. Pet Character: This entails players' selection of various attributes for their preferred pets, including: 2.1. Pet Type: Users are presented with a choice among five distinct pet categories, each with its unique characteristic

Table 3.4 Detail of TendingPETs application (Cont.)

Mode	Activities
Main character info (Cont.)	2.2 Attire: Players have the option to personalize their pets' appearances by selecting from various clothing items, including hats, shirts, and shoes. 3.Intelligence Section: This section evaluates the cognitive abilities of the pet, influenced by the player's interactions and impacting their performance in mini-games. 4. Pet Titles: Titles for pets can be earned through three methods: 4.1 Level Conditions: Pets gain titles as they progress through levels, such as 'Level 0: Newbie,' 'Level 5: Growing Pet,' 'Level 10: Master Pet,' and 'Level 15: Marvelous Pet.' 4.2 Daily Quest Achievements: Completing daily quests based on pet care can result in titles like 'Abundant' for proper care or 'Alcoholism' for improper treatment like feeding the pet alcohol. 4.3 Mini-Game Achievements: Playing mini-games provides another avenue to acquire diverse pet titles, including 'Son of the Flash,' 'King of Missing,' or 'Noob.'
Daily quests playing	This mode comprises daily tasks, each designed to enhance different aspects of the pet's well-being: 1. Task 1: Feeding: Players are tasked with selecting suitable food to feed their virtual pet, impacting the pet's physical state. Various food options, including both nutritious and less nutritious choices, are available, encouraging players to make informed decisions. 2. Task 2: Learning: This task is linked to the pet's intellect. Players must visit the virtual library within the pet's living space and engage with educational materials divided into four categories: Math, English, health education, and knowledge about tobacco and alcohol. 3. Task 3: Entertaining: This task focuses on the pet's mental well-being. Players must entertain their virtual pet using toys obtained through mini-games, aiming to improve the pet's mental state. 4. Task 4: Cleaning: Players are responsible for maintaining their pet's living space, ensuring cleanliness and comfort.

Table 3.4 Detail of TendingPETs application (Cont.)

Mode	Activities
Mini game quests	Mini-game missions encompass a total of five games, each designed with specific educational objectives: **1. 1st Mini-Game: "The First Egg for Newbies"** Objective: Enhance mathematical skills. Description: Players must successfully complete this mini-game to obtain a pet egg. Game Duration: 2 minutes. Game Details: Random math questions are presented, and players must solve them correctly to earn a pet egg. Rewards: Pet eggs of their choice. **2. 2nd Mini-Game: "Endless"** Objective: Improve visuospatial memory. Description: A memory challenge to test players. Game Duration: 2 minutes per game. Game Details: Players view words on-screen (Thai or English) and must type them in the same order. Failing three tasks consecutively or timing out ends the game. Rewards: Intelligence points, pet titles, pet care items, and experience. **3. 3rd Mini-Game: Over and Over** Objective: Enhance phonological loops and central executive performance. Description: Players explore and identify sounds together. Game Duration: 2 minutes per game. Game Details: Players listen to sounds and select answers matching the heard sounds in sequence. The game becomes more complex as levels progress. Rewards: Mental and intelligence points, pet titles, pet care items, and experience.

Table 3.4 Detail of TendingPETs application (Cont.)

Mode	Activities
Mini game quests (Cont.)	**4. 4th Mini-Game: "What's the Answer?"** Objective: Improve phonological loops and central executive performance. Description: Players demonstrate their wisdom by choosing correct answers. Game Duration: 5 minutes per game. Game Details: Players read questions and select the correct answer from four choices within a time limit. Rewards: Intelligence points, pet titles, pet care items, and experience. **5. 5th Mini-Game: "Last Boss"** Objective: Enhance working memory, academic performance, and knowledge related to alcohol and cigarettes. Description: Players use their cognitive abilities to defeat bosses. Game Duration: Until the pet's health reaches zero or all seven bosses are defeated. Game Details: Quizzes appear in sync with music, covering math, English, and alcohol and tobacco knowledge, ranging from easy to difficult. Correct answers harm bosses, while incorrect answers damage the player's pet. Conditions: Players can unlock this mini-game at pet level 4. Energy Usage: Players can play this mini-game daily until their energy bar is depleted. They receive 10 energy bars daily, with one energy bar replenished every 20 minutes. This comprehensive approach to mini-games not only offers entertainment but also contributes to various cognitive skills and knowledge enhancement.
Knowledge reading	Participants can access this section by entering the pet library, where they will find bookcases housing various informational categories available for reading at their convenience. The content within this mode is intricately connected to each of the mini-games. It is essential that participants visit this mode before partaking in any of the mini-games to acquaint themselves with the pertinent information.

Table 3.4 Detail of TendingPETs application (Cont.)

Mode	Activities
Duet mode	This unique mode is designed to foster social interaction among players and enhance their overall enjoyment and engagement within the game environment. 1. Game Description: The mode encourages players to test their knowledge and compete against each other. 2. Timing of the Game: Each round is limited to a duration of 3 minutes. 3. Game Details: In this mode, two players engage in a competition. Both players are presented with the same question and are required to identify the correct answer. The player with the highest score at the end of the allotted time wins the round. 4. Game Rewards: Successful participants are rewarded with rare items for pet management and exclusive pet titles. This mode serves as a dynamic platform for player interaction and adds an element of competition and excitement to the gaming experience.

3.5.2 Duration for playing

As there is no time restriction for accessing and engaging with this program, players have the flexibility to log in at their discretion. However, it is advisable, in accordance with research recommendations, that individuals prioritize the completion of their educational tasks and assignments before indulging in game applications. This approach can be advantageous, allowing participants to focus on their educational responsibilities before utilizing the gaming application for assessment purposes.

Note: It is noteworthy that the average daily gaming duration should not exceed two hours.

3.5.3 Player Monitoring Procedures

In order to effectively monitor player engagement and interactions, a multifaceted approach has been employed. First, a dedicated Instagram platform has been established, serving as a means for game updates and direct communication with

players to promptly address inquiries and resolve any encountered challenges. Second, a dedicated group line has been established to facilitate direct and efficient communication channels with players. Lastly, player activity is monitored through the acquisition of server backup data. Consequently, should a player opt to deactivate the game, researchers can employ the aforementioned platforms to encourage reactivation and sustain player engagement.

3.5.4 Comparison group

The comparison group, in contrast, is not granted participation in the TendingPETs application during the study period. Instead, participants in the comparison group receive conventional classroom activities as part of their regular school curriculum.

Conventional School Curriculum (Central Standard Curriculum)

The Ministry of Education typically establishes a unified curriculum framework for educational administration across all public educational institutions. Within this framework, various subjects such as mathematics, English, health education, and physical education are characterized by predefined curricula, lesson outlines, and learning objectives.

Moreover, secondary schools under the Ministry of Education employ a variety of teaching methods, including experiential learning, self-directed learning, traditional lectures, and active learning strategies within classroom settings. Lecture-based instruction remains a predominant and widely practiced teaching approach across subjects, with most public schools allocating 1-3 hours per subject for instructional purposes.

3.6 Measurement

The following outcome measures were assessed at three-time points: baseline, post-intervention (after two months), and a subsequent four-month follow-up.

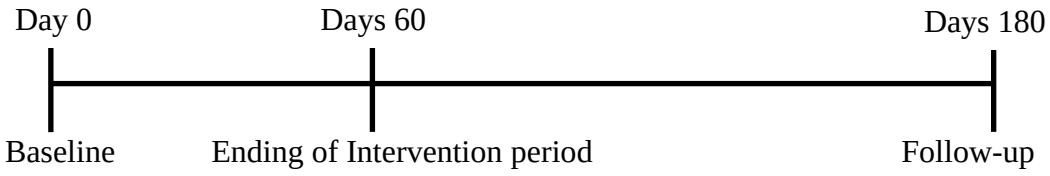


Figure 3.18 Timeline for outcomes measurement

3.7.1 Demographic characteristics

At baseline, researcher collects demographic data

3.7.1.1 Children factors: gender, anthropometric measure, eating behavior, sleeping, physical activity, tutoring, and gaming experience.

3.7.1.2 Parents factors: age, educational level, and income; categorize income (by percentile and educational level following National education act B.E. 2542) among participants in both groups by questionnaire.

3.7.2 Lucid recall

The Lucid Recall assessment tool, developed by St Clair-Thompson HL in 2013, is a fully automated instrument utilized for the evaluation of working memory. It is designed to measure three key composites of working memory:

1) Central Executive Subtests: This component assesses working memory through counting recall tasks.
2) Phonological Loop Subtests: This component evaluates working memory through word recall exercises.
3) Visuo-Spatial Sketchpad: This component measures working memory through pattern recall tasks.

Interpretation of Lucid recall

The Lucid Recall assessment typically spans a duration of 20 to 30 minutes. The results obtained from Lucid Recall encompass a range of parameters,

including standard scores, confidence intervals, centile scores, age equivalents, memory span, and average time.

Standard scores are provided within 6-month age bands, covering the age range from 7 to 16 years. The interpretation of Lucid Recall results is primarily based on standard scores. These scores are distributed in accordance with a normal curve, with a mean (average) score of 100 and a standard deviation of 15. The utilization of standard scores allows for a standardized and norm-referenced assessment of working memory, facilitating comparisons and analyses across different individuals and age groups.

The score range of 85 to 115 is considered within the 'normative' or 'average' spectrum. Scores falling below 70 are indicative of significantly lower performance, while scores exceeding 130 are indicative of notably higher performance.

Table 3.5 Standard score of Lucid recall

Standard score	**percentile score**	**Standard score**	**percentile score**
70	2	115	84
80	9	120	91
85	16	130	98
90	25		
100	50		
110	75		

Validity and Reliability of Lucid recall

St. Clair-Thompson HL (1992) established the validity of computing correlations between the scores obtained on the working memory subtests and the scores achieved on the WISC-IV Working Memory Subtests. The findings revealed a statistically significant association between the scores on the Lucid Recall subtest and the scores on the WISC-IV subtests.

Table 3.6 Lucid recall and WISC-IV subtests

Lucid recall	**WISC-IV**	
	Digit span	**Letter–number sequencing**
Word recall	.78**	.56**
Pattern recall	.52**	.35*
Counting recall	.59**	.54**

*p < .05. **p < 01.

Regarding the aspect of reliability, St. Clair-Thompson HL (1993) reported the reliability coefficients for each sub-test as follows:

Table 3.7 Lucid recall reliability

sub-test	**Age 7-9**	**Age 13**
Word recall	0.71	0.68
Pattern recall	0.69	0.77
Counting recall	0.49	0.76

3.6.3 The Alcohol, Smoking, and Substance Involvement Screening Test (ASSIST) The Alcohol, Smoking, and Substance Involvement Screening Test (ASSIST) was developed for the World Health Organization by an international group of addiction researchers and clinicians (Humeniuketal et al.,1994). The ASSIST is a questionnaire designed to be administered by a health worker to a client using paper and pencil. This assessment consists of 8 items and screens for the use of the following substances:

1) Tobacco products
2) Alcohol
3) Canabis
4) Amphetamine-type stimulants (ATS)
5) Sedative and sleeping pills (benzodiazepines)
6) Hallucinogens

7) Inhalants

8) Opioids

9) Other drugs

Each participant is questioned about the use of each substance, and if they did not use a particular substance, further questions about it are not asked.

Table 3.8 Example of questions in ASSIST

In your life which of the following substances have you ever used (non-medical use only)?
During the past 3 months how often have you had a strong desire or urge to use (drug)?

Each question in the ASSIST contains specific answers and points as part of the ASSIST choices and scoring. The ASSIST also assigns a risk score to each substance, which can range from 0 to 39. The scores and their interpretations are as follows:

1) Lower risk: The client may use substances on occasion, is not currently experiencing any problems related to their usage, and is less likely to develop problems in the future based on their current pattern of use.
2) Moderate risk: The client may be experiencing some issues currently. In any case, continued use in this manner suggests the risk of future health and other problems, including the potential for dependence.
3) High risk: The client is at a high risk of becoming dependent on that substance and is likely to experience health, social, financial, legal, and relationship issues due to their substance use.

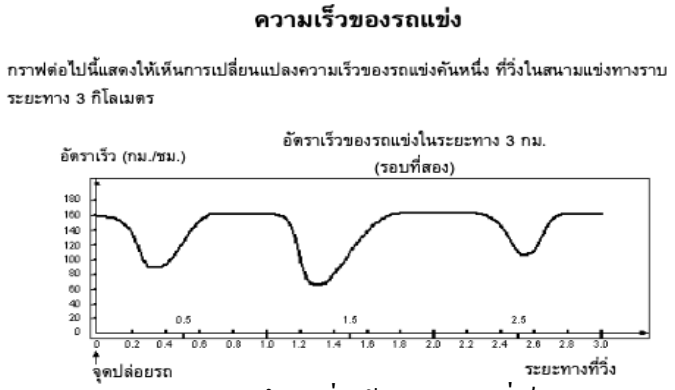
Validity and Reliability of ASSIST

Humeniuk R et al (95) shown construct validity was established by significant correlations between ASSIST scores and measures of risk factors for the development of drug and alcohol problems (r=0.48–0.76)

In part of reliability, study of Sainz MT et al (96) presented reliability of ASSIST sub scales as tobacco; alpha = 0.83, alcohol; alpha = 0.76, and marijuana; alpha = 0.73.

3.6.4 Programme for International Student Assessment: PISA

The Programme for International Student Assessment (PISA) (97), established by the Organization for Economic Cooperation and Development (OECD) (OECD, 1997), serves as a tool to gauge the performance of 15-year-old students in the domains of reading, mathematics, and science. In the context of this study, the researchers employed the PISA assessment specifically for the mathematics component. The translation of the PISA mathematics assessment into Thai was undertaken by The Institute for the Promotion of Teaching Science and Technology. PISA encompasses 19 distinct elements, each intricately tied to real-life problem-solving scenarios.



ระยะทางโดยประมาณจากจุดปล่อยรถจนถึงจุดเริ่มต้นของส่วนที่เป็นทางตรงยาวที่สุดของสนามแข่งเป็นระยะทาง เท่าไหร่ ?

Figure 3.19 PISA question examples

Each item within the PISA test is associated with a specific score range. Participants can attain the maximum score for an item by providing a correct answer. The score range for the PISA test, in this context, spans from 0 to 1,000 points.

3.6.5 English test Specification

The English test specifications were formulated by the Basic Education Commission (98). This English test comprises 20 subjective items, and the test encompasses the following content areas:

1. Conversation
2. Grammar and vocabulary
3. Reading Comprehension
4. Error Recognition

Table 3. 9 Question Examples from the English Test Specification

Error **(1)** Since ancient times, the benefits of applying facial masks **(2)** have been known to remove excess oil, **(3)** improve one's complexion, soften skin, and **(4)** moisturizer.
Error Tomorrow will **(1)** probably be **(2)** cloud in the morning, the sun will come out **(3)** around midday, and **(4)** maybe it'll rain in the afternoon.

Given the subjective nature of this test, each item is scored on a scale of 0 to 1. Participants are awarded a score of 0 for incorrect answers and one point for correct answers. Consequently, the score range for the English test specifications falls within the range of 0 to 20.

3.7 Data collection

3.7.1 Procedure for Publicizing Project Information

Collaborative Engagement with the School Headmaster: The research team collaborated with the school headmaster to elucidate the project's intricacies and secure authorization for the dissemination of project information and its execution within the school premises.

Establishment of an Instagram Account: An Instagram account was created by the researcher for the purpose of disseminating project details and facilitating communication with adolescents who express interest in the study.

3.7.2 Participant Inclusion and Exclusion Process

The inclusion and exclusion of participants into the project are a two-stage process:

3.7.2.1 Initial Screening: Adolescents attending the school are initially screened based on predetermined inclusion and exclusion criteria.

3.7.2.2 Parental Engagement: Subsequently, appointments are scheduled with adolescents who pass the initial screening, along with their parents. During these meetings, the researcher personally explains the project, provides detailed information about the TendingPETs application, outlines the benefits and risks of participation, and elaborates on the confidentiality measures for participants' data. Parents of interested participants are requested to provide informed consent. Furthermore, participants who meet the inclusion criteria undergo a second screening. Participants are informed that they can contact the researchers via phone, Line, or E-mail if they wish to withdraw from the project during its course.

In the event that a participant does not meet the criteria or their parents do not grant permission for participation, they are offered the option to undergo free testing for working memory, mathematics performance, English performance, or all three. The working memory test takes 30 minutes, mathematics performance assessment takes 1 hour, and English performance assessment also takes 1 hour. Results are conveyed to the adolescents through various online platforms, such as E-mail, Line, Facebook, or Instagram, on the day following the test.

3.7.3 Experimental Procedure

3.7.3.1 Intervention Group: Participants in the intervention group receive the TendingPETs application along with their regular classroom instruction at school for a duration of six months.

3.7.3.2 Comparison Group: Participants in the comparison group undergo regular classroom instruction at their school for six months without the TendingPETs application.

3.7.4 Data Collection Process

This study spans a duration of six months, commencing in February 2022 and concluding in August 2022. Data is collected by the researcher and a team of four research assistants, including a child psychologist, two student affairs officials, and a game administrator. Data collection occurs at three distinct time points: at the beginning of the study (first week of February 2022), at the conclusion of the intervention (after 2 months, first week of April 2022), and four months after the conclusion of the intervention (first week of August 2022). Data collection is conducted on school premises, and participants are required to bring their smartphones to scan a QR code for access testing.

Participants are scheduled for assessments of their working memory, mathematics performance, English performance, and health risk behaviors at no additional cost during each data collection session. The working memory assessment requires 30 minutes, the mathematics assessment takes one hour, the English assessment also takes one hour, and the health risk behavior assessment necessitates 10 minutes. Consequently, the total testing time is approximately 2.40 hours.

Moreover, prior to the initial data collection, the researcher provided comprehensive explanations of the game application, including its components, specifics of each mode, the number of mini-games, instructions for playing each mini-game, and demonstrations on how to use and navigate the application. Participants are also informed that they can refer to the "application guideline" in the menu within the application for ongoing reference on the rules and procedures of the game.

3.7.5 Validity and the reliability testing

3.7.5.1 Content Within the Application

TendingPETs incorporates a knowledge reading mode designed to impart knowledge in various subjects, including mathematics, English, health education, and information related to cigarettes and alcohol.

Prior to the development of the application, the researcher ensured the accuracy and quality of the content by seeking verification from experts in each respective field:

1) Mathematics: 3 math teachers specializing in 9th-grade curriculum.

2) English: 3 English teachers specializing in 9th-grade curriculum.

3) Health Education: 3 public health specialists.

4) Alcohol and Tobacco: 3 specialists in the field of alcohol and tobacco.

3.7.5.2 Assessment Tools

In the context of the English test specification, a thorough review process was undertaken, involving the evaluation and approval of the content by three experts:

1) Punika Tangprakhon, University of Thailand Cha-Am.

2) Benjaporn Pudsa, Mahidol University Nakhonsawan Campus.

3) Jantarat Nuangnit, Ratchawinit Bang Khen School.

Furthermore, prior to commencing the study, the researcher conducted a pilot test of the English test specifications on a sample of 30 adolescents aged 15 years, who shared characteristics similar to the target group.

3.7.6 Role of researcher and researcher assistance of this study

The researcher assumes multiple roles and responsibilities within this study, serving as a planner, overseer, and game administrator. The researcher's specific duties include:

Table 3.10 Summary of the researcher's role

Responsibility	Details of responsibility
Planner	Develop a comprehensive study plan encompassing all aspects of the research.
Inspector	1. Analyze player activities based on server backup data. 2. Scrutinize and authenticate all research findings. 3. Conduct weekly assessments to identify and address any issues within the application.
Game admin	1. Address inquiries and resolve issues related to the game application. 2. Furnish participants with detailed game instructions and guidance on utilizing the knowledge mode. 3. Administer and oversee the game's Instagram account for updates on game-related events

Additionally, there are four research assistants, each with specific responsibilities:

Table 3.11 Summary of the researcher's assistant’s role

Research assistants	Number	Responsibility
Child psychologist	1	1. Collaborate with the researcher in explaining and administering the Lucid recall test to the participants. 2. Analyze and interpret the Lucid recall test results.
Student Affairs Official (Follower)	2	1. Inform participants of the scheduled date and time for the measurement results. 2. Assist the researcher in the management of the Lucid recall test with the participants. 3. Maintain records of participant participation throughout different phases of the study.
Game admin	1	Address inquiries related to game-related issues, such as log-in difficulties, game progression, and challenges with accessing the assessment mode within the game.

3.8 Data analysis

3.8.1 Descriptive Statistics

Demographic data of the participants were subjected to descriptive statistical analysis, including the computation of frequency, percentage, mean, and standard deviation.

3.8.2 Analytical Statistics

3.8.2.1 Comparative Analysis: The Chi-square test and Independent t-test were employed to compare characteristics between the intervention group and the comparison group at baseline.

3.8.2.2 Analysis of Intervention Effects on Working Memory: Repeated Measures ANOVA was utilized to assess the effectiveness of the TendingPET application on working memory between the intervention group and the comparison group over time (at baseline, 2-months, and 6-months). The significance level for this study was set at 0.05.

3.8.2.3 Analysis of Intervention Effects on Academic Performance: Repeated Measures ANOVA was employed to determine the effectiveness of the TendingPETs application on academic performance between the intervention group and the comparison group over time (at baseline, 2-months, and 6-months). The significance level for this study was defined at 0.05.

3.8.2.4 Analysis of Intervention Effects on Risk Behavior: Repeated Measures ANOVA was used to evaluate the effectiveness of the TendingPETs application on risk behavior between the intervention group and the comparison group over time (at baseline, 2-months, and 6-months). The significance level for this study was set at 0.05.

3.9 Ethical consideration

The Ethics Review Committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University approved this ethical research proposal. (The clearance date is July 6, 2021: Project No. 100.1/64).)

In addition, prior to enrolling participants in the study, it is imperative to uphold ethical considerations, especially when involving children. Parents must be comprehensively briefed on the study's nature, purpose, as well as its potential risks and benefits. Subsequently, parents who make an informed decision about their child's participation are required to sign a consent form.

CHAPTER 4
RESULTS

This chapter presents the findings of a comprehensive study conducted between February and August 2022, involving 106 adolescents within a quasi-experimental research design. It's essential to note that 7 participants withdrew or were lost to follow-up during the study, resulting in a final participant count of 99 adolescents (intervention group: n=50, comparison group: n=49).

The chapter initiates by outlining the demographic profiles and inherent characteristics of the adolescent participants, followed by an in-depth analysis of their parents' attributes, setting the research context. It proceeds to meticulously assess the intervention's impact on key dimensions, such as working memory, academic performance, and risk behavior. Beyond mere observation, the chapter scrutinizes the changes and transformations within these domains, methodically presenting and comparing them in the context of the two study groups.

Subsequent sections of this chapter unveil the specific results of the study.

4.1 Adolescents Characteristics and Parental Profiles

4.2 Adolescent Working Memory

4.2.1 Adolescent Working Memory Assessment

4.2.2 Effectiveness of TendingPETs application on working memory among adolescents

4.3 Adolescent Academic Performance

4.3.1 Adolescent Mathematics Performance

4.3.2 Adolescent English Performance

4.4 Adolescent Risk Behaviors

4.4.1 Adolescent Risk Behaviors in Tobacco Products

4.4.2 Adolescent Risk Behaviors in Alcoholic beverages

4.5 Data-Driven Insights: Analyzing Mean Time of TendingPETs Application using

4.1 Adolescents characteristics and parental profiles

In the upcoming sections, we conduct a thorough analysis of the participants and parents within our study. A comprehensive understanding of their demographics and attributes is essential for contextualizing our research findings. The following sections presented the results of adolescents' characteristics and parental profiles:

In the intervention group, a slight majority of the adolescents (54.0%) were female, with an average age of 15.17 years. Their average weight was approximately 56.12 kilograms, with an average height of 163.32 centimeters, resulting in a mean body mass index of 20.99 kg/m². A significant portion (88.0%) had prior gaming experience, spending an average of 107.66 minutes per day on gaming activities. Moreover, 92.0% of them did not receive additional classroom tutoring. In terms of behavioral factors, 76.0% did not use dietary supplements and had an average daily sleep duration of 6.60 hours. Additionally, they engaged in moderately active physical activity for an average of 16.20 minutes each day.

Regarding the comparison group, 51.0% of the adolescents were male, with an average age of 15.22 years. They exhibited an average weight of 54.54 kilograms, a mean height of 164.14 centimeters, and a body mass index averaging 20.14 kg/m². A substantial proportion (79.6%) had prior gaming experience, dedicating an average of 116.51 minutes daily to gaming activities. Similarly, 92.0% of them did not participate in any special classes after school. In terms of behavioral characteristics, 75.5% did not use dietary supplements, had an average daily sleep duration of 6.27 hours, and engaged in moderately intense physical activity for 15.61 minutes each day.

A comparative analysis between the intervention group and the comparison group, examining their characteristics using the Chi-square test for gender, gaming experience, tutoring, and dietary supplement consumption, and the independent t-test for age, weight, height, body mass index, sleep duration, and physical activity, revealed no significant differences at baseline (p>0.05) (Indicated in Table 4.1).

Table 4.1 The characteristics of adolescent participants (n=99)

Factors	Intervention group (n=50)	Comparison group (n=49)	*p*
Personal factors			
Gender			0.250[a]
- Male	23 (46.0%)	25 (51.0%)	
- Female	27 (54.0%)	24 (49.0%)	
Age (years)			0.456 [b]
Mean± SD	15.17±0.25	15.22±0.29	
Min, Max	15.0, 15.9	15.0, 15.9	
Weight (kilograms)			0.541 [b]
Mean± SD	56.12±12.89	54.54±12.74	
Min, Max	40, 95	33, 85	
Personal factors (Cont.)			
Hight (centimeter)			0.516 [b]
Mean± SD	163.22±5.88	164.14±8.01	
Min, Max	149, 178	145, 185	
Body mass index (kg/m^2)			0.294 [b]
Mean± SD	20.99±4.07	20.14±3.87	
Min, Max	15.04, 32.87	14.89, 29.54	
Gaming Experience (3 months previously)			0.696 [b]
- not play game	6 (12.0%)	10 (20.4%)	
- have been gaming experiences	44 (88.0%)	39 (79.6%)	
Mean± SD	107.66, 91.13	116.51, 130.02	
Min, Max	0, 300	0, 470	
Tutoring			0.781[a]
- No	46 (92.0%)	45 (91.8%)	
- Yes	4 (8.0%)	4 (8.2%)	

Table 4.1 The characteristics of adolescent participants (n=99) (Cont.)

Factors	Intervention group (n=50)	Comparison group (n=49)	*p*
Behavior factors			
Supplementary consuming (3 months previously)			0.955 [a]
- not consume	38 (76.0%)	37 (75.5%)	
- have been consuming	12 (24.0%)	12 (24.5%)	
Sleeping hour			0.168 [b]
Mean± SD	6.60±1.16	6.27±1.23	
Min, Max	4, 8	4, 8	
Physical activity			0.896[b]
Mean± SD	16.20±20.47	15.61±24.10	
Min, Max	0, 60	0, 60	

Note: [a]Chi-square test, [b]Independent t-test with the significant level set at $p < 0.05$

In this section, we analyze parental attributes in the intervention group, focusing on fathers. On average, fathers in this group were around 46.90 years old, with a majority holding sub-bachelor's degree qualifications (66.0%). Most of them (92.0%) worked in self-employed professions, mainly in agriculture, trade, and employment, with an average monthly income of 16,294.42 baht. Maternal factors showed that mothers, on average, were about 42.26 years old, with 74.0% having sub-bachelor's degree qualifications. The majority of mothers (92.0%) were also self-employed professionals, primarily in agriculture and employment, with an average monthly income of around 13,510.00 baht. Both fathers and mothers spent approximately 2.42 hours per day on activities with their adolescents.

In the comparison group, fathers averaged around 44.61 years of age, with a significant majority holding sub-bachelor's degree qualifications (71.4%). Similarly, most of them (91.8%) were self-employed professionals, primarily in agriculture, trade, and employment, with an approximate monthly income of 16,591.84 baht. Maternal factors indicated an average age of about 41.65 years, with 79.6% having sub-bachelor's degree qualifications. 91.8% of mothers in this group were self-employed professionals, particularly in agriculture and employment, with an average monthly income of about 13,877.55 baht.

Additionally, both fathers and mothers in the comparison group spent around 2.40 hours per day on activities with their adolescents.

Comparing parental factors between the intervention and comparison groups, including education, occupation, age, income, and time spent with adolescents, revealed no significant differences at baseline (p>0.05) (As demonstrated in Table 4.2).

Table 4.2 Key Characteristics of Parents of Adolescents (n=99)

Factors	Intervention group (n=50)	Comparison group (n=49)	*p*
Father's factors			
Age (years)			0.164 [a]
Mean± SD	46.90± 8.26	44.61± 7.94	
Min, Max	35, 79	33, 70	
Educational			0.339[b]
- Below a bachelor's degree	33 (66.0%)	35 (71.4%)	
- A bachelor's degree or higher	17 (34.0%)	14 (28.6%)	
Occupational			0.986[c]
- Self-employed professional	46 (92.0%)	45 (91.8%)	
- Employment with a consistent salary	4 (8.0%)	4 (8.2%)	
Income (Baht per month)			0.908 [a]
Mean± SD	16,294.42± 9632.54	16,591.84± 15342.84	
Min, Max	0, 40,000	0, 100,000	

Note: [a]Independent t-test, [b]Chi-square test, [c]Fisher exact test with the significant level set at p< 0.05

Table 4.2 Key Characteristics of Parents of Adolescents (n=99) (Cont.)

Factors	Intervention group (n=50)	Comparison group (n=49)	*p*
Mother's factors			
Age (years)			0.537 [a]
Mean± SD	42.26±6.425	41.65± 5.93	
SD., Min, Max	30, 55	33, 57	
Educational			0.434[b]
- Below a bachelor's degree	37 (74.0%)	39 (79.6%)	
- A bachelor's degree or higher	13 (26.0%)	10 (20.4%)	
Occupational			
- Self-employed professional	46 (92.0%)	45 (91.8%)	0.986[c]
- Employment with a consistent salary	4 (8.0%)	4 (8.2%)	
Income (Baht per month)			0.846[a]
Mean± SD	13,510.00± 9020.66	13,877.55±9707.45	
Min, Max	0, 40,000	0, 50,000	
Parent's time spending with adolescents (hour per day)			0.919[a]
Mean± SD	2.42±0.79	2.40±0.76	
Min, Max	1.5, 4.0	1.5, 4.5	

Note: [a]Independent t-test, [b]Chi-square test, [c]Fisher exact test with the significant level set at $p < 0.05$

4.2 Adolescent Working Memory

4.2.1 Adolescent Working Memory Assessment

In the forthcoming presentation of this study's findings, it will undertake a comprehensive examination of working memory assessment results, employing the Lucid Recall test, a well-established instrument within the domain.

This scrutiny of working memory, facilitated by the Lucid Recall test, has unveiled a multifaceted set of outcomes. This cognitive construct is comprised of three

fundamental constituents: the Phonological Loop (PL), the Visuo-Spatial Sketch Pad (VSSP), and the Central Executive (CE). Additionally, this analysis extends beyond these individual components to encompass a composite score and provides insights into the domain of processing speed.

4.2.1.1 Baseline working memory assessment

In the context of the baseline working memory assessment within the intervention group, a nuanced distribution of scores across multiple components has been observed. This distribution can be summarized as follows:

Phonological Loop (PL): Merely one participant (2.0%) exhibited a score in the very low range (less than 70), while the significant majority of 49 participants (98.0%) obtained scores within the low range. The mean baseline score for this specific subset was 75.02 (Mean± SD=75.02±4.18).

Visuo-Spatial Sketch Pad (VSSP): In parallel to the trends observed in the PL component, one participant (2.0%) registered a score in the very low range, while a substantial majority of 45 participants (90.0%) secured scores within the low range. In addition, four participants (8.0%) transitioned into the average range. The mean baseline score for VSSP was 75.56 (Mean± SD=75.56±5.07).

Central Executive (CE): Three participants (6.0%) scored in the very low range, while 46 participants (92.0%) achieved scores in the low range. Moreover, one participant (2.0%) successfully obtained a score in the average range. The mean baseline score for the CE component was 76.86 (Mean± SD=76.86±4.28).

Composite Score: At baseline, 7 participants (14.0%) scored in the very low range, 40 participants (80.0%) in the low range, and 3 participants (6.0%) in the average range. The mean baseline score for the composite component was 75.06 (Mean± SD=75.06±4.99).

Processing Speed: This particular metric evaluates the speed at which participants processed information. Merely 1 participant (2.0%) exhibited a very low score in processing speed, while 39 participants (84.0%) secured scores in the low range. Additionally, 10 participants (14.0%) operated within the average range. The mean baseline score for this processing speed component was 78.60 (Mean± SD=78.60±5.49).

Similarly, the baseline assessment conducted within the comparison group provides insight into the initial working memory landscape, showcasing the distribution of participants in a manner comparable to the baseline results of the intervention group.

Phonological Loop (PL): At baseline, a mere 2.0% of participants exhibited very low scores (less than 70) in the Phonological Loop component. The substantial majority, comprising 98.0% of participants, occupied the low score range. The mean baseline score was 74.73±3.61, indicating a predominantly low-performance scenario.

Visuo-Spatial Sketch Pad (VSSP): The Visuo-Spatial Sketch Pad, like the PL component, demonstrated minimal variability. Notably, no participants fell into the very low score range. Instead, 98.0% resided within the low score category, with just 2.0% transitioning into the average range. The mean baseline score for VSSP was 74.71±4.51.

Central Executive (CE): The baseline assessment for the Central Executive component mirrored the trends observed in PL and VSSP. No participants scored very low or low, and a significant majority (98.0%) positioned themselves in the low score range. A mere 2.0% ventured into the average range. The mean baseline score for CE was 76.29±3.75.

Composite Score: Our analysis at baseline unveiled that 14.0% of participants secured scores within the average range, while the majority (80.0%) was positioned in the low score range. The mean baseline score for the composite component was 75.82±4.61.

Processing Speed: The Processing Speed component delved into the speed at which participants processed information. At baseline, 85.9% scored in the low range, and 14.1% operated within the average range. The mean baseline score for processing speed was 79.41±4.92, positioning it on the higher end of the performance spectrum within this context.

It is paramount to recognize that the 'Working Memory Composite' serves as a comprehensive measure of general working memory functioning, amalgamating the scores of the three subtests. Furthermore, the 'Working Memory Processing Speed' metric provides a quantification of processing velocity and is derived from the Counting Recall subtest. Consequently, the baseline results highlight the mean

scores of the composite and processing speed components, both of groups fell within the low range.

This observation suggests that the assessed working memory capacity of the participants was at a lower level. Additionally, none of the composites of working memory between the intervention group and the comparison group exhibited a significant difference at baseline ($p<0.05$). (As presented in Table 4.3).

Table 4.3 Baseline of working memory assessment (n=99)

Variables	Intervention (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
Phonological loop					
- Very low score (<70 scores)	1 (2.0)	69.00±0.00	1 (2.0)	69.00±0.00	
- Low score (70-84 scores)	49 (98.0)	75.14±4.13	48 (98.0)	74.85±3.55	
Mean±SD, Min, Max (total)	75.02±4.18, 69, 82		74.73±3.61, 69, 82		0.717[a]
Visuo-Spatial Sketch Pad					
- Very low score (<70 scores)	1 (2.0)	69.00±0.00	-	-	
- Low score (70-84 scores)	45 (90.0)	74.73±3.97	48 (98.0)	74.42±4.05	
- Average range (85-115 scores)	4 (8.0)	106.05±6.98	1 (2.0)	89.00±0.00	
Mean±SD, Min, Max (total)	75.02±4.18, 69, 82		74.71±4.51, 70, 89		0.383[a]
Central Executive					
- Very low score (<70 scores)	3 (6.0)	69.00±0.00	1 (2.0)	69.00±0.00	
- Low score (70-84 scores)	46 (92.0)	77.08±3.45	48 (98.0)	76.28±3.50	
- Average range (85-115 scores)	1 (2.0)	90.00±0.00	-	84.00±0.00	
Mean±SD, Min, Max (total)	76.86±4.28, 69, 90		76.29±3.75, 69, 84		0.480[a]

Table 4.3 Baseline of working memory assessment (n=99) (Cont.)

Variables	Intervention (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
Composite					
- Very low score (<70 scores)	7 (14.0)	68.57±0.53	4 (8.1)	68.75±0.50	
- Low score (70-84 scores)	40 (80.0)	75.33±3.61	41 (83.8)	75.58±3.39	
- Average range (85-115 scores)	3 (6.0)	86.67±2.08	4 (8.1)	85.25±0.50	
Mean±SD, Min, Max (total)	75.06±4.99, 69, 89		75.06±4.99, 69, 89		0.436[a]
Processing speed					
- Very low score (<70 scores)	1 (2.0)	69.00±0.00	-	-	
- Low score (70-84 scores)	39 (84.0)	76.60±4.05	42 (85.9)	78.02±3.49	
- Average range (85-115 scores)	10 (14.0)	86.60±1.89	7 (14.1)	87.71±4.07	
Mean±SD, Min, Max (total)	78.60±5.49, 69, 89		79.41±4.92, 70, 96		0.443[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.2.1.2 Post-intervention working memory assessment (2-month)

The post-intervention data unveiled a significant transformation in the working memory components. This transition is characterized by a shift from predominantly low and low-average scores at baseline to notable improvements in the intervention group. The following outlines the scores from the working memory assessment within the intervention group:

Phonological Loop (PL): Following the intervention, none of the participants scored in the very low or low score ranges. Instead, an impressive 86.0% of participants demonstrated significant improvements. Furthermore, a smaller yet significant group (14.0%), marking a remarkable and substantial enhancement in Phonological Loop performance. This shift is underscored by a substantial increase in the mean score, which surged to 107.80 (Mean± SD=107.80±7.81).

Visuo-Spatial Sketch Pad (VSSP): In alignment with the PL, no participants scored in the very low or low score ranges post-intervention. Instead, the majority (58.0%) advanced into the average range, while a substantial portion (38.0%) achieved high scores. These shifts signify marked and significant improvements in Visuo-Spatial Sketch Pad functioning. The mean score soared to 111.82 (Mean± SD=111.82±11.65).

Central Executive (CE): Following the intervention, no participants remained in the very low or low score categories. Instead, 60.0% of participants achieved scores in the average range, while 28.0% reached high scores. This indicates a substantial and meaningful enhancement in Central Executive functioning, reflected in the elevated mean score of 112.98 (Mean± SD=112.98±11.47).

Composite Score: After the intervention, no participants scored in the very low or low score ranges. A significant majority (72.0%) achieved scores within the average range, and 20.0% reached high scores. These outcomes underscore a substantial and comprehensive improvement in working memory. The enhanced mean score of 111.40 (Mean± SD=111.40±10.56) substantiates the positive impact of the intervention on the composite working memory measure.

Processing Speed: No participants scored in the very low or low score ranges. Instead, a significant majority (62.0%) attained scores in the average range, and 30.0% achieved high scores. This indicates a notable improvement in processing speed subsequent to the intervention, supported by the mean score of 112.10 (Mean± SD=112.10±11.81).

Contrastingly, the post-intervention data within the comparison group revealed a moderate transformation in working memory components. The transition was observed from predominantly low and low-average scores at baseline to slightly improved scores post-intervention. Here were the scores for each component of working memory in the comparison group at the 2-month mark.

Phonological Loop (PL): After the intervention, a transformation occurred in the Phonological Loop component, with none of the participants scoring in the very low or low categories. Instead, 6.0% transitioned into the average range. The mean post-intervention score rose to 77.10±7.54.

Visuo-Spatial Sketch Pad (VSSP): None of the participants scored in the very

low or low categories, and 6.0% transitioned into the average range. The mean post-intervention score for VSSP was calculated at 75.59±4.86.

Central Executive (CE): No participants scored in the very low or low categories within the Central Executive component. Instead, 6.0% of participants achieved scores in the average range, and 94.0% moved into the low score range. The mean post-intervention score for CE was calculated at 78.00±5.16.

Composite Score: None of the participants scored in the very low or low categories. Instead, 6.0% achieved scores in the average range, while the majority (94.0%) fell into the low score range. The enhanced mean post-intervention score was calculated at 77.00±4.64.

Processing Speed: None of the participants scored in the very low or low categories, while 6.0% operated within the average range. Notably, 83.8% reached the low score range. The mean post-intervention score for processing speed was 80.35±5.18. (Table 4.4).

In summary, following the intervention in the intervention group, substantial improvements in working memory components were observed. The mean scores for these components increased notably. These findings highlight the effectiveness of the intervention in elevating working memory functioning among participants. Conversely, the comparison group experienced a moderate transformation in working memory components post-intervention, with some slight improvements but remaining in the low to low-average score ranges.

This contrast underscores the significant impact of the intervention on working memory enhancement in the intervention group when compared to the comparison group ($p<0.05$). (As presented in Table 4.4).

Table 4.4 Post-intervention of working memory assessment (2-month) (n=99)

Variables	Intervention (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
Phonological loop					
- Low score (70-84 scores)	-	-	46 (94.0)	75.75±3.68	
- Average range (85-115 scores)	43 (86.0)	108.16±7.46	3 (6.0)	106.50±9.19	
- High score (116-129 scores)	7 (14.0)	106.05±6.97	-	-	
Mean±SD, Min, Max (total)	107.80±7.81, 90, 120		77.10±7.54, 70, 113		<0.001[a]
Visuo-Spatial Sketch Pad					
- Low score (70-84 scores)	-	-	46 (94.0)	74.72±3.76	
- Average range (85-115 scores)	28 (58.0)	103.89±8.05	3 (6.0)	87±3.46	
- High score (116-129 scores)	18 (38.0)	121.57±3.49	-	-	
- Very high score (≥130 scores)	3 (4.0)	134.00±0.00	-	-	
Mean±SD, Min, Max (total)	111.82±11.65, 90, 134		75.59±4.86, 70, 91		<0.001[a]
Central Executive					
- Low score (70-84 scores)	-	-	46 (94.0)	77.13±3.92	
- Average range (85-115 scores)	30 (60.0)	105.40±6.67	3 (6.0)	91.33±3.06	
- High score (116-129 scores)	14 (28.0)	121.64±3.66	-	-	
- Very high score (≥130 scores)	6 (12.0)	133.00±2.19	-	-	
Mean±SD, Min, Max (total)	112.98±11.47, 95, 135		78.00±5.16, 70, 94		<0.001[a]
Composite					
- Low score (70-84 scores)	-	-	46 (94.0)	76.13±3.35	
- Average range (85-115 scores)	36 (72.0)	106.22±6.75	3 (6.0)	86.76±1.26	
- High score (116-129 scores)	10 (20.0)	121.70±3.23	-	-	
- Very high score (≥130 scores)	4 (8.0)	132.25±1.50	-	-	
Mean±SD, Min, Max (total)	111.40±10.56, 95, 134		77.00±4.64, 70, 88		<0.001[a]

Table 4.4 Post-intervention of working memory assessment (2-month) (n=99) (Cont.)

Variables	Intervention (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
Processing speed					
- Low score (70-84 scores)	-	-	41 (83.8)	78.73±3.47	
- Average range (85-115 scores)	31 (62.0)	104.48±7.62	8 (16.2)	88.63±4.68	
- High score (116-129 scores)	15 (30.0)	122.67±2.79	-	-	
- Very high score (≥130 scores)	4 (8.0)	131.50±1.29	-	-	
Mean±SD, Min, Max (total)	112.10±11.81, 92, 133		80.35±5.18, 70, 99		<0.001[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.2.1.3 A subsequent 4-month follow-up working memory assessment

The post-intervention phase showcased inspiring progress. Now, the 4-month follow-up data revealed the long-term impact and complexities of sustainability on working memory in the intervention group:

Phonological Loop (PL): Following the intervention, the Phonological Loop component exhibited a remarkable mean score of 107.80. However, at the 4-month follow-up, there was a slight decrease in the mean score to 106.28, indicating a modest decline. Nevertheless, this component's performance still shows significant improvement compared to the baseline.

Visuo-Spatial Sketch Pad (VSSP): The Visuo-Spatial Sketch Pad displayed an impressive mean score of 111.82, reflecting enhanced performance. Encouragingly, the 4-month follow-up maintained a mean score of 110.06, indicating stability in the improvements, with no significant change.

Central Executive (CE): The Central Executive component revealed a substantial post-intervention mean score of 112.98, signifying significant improvement. Impressively, the 4-month follow-up maintained this mean score at 111.60, indicating a sustained enhancement in Central Executive functioning.

Composite Score: Following the intervention, the composite working memory score boasted mean of 109.96, reflecting overall enhancement. Importantly, the 4-month follow-up retained this mean score at 109.96, indicating that the improvements in composite working memory have been consistently maintained.

Processing Speed: The mean score for processing speed post-intervention was 111.38, demonstrating a notable increase. At the 4-month follow-up, there was a slight decrease to 111.28, suggesting a minor decline in performance. However, it remains significantly improved compared to the baseline.

In summary, the intervention group exhibited remarkable improvements in working memory components post-intervention, with significant mean score increases in Phonological Loop (PL), Visuo-Spatial Sketch Pad (VSSP), Central Executive (CE), Composite Score, and Processing Speed. However, during the 4-month follow-up, there were slight declines or minor fluctuations in some of these components, but overall, the enhancements were sustained compared to baseline.

In contrast, within the comparison group, the 4-month follow-up exhibited a consistent pattern similar to the post-intervention phase. This stability was reflected in the mean scores, which displayed only minor fluctuations.

Phonological Loop (PL): At the 4-month follow-up, a similar trend was observed in the Phonological Loop component as at the post-intervention stage. None of the participants scored in the very low or low categories, with 6.0% remaining in the average range. The mean score for PL post-intervention was 77.10±7.54, which slightly increased to 77.55±7.50.

Visuo-Spatial Sketch Pad (VSSP): The 4-month follow-up results for the Visuo-Spatial Sketch Pad mirror the post-intervention phase. Again, none of the participants scored in the very low or low categories, with 6.0% in the average range. The mean score for VSSP remained consistent, measuring 75.59±4.85, highlighting the stability in this domain.

Central Executive (CE): After the 4-month interval, the Central Executive component maintained its post-intervention progress. None of the participants scored in the very low or low categories, while 6.0% remained in the average range. The mean score for CE post-intervention was 78.00, showing a slight increase to 78.04±5.31.

Composite Score: Similar to CE, the composite score exhibited stability at the 4-month follow-up. No participants scored in the very low or low categories, and 6.0% remained in the average range. The mean score for the composite score post-intervention was 77.00, and it recorded a minor increase to 77.02±4.71 at the 4-month follow-up.

Processing Speed: The Processing Speed component demonstrated resilience at the 4-month follow-up. Like the previous stages, none of the participants scored in the very low or low categories, while 6.0% remained in the average range. The mean score for processing speed post-intervention was 80.35, maintaining its high performance at 80.31±5.34 during the 4-month follow-up.

The comparison group displayed consistent patterns in Phonological Loop (PL), Visuo-Spatial Sketch Pad (VSSP), Central Executive (CE), Composite Score, and Processing Speed during both the post-intervention and 4-month follow-up phases. The minor fluctuations observed did not lead to significant changes.

To summarize, significant differences were observed in the components of working memory when comparing the intervention group and the comparison at a subsequent 4-month follow-up (*p<0.001*). (As displayed in Table 4.5).

Table 4.5 A subsequent 4-month follow-up of working memory assessment (n=99)

Variables	**Intervention (n=50)**		**Comparison group (n=49)**		***p***
	Number (%)	**Mean±SD**	**Number (%)**	**Mean±SD**	
Phonological loop					
- Low score (70-84 scores)	-	-	46 (94.0)	76.02±4.00	
- Average range (85-115 scores)	45 (90.0)	105.25±6.79	3 (6.0)	101.00±10.53	
- High score (116-129 scores)	5 (10.0)	118.40±1.34	-	-	
Mean±SD, Min, Max (total)	106.28±7.83, 91, 120		77.55±7.50, 70, 112		<0.001[a]

Table 4.5 A subsequent 4-month follow-up of working memory assessment (n=99) (Cont.)

Variables	Intervention (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
Visuo-Spatial Sketch Pad					
- Low score (70-84 scores)	-	-	46 (94.0)	74.83±3.86	
- Average range (85-115 scores)	29 (58.0)	101.75±7.42	3 (6.0)	87.33±3.21	
- High score (116-129 scores)	19 (38.0)	120.21±2.74	-	-	
- Very high score (≥130 scores)	2 (4.0)	134.00±1.00	-	-	
Mean±SD, Min, Max (total)	111.06±11.76, 90, 134		75.59±4.85, 70, 91		<0.001[a]
Central Executive					
- Low score (70-84 scores)	-	-	46 (94.0)	77.15±3.97	
- Average range (85-115 scores)	33 (66.0)	105.18±7.08	3 (6.0)	91.67±5.13	
- High score (116-129 scores)	12 (24.0)	120.5±3.37	-	-	
- Very high score (≥130 scores)	5 (10.0)	132.6±2.19	-	-	
Mean±SD, Min, Max (total)	111.60±11.31, 95, 135		78.04±5.31, 70, 96		<0.001[a]
Composite					
- Low score (70-84 scores)	-	-	46 (94.0)	76.30±3.55	
- Average range (85-115 scores)	33 (66.0)	104.78±6.63	3 (6.0)	88.00±1.00	
- High score (116-129 scores)	12 (24.0)	121.75±4.00	-	-	
- Very high score (≥130 scores)	2 (4.0)	132.50±2.12	-	-	
Mean±SD, Min, Max (total)	109.96±10.47, 95, 134		77.02±4.71, 70, 89		<0.001[a]
Processing speed					
- Low score (70-84 scores)	-	-	41 (83.8)	78.61±3.45	
- Average range (85-115 scores)	31 (62.0)	103.96±7.25	8 (16.2)	89.00±4.89	
- High score (116-129 scores)	17 (34.0)	122.41±3.26	-	-	
- Very high score (≥130 scores)	2 (4.0)	132.50±0.70	-	-	
Mean±SD, Min, Max (total)	111.38±11.44, 92, 133		80.31±5.34, 70, 100		<0.001[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.2.2 Effectiveness of the TendingPETs application on working memory

This analysis employed repeated measures ANOVA to investigate the effectiveness of the TendingPETs application on working memory performance in a study involving 99 participants, categorized into an intervention group and a comparison group at baseline, 2-month, and a subsequent 4-month follow-up. The analysis revealed several key findings, and here's the interpretation of the results:

4.2.2.1 Repeated measures ANOVA within-subjects analysis

1) Phonological loop

Time: The variation in phonological loop scores across different time points was significant. The F-statistic of 842.757 with 1.176 degrees of freedom for "Time" indicated that the working memory performance changed significantly over time, as the p-value of <0.001. This underscores the temporal effect on working memory within the entire subjects.

Intervention x Time: The interaction between intervention and time was also significant, with an F-statistic of 610.834 and 1.176 df. The p-value of <0.001 indicated that the working memory performance changes over time are influenced by the intervention. This points to the specific impact of the TendingPETs application on working memory changes over time.

Error (Within-Group Error): This component represented the variability in PL scores within the groups. The Mean Square value of 19.995 revealed the average variance within the groups.

2) Visuo-Spatial Sketch Pad

Time: The analysis of VSSP performance within subjects indicated a significant time effect. The sum of squares was 21,648.847, with a corresponding mean square of 200,017.719. The F-test yielded a significant result ($F = 562.141$, $p < 0.001$).

Intervention x Time: The interaction between the intervention and time was also found to be highly significant. The sum of squares for this interaction was 19,753.521, with a mean square of 18,265.195. The F-test statistic showed significance ($F = 512.926$, $p < 0.001$).

Error Terms (Within-Group Error): The error component, accounting for variability and measurement error within the data, had a sum of squares of 3,735.611 and a mean square of 19.955.

3) Central Executive

Time: The within-subject analysis for the Central Executive component indicated a highly significant time effect. The sum of squares attributed to time was 22,809.905, and the corresponding mean square was 21,046.399. The F-test statistic was highly significant (F = 714.986, $p < 0.001$). This finding demonstrated that CE performance significantly evolved across the time points assessed in the study.

Intervention x Time: The analysis also revealed a highly significant interaction effect between intervention and time. The sum of squares for this interaction was 18,756.733, with a mean square of 17,306.591. The F-test statistic was highly significant (F= 587.937, $p < 0.001$).

Error Terms (Within-Group Error): The error component in the within-group analysis, which accounts for variance and discrepancies between individual data points, had a sum of squares of 3,094.533 and a mean square of 35.610.

4) Composite

Time: The within-subjects analysis for the composite component showed highly significant changes over time. The sum of squares attributed to time was 22,384.471, and the corresponding mean square was 20,228.193. The F-test statistic was highly significant (F = 839.599, $p < 0.001$).

Intervention x Time: The within-subjects analysis also indicated a highly significant interaction effect between the intervention and time. The sum of squares attributed to this interaction was 19,579.501, and the corresponding mean square was 17,693.424. The F-test statistic was highly significant (F= 734.390, $p < 0.001$).

Error Terms (Within-Group Error): The error component in the within-subjects analysis, accounting for variance and discrepancies within each participant's data points, had a sum of squares of 2,586.109 and a mean square of 24.093.

5) Processing speed

Time: The within-subjects analysis for the processing speed component unveiled a substantial time effect. The sum of squares attributed to time was 19,144.754, with a corresponding mean square of 18,747.538. The F-test statistic was highly significant (F= 479.262, $p < 0.001$).

Intervention x Time: Additionally, the interaction between the intervention and time yielded significant results. The sum of squares for this interaction was 17,134.815, with a mean square of 16,779.301. The F-test statistic was also highly significant ($F = 428.946$, $p < 0.001$).

Error Terms (Within-Group Error): The error component in the within-subjects analysis, representing unexplained variance within each group, had a sum of squares of 3,874.795 and a mean square of 39.118. (Demonstrated in Table 4.6).

In summary, the repeated measures ANOVA demonstrated that the TendingPETs intervention had a favorable and statistically significant influence on several working memory components within the intervention group over time. These findings underscored the effectiveness of the intervention in improving working memory performance.

4.2.2.2 Repeated measures ANOVA between-subjects analysis

1) Phonological loop

Intervention: There was a significant main effect of intervention on working memory scores. The F-statistic of 20,215.651 with 1 df and a $p < 0.001$ demonstrated that there were substantial differences in working memory between the intervention and comparison groups. This highlights the overall impact of the TendingPETs application on working memory.

Error (Between-Group Error): This component represented the variance between the groups. The Mean Square value of 109.698 represented the average variance between the intervention and comparison groups.

2) Visuo-Spatial Sketch Pad

Intervention: The analysis of VSSP performance between subjects revealed a significant intervention effect. The sum of squares attributed to the intervention was 42,366.019, and the corresponding mean square was 42,366.019. The F-test statistic was found to be highly significant ($F = 290.487$, $p < 0.001$).

Error Terms (Between-Group Error): The error component in the between-group analysis, which accounts for variance and discrepancies between individual data points, had a sum of squares of 14,146.950 and a mean square of 145.845.

3) Central Executive

Intervention: The between-subject analysis for the Central Executive component indicated a significant intervention effect. The sum of squares attributed to the intervention was 39,403.520, and the corresponding mean square was 39,403.520. The F-test statistic was highly significant ($F = 276.359$, $p < 0.001$).

Error Terms (Between-Group Error): The error component in the between-group analysis, which accounts for variance and discrepancies between individual data points within each group, had a sum of squares of 13,830.365 and a mean square of 142.581.

4) Composite

Intervention: The between-subjects analysis for the composite score component revealed a highly significant effect of the intervention. The sum of squares attributed to the intervention was 36,571.251, and the corresponding mean square was 36,571.251. The F-test statistic was highly significant ($F = 281.653$, $p < 0.001$).

Error Terms (Between-Group Error): The error component in the between-subjects analysis, representing unexplained variance within each group, had a sum of squares of 12,594.958 and a mean square of 129.845.

5) Processing speed

Intervention: The between-subjects analysis focusing on the impact of the intervention revealed significant findings. The sum of squares attributed to the intervention was 31,728.973, and the corresponding mean square was 31,728.973. The F-test statistic was significant ($F = 281.653$, $p < 0.001$).

Error Terms (Between-Group Error): The error component in the between-subjects analysis, which reflects unexplained variance between the groups, had a sum of squares of 14,668.832 and a mean square of 151.225 (Demonstrated in Table 4.6).

In summary, the between-subjects analysis using repeated measures ANOVA demonstrated a significant main effect of the TendingPETs intervention on various working memory components. This impact was evident across the Phonological Loop, Visuo-Spatial Sketch Pad, Central Executive, Composite Score, and Processing Speed. The highly significant findings emphasize the effectiveness of the TendingPETs application in positively influencing working memory in the

intervention group. These results hold substantial importance, suggesting the potential of the intervention to enhance working memory in practical applications and educational contexts.

Table 4.6 An analysis of working memory performance by repeated measures ANOVA between the intervention group and the comparison group (n=99)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Phonological loop					
Within subjects					
Time	19,778.834	1.176	16,817.424	842.757	<0.001*
Intervention x time	14,335.791	1.176	12,189.346	610.834	<0.001*
Error (within-group error)	2276.512	114.081	19.995		
Between subjects					
Intervention	29,412.804	1	29,412.804	20,215.651	<0.001*
Error (between-group error)	10,640.711	97	109.698		
Visuo-Spatial Sketch Pad					
Within subjects					
Time	21,648.847	1.081	20,0017.719	562.141	<0.001*
Intervention x time	19,753.521	1.081	18,265.195	512.926	<0.001*
Error (within-group error)	3,735.611	114.081	19.955		
Between subjects					
Intervention	42,366.019	1	42,366.019	290.487	<0.001*
Error (between-group error)	14,146.950	97	145.845		
Central Executive					
Within subjects					
Time	22,809.905	1.084	21,046.399	714.986	<0.001*
Intervention x time	18,756.733	1.084	17,306.591	587.937	<0.001*
Error (within-group error)	3,094.533	105.128	35.610		
Between subjects					
Intervention	39,403.520	1	39,403.520	276.359	<0.001*
Error (between-group error)	13,830.365	97	142.581		

Table 4.6 An analysis of working memory performance by repeated measures ANOVA between the intervention group and the comparison group (n=99) (Cont.)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Composite					
Within subjects					
Time	22,384.471	1.107	20,228.193	839.599	<0.001*
Intervention x time	19,579.501	1.107	17,693.424	734.390	<0.001*
Error (within-group error)	2,586.109	107.340	24.093		
Between subjects					
Intervention	36,571.251	1	36,571.251	281.653	<0.001*
Error (between-group error)	12,594.958	97	129.845		
Processing speed					
Within subjects					
Time	19,144.754	1.021	18,747.538	479.262	<0.001*
Intervention x time	17,134.815	1.021	16,779.301	428.946	<0.001*
Error (within-group error)	3,874.795	99.055	39.118		
Between subjects					
Intervention	31,728.973	1	31,728.973	281.653	<0.001*
Error (between-group error)	14,668.832	97	151.225		

Note: significant at 0.05 level.

4.2.2.3 Pairwise comparison of the difference measurement of working memory between the intervention group and the comparison group

Additionally, there was an interpretation of the pairwise comparison results for working memory performance between the intervention group and the comparison group:

1) Phonological Loop

Baseline: There is no significant difference in the mean performance of the Phonological Loop between the intervention and comparison groups ($p = 0.717$). The 95% confidence interval for the difference spans from -1.273 to 1.844.

Post-intervention: A significant difference is observed in the mean performance of the Phonological Loop between the intervention and comparison groups ($p < 0.001$). The mean difference is 30.698, with a 95% confidence

interval ranging from 27.633 to 33.763. This indicated a substantial improvement in the intervention group compared to the comparison group.

4-month follow-up: Similar to the post-intervention results, a significant difference is found in the mean performance of the Phonological Loop between the intervention and comparison groups ($p< 0.001$). The mean difference is 28.729, with a 95% confidence interval between 25.668 and 31.790. This further confirmed the sustained enhancement in the intervention group compared to the comparison group.

2) Visuo-Spatial Sketch Pad

Baseline: The mean difference in performance of the Visuo-Spatial Sketch Pad between the intervention and comparison groups was 0.846, but it was not statistically significant ($p= 0.383$). The 95% confidence interval for the difference ranges from -1.071 to 2.762.

Post-intervention: A significant difference is observed in the mean performance of the Visuo-Spatial Sketch Pad between the intervention and comparison groups ($p< 0.001$). The mean difference is 36.351, with a 95% confidence interval from 32.788 to 39.913. This indicated a substantial improvement in the intervention group compared to the comparison group.

4-month follow-up: A highly significant difference is found in the mean performance of the Visuo-Spatial Sketch Pad between the intervention and comparison groups ($p< 0.001$). The mean difference is 34.468, with a 95% confidence interval between 30.865 and 38.071. This further confirms the sustained enhancement in the intervention group compared to the comparison group.

3) Central Executive

Baseline: The mean difference in Central Executive performance between the intervention and comparison groups was 0.574, and this difference was not statistically significant ($p= 0.480$). The 95% confidence interval for the difference ranges from -1.033 to 2.181. At baseline, there was no significant difference in Central Executive performance between the two groups.

Post-intervention: In contrast, after the intervention, there was a highly significant difference in the mean Central Executive performance between the

intervention and comparison groups ($p< 0.001$). The mean difference is 34.980, with a 95% confidence interval from 31.418 to 38.542.

4-month follow-up: The 4-month follow-up shows results similar to the post-intervention findings. There is a highly significant difference in Central Executive performance between the intervention and comparison groups ($p<0.001$). The mean difference was 33.559, and the 95% confidence interval ranges from 30.023 to 37.095.

4) Composite

Baseline: there was no significant difference in the mean Composite scores between the intervention and comparison groups. The mean difference is -0.756, and the p-value is 0.436. The 95% confidence interval for the difference spans from -2.674 to 1.162, indicating that the groups had similar composite scores initially.

Post-Intervention: A substantial and statistically significant difference in the mean composite scores was observed between the intervention and comparison groups ($p< 0.001$). The mean difference is 34.400, with a 95% confidence interval ranging from 31.135 to 37.665. This indicated an improvement in general working memory function in the intervention group compared to the comparison group after the intervention.

4-Month Follow-Up: There remained a significant difference in the mean composite scores between the intervention and comparison groups ($p< 0.001$). The mean difference was 32.940, and the 95% confidence interval fallen between 29.688 and 36.191. This suggested that the improvement in general working memory function in the intervention group appears not only statistically significant but also appears to be maintained over the 4-month follow-up period.

5) Processing speed

Baseline: the difference in mean processing speed between the intervention and comparison groups was -0.808, with a standard error (SE) of 1.048. The p-value was 0.443, indicating that this difference was not statistically significant. The 95% confidence interval for the mean difference spans from -2.889 to 1.272. These results suggested that there was no significant distinction in processing speed between the two groups before the intervention.

Post-Intervention: Following the intervention, there appeared to be a notable change in the mean processing speed between the intervention and comparison groups, with a mean difference of 31.753. The p-value was significant, less than 0.001, suggesting the presence of a noteworthy difference. The 95% confidence interval for the mean difference ranges from 28.101 to 35.405. These results tentatively indicated a substantial enhancement in the speed of processing of working memory in the intervention group compared to the comparison group following the intervention.

4-Month Follow-Up: The findings at the 4-month follow-up exhibited a pattern consistent with the post-intervention phase. There seem to be a notable difference in mean processing speed between the intervention and comparison groups, with a mean difference of 31.074. The p-value remains significant, less than 0.001. The 95% confidence interval for the mean difference extends from 27.501 to 34.647. This cautiously suggested that the enhancements in the speed of processing of working memory observed in the intervention group continue to be significant and were seemingly maintained over the 4-month follow-up period (Represented in Table 4.7).

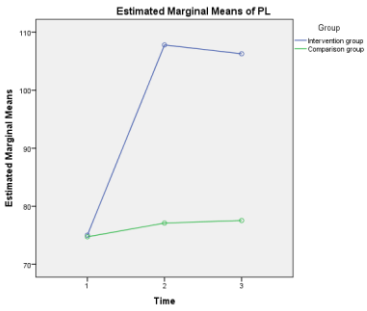
Table 4.7 Pairwise comparison of the difference measurement of working memory performance between the intervention group and the comparison group (n=99)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Phonological loop							
Baseline	Intervention	Comparison	0.285	0.558	0.717	-1.273	1.844
Post-intervention	Intervention	Comparison	30.698	1.545	<0.001*	27.633	33.763
4-month follow-up	Intervention	Comparison	28.729	1.542	<0.001*	25.668	31.790
Visuo-Spatial Sketch Pad							
Baseline	Intervention	Comparison	0.846	0.966	0.383	-1.071	2.762
Post-intervention	Intervention	Comparison	36.351	1.795	<0.001*	32.788	39.913
4-month follow up	Intervention	Comparison	34.468	1.815	<0.001*	30.865	38.071

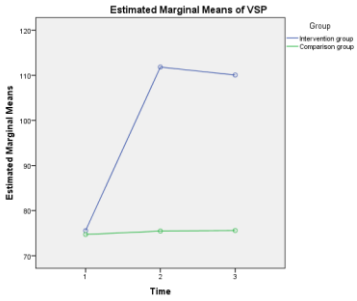
Table 4.7 Pairwise comparison of the difference measurement of working memory performance between the intervention group and the comparison group (n=99) (Cont.)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Central Executive							
Baseline	Intervention	Comparison	0.574	0.810	0.480	-1.033	2.181
Post-intervention	Intervention	Comparison	34.980	1.795	<0.001*	31.418	38.542
4-month follow up	Intervention	Comparison	33.559	1.782	<0.001*	30.023	37.095
Composite							
Baseline	Intervention	Comparison	-0.756	0.966	0.436	-2.674	1.162
Post-intervention	Intervention	Comparison	34.400	1.645	<0.001*	31.135	37.665
4-month follow up	Intervention	Comparison	32.940	1.638	<0.001*	29.688	36.191
Processing speed							
Baseline	Intervention	Comparison	-0.808	1.048	0.443	-2.889	1.272
Post-intervention	Intervention	Comparison	31.753	1.840	<0.001*	28.101	35.405
4-month follow up	Intervention	Comparison	31.074	1.800	<0.001*	27.501	34.647

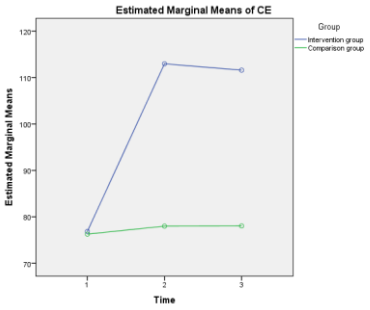
Note: [a]Adjustment for multiple comparisons: Bonferroni, significant level at 0.05.



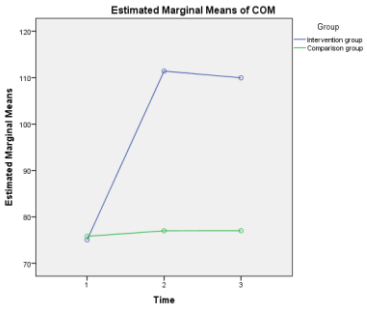
(a) Phonological loop



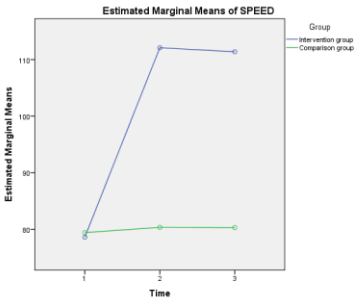
(b) [b]Visuo-Spatial Sketch Pad



(c) Central Executive



(d) Composite score



(e) Processing speed

Figure 4.1 Estimated marginal means of working memory

In summary, the pairwise comparisons consistently indicated that the intervention group exhibited notable improvements in working memory components compared to the comparison group. These improvements were not only significant immediately after the intervention but were also sustained and even enhanced during the 4-month follow-up period. These results underscored the profound and lasting effects of the intervention on various facets of working memory function.

4.3 Adolescents Academic Performance

This study examined how the TendingPETs application influences adolescent academic performance in Mathematics and English.

In the following sections, the researcher presented the results of study, shedding light on how the TendingPETs application influenced the academic performance of adolescents in these key subjects.

4.3.1 Adolescent Mathematics Performance

4.3.1.1 Adolescent Mathematics Performance Assessment

Mathematics performance was evaluated under the 9th-grade curriculum using the Programme for International Student Assessment (PISA) developed by the Organization for Economic Co-operation and Development (OECD).

In the intervention group, the initial evaluation of mathematics performance revealed a mean score of 4.80, accompanied by a standard deviation (S.D) of 1.81. Subsequent assessments conducted at the two-month interval unveiled a substantial improvement, with the mean score rising to 11.52 and a notably increased S.D of 4.98. Importantly, this enhanced performance was found to persist at the four-month follow-up, where the mean score remained notably elevated at 9.54, thus affirming the enduring positive impact of the intervention over the study's duration.

Conversely, the outcomes within the comparison group portrayed an initial mean mathematics score of 4.29, coupled with an S.D of 1.69. After the passage of two months, the mean score exhibited some improvement, ascending to 5.49, accompanied by an S.D of 3.14. While this improvement was retained at the four-month follow-up, with the mean score remaining stable at 5.14, it is important to note that this enhancement was of a lesser magnitude compared to the intervention group (Table 4.8).

Table 4.8 Assessment of score Mathematics performance in adolescents (n=99)

Measurement	Intervention group (n=50)	Comparison group (n=49)	*p*
Baseline			
Mean± SD, Min, Max	4.80±1.81, 1, 9	4.29±1.69, 0, 7	0.149[a]
Post-intervention (After 2-month)			
Mean± SD, Min, Max	11.52±4.98, 3, 18	5.49±3.14, 1, 18	<0.001[a]
A subsequent 4-month follow-up			
Mean± SD, Min, Max	9.54±4.95, 2, 17	5.14±2.85, 1, 16	<0.001[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.3.1.2 Effectiveness of TendingPETs application on Mathematics performance among adolescents

The repeated measures ANOVA for Mathematics performance revealed a significant effect within and between subjects and due to the interaction between the intervention and time.

1) Repeated measures ANOVA within-subjects analysis

Within subjects, researcher observed a substantial sum of squares (821.069) with 1.314 degrees of freedom, resulting in a mean square of 625.057. The F-test statistic of 98.498 associated with this component was significant, as indicated by the p-value of less than 0.001. This suggested that academic performance in mathematics significantly varied across different time points.

The interaction between intervention and time also showed a significant effect, with a sum of squares of 397.352, 1.314 degrees of freedom, and a mean square of 302.493. The F-test statistic for this interaction was 47.668, and the associated p-value was less than 0.001, indicating that the intervention had a significant impact on the changes in mathematics performance over time.

In contrast, the within-group error sum of squares was 808.580, with 127.418 degrees of freedom, resulting in a mean square of 6.346. This component served as the error term in the analysis, capturing the unexplained variance.

2) Repeated measures ANOVA between-subjects analysis

The sum of squares for the intervention factor was 987.584, with 1 degree of freedom, resulting in a mean square of 987.584. The F-test statistic associated with this component was 34.551, and the p-value was less than 0.001, indicating a highly significant effect. This suggested that there were significant differences in mathematics performance between the intervention and comparison groups.

Conversely, the between-group error sum of squares was 2,772.564, with 97 degrees of freedom, leading to a mean square of 28.583. This component represented the unexplained variance between individual participants in the study. (Table 4.9)

Table 4.9 An analysis of Mathematics performance by repeated measures ANOVA between the intervention group and the comparison group (n=99)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Within subjects					
Time	821.069	1.314	625.057	98.498	<0.001*
Intervention x time	397.352	1.314	302.493	47.668	<0.001*
Error (within-group error)	808.580	127.418	6.346		
Between subjects					
Intervention	987.584	1	987.584	34.551	<0.001*
Error (between-group error)	2,772.564	97	28.583		

Note: significant at 0.05 level.

3) Pairwise comparison of the difference measurement of Mathematics performance between the intervention group and the comparison group

In the context of Mathematics performance, the pairwise comparisons between the intervention group and the comparison group were as follows:

Baseline: The mean difference in Mathematics Performance between the intervention and comparison groups was 0.514, with a standard error (SE) of 0.354. The p-value for this comparison was 0.149, suggesting that the difference was not statistically significant. The 95% confidence interval for the mean difference ranges from -0.187 to 1.216.

Post-Intervention: At the post-intervention phase, the intervention group exhibited a mean difference of 6.030 in Mathematics performance compared to the comparison group, with a SE of 0.839. The p-value was significant, less than 0.001. The 95% confidence interval for the mean difference lied between 4.365 and 7.696, emphasizing the significant improvement in Mathematics performance within the intervention group.

4-Month Follow-Up: The results at the 4-month follow-up demonstrated that the intervention group maintains a significant difference in Mathematics performance compared to the comparison group. The mean difference was 4.397, with a SE of 0.814, and the p-value remains highly significant, less than 0.001. The 95% confidence interval for the mean difference spans from 2.782 to 6.013, further

underlining the sustained and significant improvement in Mathematics performance within the intervention group. (Table 4.10)

Table 4.10 Pairwise comparison of the difference measurement of Mathematics performance between the intervention group and the comparison group (n=99)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Baseline	Intervention	Comparison	0.514	0.354	0.149	-0.187	1.216
Post-intervention	Intervention	Comparison	6.030	0.839	<0.001*	4.365	7.696
4-month follow up	Intervention	Comparison	4.397	0.814	<0.001*	2.782	6.013

Note: [a]Adjustment for multiple comparisons: Bonferroni, significant level at 0.05.

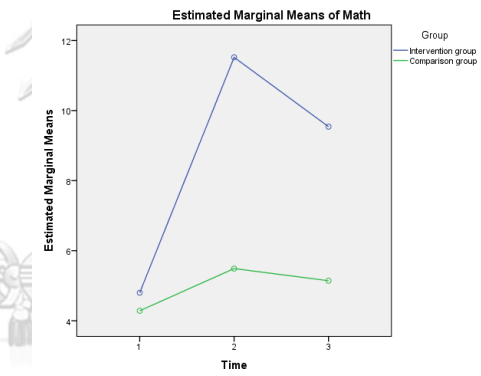


Figure 4.2 Estimated marginal means of Mathematics performance

In summary, the results suggest that the TendingPETs intervention had a significant impact on mathematics performance in adolescents over time. Within-subjects analysis showed variations in performance across different time points, and the interaction effect emphasized the intervention's influence on these changes. The between-subjects analysis highlighted significant differences in mathematics performance between the intervention and comparison groups, underlining the effectiveness of the intervention in enhancing mathematics skills among adolescents.

4.3.2 Adolescent English Performance

In the subsequent sections, we will undertake a comprehensive analysis of the results, offering insights into the performance of adolescents based on the English test specifications formulated by the Basic Education Commission.

4.3.2.1 Adolescent English Performance Assessment

Within the Intervention group, the initial evaluation unveiled a mean English score of 6.40, coupled with a standard deviation (S.D) of 1.95. Following a two-month period, a substantial and statistically significant improvement emerged, manifesting as a noteworthy escalation in the mean score to 15.08, accompanied by an S.D of 3.17. This remarkable ascent underscores a substantial augmentation in English proficiency, directly attributable to the implemented intervention. Furthermore, upon conducting a four-month follow-up, the mean score remained conspicuously elevated at 13.96, affirming the enduring efficacy of the intervention.

In contrast, the comparison group exhibited an initial mean English score of 6.51, along with an S.D of 2.47. After the passage of two months, a discernible but less pronounced improvement materialized, reflected in a mean score of 9.22, accompanied by an S.D of 4.28. While this improvement is noteworthy, it fell short of attaining the same level of statistical significance observed within the intervention group. Upon reaching the four-month follow-up stage, the mean score exhibited stability at 8.37, providing evidence of the persistence of the observed improvement over time (Table 4.11).

Table 4.11 Assessment of score English performance in adolescents (n=99)

Measurement	Intervention group (n=50)	Comparison group (n=49)	*p*
Baseline			
Mean± SD, Min, Max	6.40±1.95, 2, 10	6.51±2.47, 2, 10	0.806 [a]
Post-intervention (After 2-month)			
Mean± SD, Min, Max	15.08±3.17, 5, 20	9.22±4.28, 2, 20	<0.001[a]
A subsequent 4-month follow-up			
Mean± SD, Min, Max	13.96±3.61, 5, 20	8.37±4.51, 2, 20	<0.001[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.3.2.2 Effectiveness of TendingPETs application on English performance among adolescents

1) Repeated measures ANOVA within-subjects analysis

In the context of within-subjects analysis, the sum of squares associated with the "Time" factor amounted to 1,834.789, featuring 1.207 degrees of freedom, which led to a mean square of 1,520.170. The F-test statistic related to this factor registered at 325.072, and the p-value was less than 0.001, signifying a highly significant effect of time. These findings indicate that English academic performance underwent significant changes during the study period.

Furthermore, the interaction denoted as "Intervention x Time" also displayed a noteworthy impact. The sum of squares for this interaction equaled 562.439, with 1.207 degrees of freedom, resulting in a mean square of 465.995. The F-test statistic corresponding to this factor was 99.648, and the p-value was less than 0.001. These results suggest that the intervention exerted a significant influence on the alterations in English performance over time.

In contrast, the sum of squares for the within-group error was 547.493, with 117.075 degrees of freedom, resulting in a mean square of 4.676. This component encapsulated the unexplained variance among individual participants.

2) Repeated measures ANOVA between-subjects analysis

In the context of between-subjects analysis, the sum of squares attributed to the "Intervention" factor amounted to 1,060.424, featuring 1 degree of freedom, resulting in a mean square of 1,060.424. The F-test statistic associated with this factor registered at 35.223, and the p-value was less than 0.001, signifying a highly significant effect of the intervention. These findings indicate that the intervention had a significant impact on English academic performance compared to the comparison group.

In contrast, the sum of squares for the between-group error was 2,920.270, with 97 degrees of freedom, leading to a mean square of 30.106. This component represented the unexplained variance between the groups of participants (As mentioned in Table 4.12).

Table 4.12 An analysis of English performance by repeated measures ANOVA between the intervention group and the comparison group (n=99)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Within subjects					
Time	1,834.789	1.207	1520.170	325.072	<0.001*
Intervention x time	562.439	1.207	465.995	99.648	<0.001*
Error (within-group error)	547.493	117.075	4.676		
Between subjects					
Intervention	1,060.424	1	1,060.424	35.223	<0.001*
Error (between-group error)	2,920.270	97	30.106		

Note: significant level at 0.05.

3) Pairwise comparison of the difference measurement of English performance between the intervention group and the comparison group

Baseline: The mean difference in English performance between the intervention and comparison groups was -0.110, with a standard error (SE) of 0.447. The p-value for this comparison was 0.806, indicating a lack of statistical significance. The 95% confidence interval for the mean difference extended from -0.998 to 0.778.

Post-Intervention: Following the intervention, the intervention group showcased a significant mean difference of 5.856 in English performance compared to the comparison group, with a SE of 0.756. The p-value was highly significant, less than 0.001. The 95% confidence interval for the mean difference ranges from 4.355 to 7.356, underscoring a marked improvement in English performance within the intervention group.

4-Month Follow-Up: The results at the 4-month follow-up mirror the post-intervention findings. The intervention group maintains a significant mean difference of 5.593 in English performance compared to the comparison group. The SE was 0.820, and the p-value remains highly significant, less than 0.001. The 95% confidence interval for the mean difference spans from 3.965 to 7.221, reaffirming the sustained and significant improvement in English performance within the intervention group. (Table 4.13)

Table 4.13 Pairwise comparison of the difference measurement of English performance between the intervention group and the comparison group (n=99)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Baseline	Intervention	Comparison	-0.110	0.447	0.806	-0.998	0.778
Post-intervention	Intervention	Comparison	5.856	0.756	<0.001*	4.355	7.356
4-month follow up	Intervention	Comparison	5.593	0.820	<0.001*	3.965	7.221

Note: [a]Adjustment for multiple comparisons: Bonferroni, significant level at 0.05.

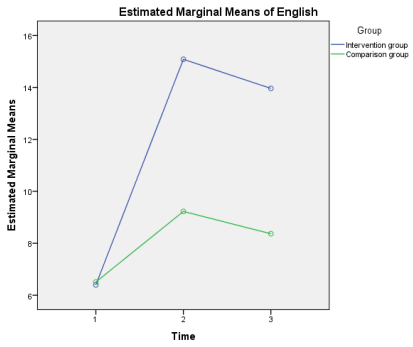


Figure 4.3 Estimated marginal means of English performance

In summary, the findings suggest that initially, at the baseline, there was no statistically significant disparity in English performance between the intervention and comparison groups. Nevertheless, subsequent to the intervention, a substantial and notably significant enhancement in English performance was observed within the intervention group when compared to the comparison group. This improvement persisted and was consistent at the 4-month follow-up, thus underscoring the efficacy of the intervention in augmenting English proficiency among adolescents.

4.4 Adolescent Risk Behaviors

In the following sections, researcher conduct a comprehensive analysis of risk behaviors among adolescents in researcher study, focusing on alcohol and tobacco use. By utilizing the ASSIST tool at three time points (baseline, post-intervention at 2 months, and the subsequent 4-month follow-up).

4.4.1 Adolescent Risk Behavior in Tobacco Products

4.4.1.1 Assessment of Adolescent Risk Behavior in Tobacco Products

1) Assessment of adolescent risk behavior in Tobacco Products at baseline

At the baseline assessment, the majority of participants (76.0%) in the intervention group exhibited low-risk behaviors in tobacco product use. This initial prevalence of low-risk behavior is indicative of a commendable level of risk aversion among the majority of participants. Conversely, 24.0% of the adolescents were classified as moderate risk in tobacco product use at baseline, reflecting a degree of risk behavior. The mean score for this group was 1.92, which signifies a relatively low but non-negligible level of risk behavior.

While the results of the comparison group revealed a substantial majority of participants (76.0%) in the comparison group displayed low-risk behaviors in tobacco product use at the baseline assessment. This initial observation highlights a commendable level of risk aversion among the majority of the participants within this group. In contrast, 23.0% of the adolescents were categorized as demonstrating moderate risk behaviors associated with tobacco product use at baseline. The mean score for this moderate-risk subgroup was 1.92, indicating a relatively low but non-negligible level of risk behavior. Furthermore, a small proportion of adolescents (1.0%) were identified as belonging to the high-risk group. Although this is a minor percentage, it is an essential aspect that warrants careful monitoring and focused attention. (Table 4.14).

Table 4.14 Baseline of Tobacco products use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–1 score)	38 (76.0)	0±0.00	38 (76.0)	0±0.00	
- Moderate risk (2–11 score)	12 (24.0)	8.00±2.86	10 (23.0)	7.64±4.13	
- High risk (12 score or above)	-	-	1 (1.0)		
Mean±SD (total), Min, Max	1.92±3.70, 0, 11		1.71±3.63, 0, 16		0.781[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

2) Assessment of adolescent risk behavior in Tobacco Products at post-intervention (After 2-month)

Upon closer examination of the data following the 2-month period within the intervention group, a notable trend emerged. The percentage of adolescents classified as exhibiting moderate-risk behavior in relation to tobacco products decreased to 20.0%. This decline in moderate-risk behaviors, occurring within a relatively short two-month interval, signifies a positive impact associated with the intervention. Furthermore, the mean score for this group exhibited a notable decrease to 0.94, indicating a significant reduction in risk behavior concerning the use of tobacco products.

Conversely, the results obtained from the comparison group revealed an intriguing trend. The percentage of adolescents classified under the moderate-risk behavior category concerning tobacco products exhibited a slight decrease to 20.4%. This reduction in moderate-risk behaviors is an important observation, signifying some influence on risk behavior. Moreover, the mean score for this group also displayed a slight decrease to 1.35. (Table 4.15)

Table 4.15 Post intervention of Tobacco Products use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–1 score)	40 (80.0)	0±0.00	39 (79.6.0)	0±0.00	
- Moderate risk (2–11 score)	10 (20.0)	4.70±2.90	10 (20.4)	6.60±2.76	
Mean±SD (total), Min, Max	0.94±2.26, 0, 11		1.35±2.94, 0, 11		0.442

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

3) Assessment of adolescent risk behavior in Tobacco Products at a subsequent 4-month follow-up

The data collected at the 4-month follow-up provided further insight into the situation. During this phase, the percentage of adolescents classified as exhibiting moderate-risk behavior decreased to 16.0%, and their mean score dropped to 0.68. This substantial reduction in moderate-risk behavior over the study period

underscores the intervention's sustained impact on mitigating risk behaviors related to tobacco product use.

The 4-month follow-up data revealed consistency in the observed patterns. At this stage, the percentage of adolescents within the moderate-risk category remained similar to the levels observed at the 2-month mark. This stability suggests that the impact observed at the 2-month follow-up was maintained over the subsequent 4-month period (Table 4.16).

Table 4.16 A subsequent 4-month follow-up of Tobacco products use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–1 score)	42 (84.0%)	0±0.00	39 (79.6.0%)	0±0.00	
- Moderate risk (2–11 score)	8 (16.0%)	4.25±2.96	10 (20.4%)	6.40±2.95	
Mean±SD (total), Min, Max	0.68±1.93, 0, 11		1.31±2.90, 0, 11		0.211[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.3.2.2 Effectiveness of TendingPETs application on Tobacco Products use among adolescents

The analysis of risk behaviors, specifically focusing on the use of tobacco products group at baseline, 2-month, and a subsequent 4-month follow-up revealed intriguing insights.

1) Repeated measures ANOVA within-subjects analysis

Within subjects, the sum of squares for the "Time" factor was 38.130, with 1.091 degrees of freedom, leading to a mean square of 34.959. The F-test statistic associated with this factor was 14.469, and the p-value was highly significant, less than 0.001. This indicates a substantial effect of time on the use of tobacco products, reflecting significant changes over the course of the study.

On the other hand, the "Intervention x Time" interaction exhibited a mean square of 8.435, with 1.091 degrees of freedom. However, the F-test statistic for this factor was 3.491, and the p-value was 0.061. While the p-value is not less than 0.05, suggesting a lack of significance, the interaction effect is still worth noting due to its

potential relevance in the context of tobacco products use, even though it did not reach conventional levels of statistical significance.

The within-group error sum of squares was 255.621, with 105.798 degrees of freedom, resulting in a mean square of 2.416. This component represents the unexplained variance within individual participants.

2) Repeated measures ANOVA between-subjects analysis

The sum of squares for the "Intervention" factor was 5.647, with 1 degree of freedom, resulting in a mean square of 5.647. The F-test statistic associated with this factor was 0.238, and the p-value was 0.627. This indicates that the intervention did not have a significant effect on tobacco product use, as the p-value is notably greater than the conventional threshold of 0.05.

Conversely, the between-group error sum of squares amounted to 2,303.269, with 97 degrees of freedom, resulting in a mean square of 23.745. This component accounts for the unexplained variance between individual participants.

In summary, the intervention did not produce a significant impact on the use of tobacco products, as indicated by the non-significant p-value. (Table 4.17)

Table 4.17 An analysis of Tobacco products use by repeated measures ANOVA between the intervention group and the comparison group (n=99)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Within subjects					
Time	38.130	1.091	34.959	14.469	<0.001*
Intervention x time	9.201	1.091	8.435	3.491	0.061
Error (within-group error)	255.621	105.798	2.416		
Between subjects					
Intervention	5.647	1	5.647	0.238	0.627
Error (between-group error)	2,303.269	97	23.745		

Note: significant level at 0.05.

3) Pairwise comparison of the difference measurement of Tobacco products use between the intervention group and the comparison group

Table 4.18 presented the pairwise comparisons of the difference in tobacco product use between the intervention group and the comparison group. The results indicate the following:

Baseline: The mean difference in tobacco product use between the intervention and comparison groups was 0.206, with a standard error (SE) of 0.738. The p-value for this comparison was 0.781, suggesting that there was no statistically significant difference in tobacco product use between the two groups at the baseline. The 95% confidence interval for the mean difference ranged from -1.258 to 1.669.

Post-Intervention: At the post-intervention phase, the mean difference decreased to -0.407, with a SE of 0.527. However, the p-value remained non-significant at 0.442, indicating that there was no statistically significant difference in tobacco product use between the intervention and comparison groups immediately after the intervention. The 95% confidence interval for the mean difference extended from -1.452 to 0.638.

4-Month Follow-Up: The mean difference further decreased to -0.626 at the 4-month follow-up, with a SE of 0.495. While the p-value (0.209) suggested a slightly non-significant trend, the result remains inconclusive, indicating that there was no clear statistically significant difference in tobacco product use between the intervention and comparison groups at this follow-up point. The 95% confidence interval for the mean difference ranged from -1.608 to 0.356.

Table 4.18 Pairwise comparison of the difference measurement of Tobacco products use between the intervention group and the comparison group (n=99)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Tobacco products use							
Baseline	Intervention	Comparison	0.206	0.738	0.781	-1.258	1.669
Post-intervention	Intervention	Comparison	-0.407	0.527	0.442	-1.452	0.638
4-month follow up	Intervention	Comparison	-0.626	0.495	0.209	-1.608	0.356

Note: [a]Adjustment for multiple comparisons: Bonferroni, significant level at 0.05.

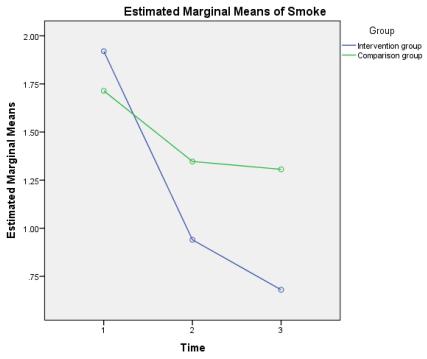


Figure 4.4 Estimated Marginal Means of Tobacco product use

In summary, the comparisons for tobacco product use between the intervention and comparison groups did not reveal any statistically significant differences at any of the assessed time points, including baseline, post-intervention, and the 4-month follow-up. The trends in tobacco product use appeared to be similar between the two groups during the course of the study.

4.4.2 Adolescent Risk Behavior in Alcoholic beverages

4.4.2.1 Assessment of Adolescent Risk Behavior in Alcoholic beverages

1) Assessment of adolescent risk behavior in Alcoholic beverages at baseline

During the baseline assessment, a significant majority of participants (74.0%) within the intervention group demonstrated behaviors associated with low-risk alcohol consumption. In contrast, 26.0% of the adolescents exhibited behaviors classified as moderate-risk related to alcoholic beverage use at baseline. The mean score was 2.54, signifying a noteworthy, albeit relatively low, level of risk.

Regarding the comparison group, the results revealed that a significant majority of participants (69.4%) displayed low-risk behaviors in their consumption of alcoholic beverages during the baseline assessment. In contrast, 30.6% of the adolescents were categorized as exhibiting moderate-risk behaviors associated with alcoholic beverage consumption at the baseline. The mean score for this subgroup denoting moderate risk was 2.45, highlighting a risk level that, while relatively low, remained of notable significance. (Presented in Table 4.19).

Table 4.19 Baseline of Alcoholic beverages use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–4 score)	37 (74.0)	0.28±0.81	34 (69.4)	0.41±1.02	
- Moderate risk (5–17 score)	13 (26.0)	9.00±3.96	15 (30.6)	7.07±2.60	
Mean±SD (total), Min, Max	2.54±4.39, 0, 15		2.45±3.50, 0, 13		0.910[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

2) Assessment of adolescent risk Behavior in Alcoholic beverages at post-intervention (After 2-month)

A more detailed examination of the data following the 2-month intervention period reveals a substantial trend. The percentage of adolescents categorized with moderate-risk behaviors linked to alcoholic beverage consumption decreased to 14.0%. This marked reduction in moderate-risk behaviors over a relatively brief two-month span signifies a positive and substantial impact attributable to the intervention. Furthermore, the mean score for this group experienced a significant reduction to 1.44, indicating a meaningful decrease in risk behavior associated with alcoholic beverage consumption.

Upon closer examination of the data following the 2-month intervention period, an intriguing pattern emerged. The percentage of adolescents classified under the moderate-risk behavior category, particularly related to alcoholic beverages, exhibited a slight reduction, decreasing to 28.6%. The mean score for this subgroup notably decreased to 2.22, signifying a reduction in risk behavior concerning the use of alcoholic beverages. (Table 4.20)

Table 4.20 Post-intervention of Alcoholic beverages use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–4 score)	43 (86.0)	0.42±0.99	35 (71.0)	0.40±1.01	
- Moderate risk (5–17 score)	7 (14.0)	7.71±3.25	14 (28.6)	6.78±2.46	
Mean±SD (total), Min, Max	1.44±2.94, 0, 14		2.22±3.29, 0, 13		0.043[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

3) Assessment of adolescent risk behavior in Alcoholic beverages at a subsequent 4-month follow-up

Data obtained at the 4-month follow-up stage adds to our understanding. At this juncture, the percentage of adolescents classified within the moderate-risk category saw an additional decrease to 6.0%, accompanied by a mean score of 1.04. This substantial and sustained reduction in moderate-risk behavior observed throughout the study period underscores the idea that the intervention had a persistent and meaningful effect in mitigating risk behaviors concerning alcoholic beverage consumption.

The findings at the 4-month follow-up stage remained consistent with those observed at the 2-month assessment. The percentage of adolescents within the moderate-risk category remained similar to the levels recorded at the 2-month mark. However, it is worth noting that the mean score for this group decreased to 2.20 (Table 4.21).

Table 4.21 A subsequent 4-month follow-up of Alcoholic beverages use assessment (n=99)

Variables	Intervention group (n=50)		Comparison group (n=49)		*p*
	Number (%)	Mean±SD	Number (%)	Mean±SD	
- Lower risk (0–4 score)	47 (94.0)	0.52±1.03	35 (71.0)	0.40±1.01	
- Moderate risk (5–17 score)	3 (6.0)	9.33±4.51	14 (28.6)	6.71±2.39	
Mean±SD (total), Min, Max	1.04±2.51, 0, 14		2.20±3.25, 0, 13		0.049[a]

Note: [a] Between-group comparisons were adjusted using the Independent t-test, significant level at 0.05.

4.4.2.2 Effectiveness of TendingPETs application on Alcoholic beverages use among adolescents

The analysis of tobacco products group at baseline, 2-month, and a subsequent 4-month follow-up revealed intriguing insights.

1) Repeated measures ANOVA within-subjects analysis

Within subjects, the sum of squares for the "Time" factor was 41.045, with 1.112 degrees of freedom, resulting in a mean square of 36.895. The F-test statistic associated with this factor was 15.766, and the p-value was highly significant, being less than 0.001. This suggests that the factor "Time" had a significant effect on alcoholic beverage consumption. Over the course of the study, there were significant changes in the patterns of alcohol consumption.

Furthermore, the "Intervention x Time" interaction also exhibited a significant effect. The sum of squares for this interaction was 20.506, with 1.112 degrees of freedom, resulting in a mean square of 18.433. The F-test statistic for this factor was 7.877, with a p-value of 0.005, indicating a significant impact of the intervention on the changes in alcoholic beverage consumption over time. This implies that the intervention influenced the patterns of alcohol consumption, resulting in a significant interaction effect.

Conversely, the within-group error sum of squares was 252.524, with 107.912 degrees of freedom, leading to a mean square of 2.340. This component accounts for the unexplained variance within individual participants.

2) Repeated measures ANOVA between-subjects analysis

There was a significant main effect of intervention on the observed variables, as evidenced by a sum of squares of 28.464 and 1 degree of freedom. The mean square value of 28.464 and the F-test statistic of 11.907 with a p-value of 0.003 suggest substantial differences in the observed variables between the intervention and comparison groups.

Conversely, the between-group error, reflecting unexplained variance between individual participants, had a sum of squares of 3,042.748 and 97 degrees of freedom. The mean square value of 31.369 provides an average measure of variance between the groups.

In summary, the results indicate significant effects of both time and intervention on the observed variables. The interaction effect underscores that the changes over time are influenced by the intervention, and the intervention itself has a significant impact on the observed variables. (Table 4.22).

Table 4.22 An analysis of Alcoholic beverages use by repeated measures ANOVA between the intervention group and the comparison group (n=99)

Variables	Sum of squares	df	Mean square	*F*-test	*p*
Within subjects					
Time	41.045	1.112	36.895	15.766	<0.001*
Intervention x time	20.506	1.112	18.433	7.877	0.005*
Error (within-group error)	252.524	107.912	2.340		
Between subjects					
Intervention	28.464	1	28.464	11.907	0.003*
Error (between-group error)	3,042.748	97	31.369		

Note: significant level at 0.05.

3) Pairwise comparison of the difference measurement of Alcoholic beverages use between the intervention group and the comparison group

Baseline: The mean difference between the intervention and comparison groups at baseline is 0.91. The standard error associated with this difference is 0.800. The p-value is 0.910, suggesting a lack of statistical significance. The 95% confidence interval ranges from -1.496 to 1.678.

Post-intervention: The mean difference between the intervention and comparison groups post-intervention is -0.784. The standard error associated with this difference is 0.627. The p-value is 0.041, there are statistically significant differences, suggesting an impact of the intervention on the groups' means. The 95% confidence interval ranges from -2.030 to -0.461.

4-month Follow-up: The mean difference between the intervention and comparison groups at the 4-month follow-up is -1.164. Standard Error (SE): The standard error associated with this difference is 0.583. The p-value is 0.049, indicating statistical significance. The 95% confidence interval ranges from -0.007 to 0.139. (Table 4.23).

Table 4.23 Pairwise comparison of the difference measurement of Alcoholic beverages use between the intervention group and the comparison group (n=99)

Variables	Group		Mean difference	SE	*p*	95% confidence interval for difference[a]	
	i	j	i-j			Lower	Upper
Baseline	Intervention	Comparison	0.91	0.800	0.910	-1.496	1.678
Post-intervention	Intervention	Comparison	-0.784	0.627	0.041*	-2.030	-0.461
4-month follow up	Intervention	Comparison	-1.164	0.583	0.049*	-0.007	0.139

Note: [a]Adjustment for multiple comparisons: Bonferroni, significant level at 0.05.

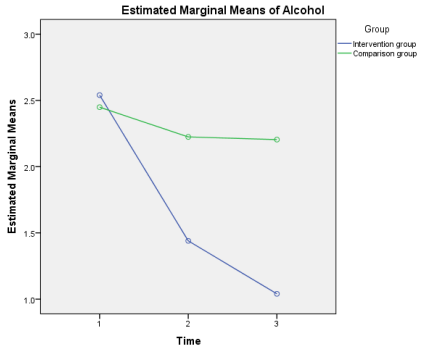


Figure 4.5 Estimated marginal means of Alcoholic beverages use

In summary, the pairwise comparisons for alcoholic beverage consumption demonstrated no significant difference at baseline. However, a

statistically significant decrease in alcoholic beverage consumption was observed in the intervention group compared to the comparison group at post-intervention and the 4-month follow-up. This suggests that the intervention may have had a lasting impact on reducing alcoholic beverage consumption in the intervention group.

4.5 Data-Driven Insights: Analyzing Mean Time of TendingPETs Application using

In this section, the researcher delved into data-driven insights by analyzing the mean time spent on the TendingPETs application. This exploration aims to provide valuable observations and patterns regarding user engagement with the application

4.5.1 The mean time and temporal distribution of user participation

The table 4.22 provided insights into the mean time (in minutes) that players spent on the TendingPETs application during specific time periods throughout a 24-week period. The data is presented in the format of the mean, standard deviation, minimum, and maximum values for each time period.

1) Weeks 1-3: The mean time spent during the evening hours (15.00-17.59 PM) showed a gradual increase from 15.25 minutes to 41.24 minutes over the first three weeks.

2) Weeks 4-8: The mean time during the evening hours continues to increase, reaching a peak of 73.22 minutes in Week 7.

3) Weeks 9-12: There's a slight decrease in mean time during the evening hours, stabilizing around 50 minutes.

4) Weeks 13-16: The mean time decreases further, settling around 45 minutes during the evening hours. The number of players continues to fluctuate.

5) Weeks 17-20: The mean time sees a gradual decrease, reaching 40.98 minutes in Week 19. There's variability in the number of players.

6) Weeks 21-24: The mean time continues to decrease, reaching 23.90 minutes in Week 24. The number of players shows fluctuations.

Overall, the data suggests variations in player engagement with the TendingPETs application during different time periods, with some fluctuations in both

mean time and the number of players throughout the 24-week period. The detailed breakdown provides a nuanced understanding of user behavior over time. (Table 4.24)

Table 4.24 Analyzing Mean Time of TendingPETs Application using

Week	Mean±SD, Min , Max (minutes)	Temporal distribution of user participation		
		15.00-17.59 PM	18.00-20.59 PM	21.00-23.59 PM
First day	15.25±7.89, 10, 26	53	-	-
1	28.16±6.61, 15, 41	12	31	10
2	35.14±6.31, 24, 58	13	29	11
3	41.24±6.55, 31, 65	8	38	7
4	43.48±7.69, 30, 67	11	38	14
5	65.64±16.54, 31, 91	6	29	18
6	54.36±11.50, 35, 86	7	34	11
7	73.22±11.78, 26, 90	5	40	7
8	71.60±12.56, 41, 91	5	43	4
9	64.20±5.02, 58, 83	3	47	5
10	52.56±10.12, 38, 73	6	36	10
11	56.06±11.17, 40, 80	2	30	20
12	50.56±10.09, 37, 87	-	31	19
13	49.58±8.29, 34, 67	1	41	8
14	50.36±8.04, 40, 79	6	31	13
15	48.82±8.38, 37, 69	5	29	16
16	47.80±8.26, 35, 79	4	37	9
17	45.02±8.40, 33, 70	4	37	9
18	41.34±5.77, 30, 57	-	41	9
19	40.98±5.31, 30, 58	3	33	14
20	38.26±5.74, 29, 53	5	43	2
21	33.50±5.03, 25, 50	7	34	99
22	29.96±5.01, 20, 47	9	38	3
23	27.92±5.95, 18, 42	-	34	16
24	23.90±6.10, 14, 38	-	39	11

The comprehensive scrutiny of the mean time allocation within a 24-day span on the TendingPETs application furnishes invaluable insights for the refinement of optimization strategies and the augmentation of user engagement.

1) Discernible Usage Patterns: The data reveals conspicuous patterns in user engagement. Particularly noteworthy is the incremental augmentation of mean time spent during the evening hours (15:00-17:59 PM) during the initial weeks, culminating in a zenith of 73.22 minutes in Week 7.

2) Focused Exploration of Peak Engagement: The temporal juncture spanning Weeks 4-8, characterized by maximal mean time, serves as a focal point for in-depth exploration.

3) Stability and Subsequent Decline: The stabilization of mean time around the threshold of 50 minutes during Weeks 9-12, followed by a subsequent decrement.

4) Temporal Dynamics of User Engagement: The discerned attenuation in engagement during the evening hours in subsequent weeks accentuates the imperative of adapting strategies to sustain interest during specified temporal epochs.

5) Dynamic Player Engagement Trends: Fluctuations in both mean time and the quantity of participating players imply a dynamic user comportment.

In summation, these findings empowered with actionable insights to elevate the collective user experience, optimize application features, and judiciously deploy events or notifications, thereby maximizing user engagement."

4.5.2 User Participation Satisfaction in the Application

The user participation satisfaction in the application was assessed through various items, each rated on a scale from 1 to 5, where a higher score indicates greater satisfaction. The mean scores and standard deviations (Mean±SD) for each item are presented in Table 4.25.

The participants expressed particularly high satisfaction with the ease of navigation (Mean=4.32, SD=0.055), indicating that they found the application easy to navigate.

The user-friendly interface also received positive feedback, with a mean score of 4.12 (SD=0.89).

Additionally, participants were highly satisfied with the range of features provided by the application (Mean=4.69, SD=0.47) and the clarity of instructions (Mean=4.66, SD=0.54).

The application's responsiveness to user actions received a mean score of 4.01 (SD=0.43), indicating swift response times.

Overall, participants reported a high level of satisfaction with the application, as reflected in the mean overall satisfaction score of 4.49 (SD=0.52).

These results suggest that users found the application to be user-friendly, feature-rich, and overall satisfactory in meeting their needs and expectations.

Table 4.25 User Participation Satisfaction in the Application

Items	**Mean±SD**
1. The application is easy to navigate	4.32±.055
2. The interface of the application is user-friendly	4.12±0.89
3. The application provides an adequate range of features	4.69±0.47
4. Instructions within the application are clear and easy to follow	4.66±0.54
5. The application responds quickly to actions	40.1±0.43
6. Overall satisfaction	4.49±0.52

Note: Minimum score is 1, Maximum score is 5

CHAPTER 5
DISCUSSION

In the following sections, the researcher will delve deeper into the implications of these findings, considering their broader relevance in educational, psychological, and health contexts. The discussion will also provide a platform for reflecting on the limitations of the study and avenues for future research. Through this comprehensive exploration, the aim is to enrich our understanding of the multifaceted relationship between working memory, academic performance, and risk behaviors, ultimately contributing to the advancement of knowledge in these domains.

5.1 Study highlight

5.1.1 Relevance to Research Objectives

These research objectives were framed with precision to better understand the dynamics of working memory over time and its potential relationship with academic performance and risk behaviors. The study assumes particular significance in the ongoing discourse surrounding the malleability of working memory and its potential implications for crucial life outcomes.

5.1.2 Key Findings and Statistical Significance

The application of repeated measures ANOVA in this study provided valuable insights. Statistical analyses revealed outcomes that suggest noteworthy trends in the trajectories of working memory performance within both the intervention and comparison groups. Improvements observed in the intervention group, which extended over a 4-month follow-up period, seem to underscore the potential effectiveness of TendingPETs application. These findings, while distinguished by their statistical significance, appear to shed light on the potential to enhance working memory performance.

5.1.3 Methodological Impact

The methodological approach adopted in this research played a substantial role in safeguarding the validity of the results. Vigorous data collection, the selection of appropriate statistical tests, and meticulous analysis collectively contributed to strengthening the trustworthiness of our findings. It's important to underscore that our methods align with recognized standards in the field, which contributes to the reliability of the observed effects.

5.1.4 Interpretation and Implications

The results gleaned from this study suggest that working memory may be amenable to targeted interventions, potentially leading to enhancements in various facets of cognitive function. These revelations seem to carry implications for educators, psychologists, and policymakers. The prospect of tailored interventions aimed at potentially fortifying working memory holds promise for improving academic performance. Furthermore, the observed changes in risk behaviors appear to suggest a complex interplay between cognitive and behavioral domains.

5.2 Discussion

5.2.1 Research hypothesis: TendingPETs application effect on working memory among adolescent in Phrae province, Thailand.

In this study, 99 participants were divided into an intervention group and a comparison group to explore the potential impact of the TendingPETs application on various working memory components. Utilizing repeated measures ANOVA, we observed compelling evidence of significant improvements in working memory within the intervention group, particularly when compared to the comparison group. The mean score differences indicated advancements across multiple facets of working memory, including the Phonological Loop (Post-intervention: +30.698; 4-Month Follow-Up: +28.729), the Visuo-Spatial Sketch Pad (Post-intervention: +36.351; 4-Month Follow-Up: +34.468), the Central Executive (Post-intervention: +34.980; 4-Month Follow-Up: +33.559, CI), the Composite (Post-intervention: +34.400; 4-Month Follow-Up:

+32.940), and Processing Speed (Post-intervention: +31.753; 4-Month Follow-Up: +31.074).

These findings suggest enduring enhancements in working memory, indicating a sustained impact attributed to the TendingPETs application. It's crucial to acknowledge that these observed improvements are intricately linked to the application's mini-games, strategically designed to target specific working memory components.

Table 4.3, which presents the baseline working memory assessment, revealed no significant differences ($p>0.05$) in working memory components between the intervention and comparison groups. However, after the post-intervention assessment, significant positive changes were observed in all working memory components within the intervention group compared to the comparison group ($p<0.001$) (Presented in Table 4.4).

Specifically, the Phonological Loop, encompassing subcomponents such as the phonological store and articulatory rehearsal, showed significant improvement. The "Over and Over" mini-game, inspired by N-back games, effectively challenges participants to recall items presented 'n' steps back in a sequence, reinforcing the phonological store and engaging participants in auditory information processing, storage, and recall. This aligns with prior research, such as Pelegrina et al. (107), suggesting the potential benefits of computerized verbal N-back tasks in enhancing working memory.

Moving to the Visuo-Spatial Sketch Pad (VSSP) component, there was a notable improvement in post-intervention assessments. This enhancement can be attributed to the "Endless" mini-game, designed to align with VSSP's fundamental principles by challenging participants to recall and reproduce intricate spatial patterns. As the game progresses in complexity, it stimulates greater involvement of the VSSP, supporting the proposition that TendingPETs positively influences visuo-spatial working memory.

The third critical component, the Central Executive, responsible for attention allocation and information integration, also demonstrated enhancement in adolescents within the intervention group. This improvement may be linked to the enhanced Phonological Loop and Visuo-Spatial Sketch Pad components.

Incorporating Alan Baddeley's model of working memory, the study provides a theoretical framework to comprehend the intricate interplay among these components. The Phonological Loop's role in transient storage and manipulation of auditory or verbal information reduces the cognitive load on the Central Executive, facilitating more efficient management of tasks requiring verbal working memory.

Simultaneously, enhancing the Visuo-Spatial Sketch Pad aids in manipulating and retaining visual elements, benefiting tasks involving mental imagery and strategic planning. The research by Kane and Engle (110) sheds light on the relationship between working-memory capacity and attention control, emphasizing the pivotal role of the Central Executive. When working memory components operate optimally, the Central Executive can allocate cognitive resources more prudently, leading to overall improvements in working memory performance.

Thus, the TendingPETs application's enhancement of core working memory components aligns with improvements in adolescents' working memory performance, as indicated by increases in composite scores and processing speed. These findings are consistent with prior research by Colzato LS et al. (2013) (17), Stanmore E et al. (2017) (84), and Boendermaker WJ et al. (2018) (85).

Moreover, it is interesting to consider the specific age of the participants in this study. The data pertaining to the developmental trajectory of working memory skills yield valuable insights into why TendingPETs manifest particularly positive results among 15-year-old adolescents.

An intriguing facet of this study is the specific age group under consideration. The data, which shed light on the developmental course of working memory skills, provide compelling rationales for the remarkable outcomes observed specifically in 15-year-old adolescents. Cognizant of prior research, such as studies by Casey et al. (54) and Klingberg et al. (55), we recognize the consistent indication that the most pronounced development of working memory skills occurs in individuals during the transitional phase from infancy to middle childhood. Intriguingly, this developmental period coincides precisely with the age range of the 15-year-old adolescents who participated in this study. Notably, between 10 and 14 years of age, there is a zenith in frontal and parietal gray matter volume, closely linked to the maturation of working memory. This neurodevelopmental context lends robust support to the proposition that interventions

targeting working memory are particularly efficacious during adolescence, a phase characterized by heightened neural plasticity in this domain.

Moreover, upon closer scrutiny of the data, a critical period for the enhancement of working memory capacity becomes evident, particularly before mid-adolescence. This observation suggests that 15-year-olds find themselves in a pivotal developmental juncture where their working memory capacity remains adaptable. Evidently, TendingPETs, strategically timed and thoughtfully designed, appear to harness this window of developmental plasticity with remarkable efficacy.

An aspect of paramount importance revolves around the sensitivity to intervention, which 15-year-olds, among other adolescents, unequivocally exhibit. Adolescents in this age bracket find themselves at a critical crossroads, with cognitive development and academic performance assuming paramount significance. They manifest a heightened willingness to actively engage with interventions aimed at augmenting their cognitive skills. Notably, their motivation to participate and interact with cognitive-enhancing applications, such as TendingPETs, significantly augments the likelihood of intervention success.

It seems like TendingPETs application positive effect on working memory in the intervention group. However, a noteworthy aspect revealed in Table 4.5, reflecting the subsequent 4-month follow-up of the working memory assessment, adds an intriguing layer to our understanding of the TendingPETs application's impact. The data indicates a slight reduction in scores across all components of working memory during this follow-up period, coinciding with a decline in the participation of the intervention group.

This finding suggests a potential relationship between the level of engagement with the TendingPETs application and the observed changes in working memory scores. Notably, the decrease in participation may signify a waning interest or reduced commitment to the application over time. This prompts a valuable consideration for the developers of TendingPETs to explore strategies aimed at maintaining and enhancing player attention throughout the extended usage period.

5.2.2 Research hypothesis: TendingPETs application effect on academic performance among adolescent in Phrae province, Thailand.

The analysis of within-subjects variance demonstrated a substantial time-dependent increase in academic performance among participants. The interaction between the TendingPETs application and time was highly significant for subjects, indicating the TendingPETs application's notable impact on academic performance throughout the study. Specifically, the intervention group displayed significant improvements in mathematics performance with mean differences of 6.030 post-intervention and 4.397 at the 4-month follow-up compared to the comparison group. In English performance, post-intervention and at the 4-month follow-up, the intervention group maintained substantial improvements with mean differences of 5.856 and 5.593, respectively.

At the baseline of study, Mathematics and English scores between the intervention group and the comparison group had no significant difference ($p>0.05$) which are displayed on Table 4.8 and Table 4.11.

Following a two-month period, the empirical data obtained through this study is compelling. Significant effects, both within and between subjects, were discerned, primarily driven by the interaction between the intervention, represented by the TendingPETs application, and time ($p<0.001$) . These pronounced effects chiefly manifested in the domains of mathematics and English, subjects pivotal to adolescent development. Employing repeated measures ANOVA, our analysis unveiled noteworthy temporal changes, underscoring the substantial influence of the TendingPETs intervention on academic performance.

It can be inferred that a central feature of the TendingPETs application is the inclusion of mini-games that substantially contribute to enhancing cognitive and academic abilities. One standout example is the "Last Boss" mini-game. This cognitive challenge ingeniously integrates elements of mathematics, English, and essential knowledge concerning alcohol and cigarettes. In this holistic gaming experience, participants progressively advance from rudimentary tasks to more intricate ones, all while synchronizing their responses with a musical backdrop. The results distinctly indicate notable improvements in proficiency in mathematics and English, further highlighting the application's influence on academic development.

Furthermore, the "Knowledge Reading Mode" within the application assumes the role of an invaluable source of information. Categorized into mathematics, English, health education, and information on alcohol and cigarettes, this mode provides structured learning. Participants are strongly encouraged to immerse themselves in this wellspring of knowledge before embarking on mini-game adventures. The rich learning experience it offers significantly impacts academic performance by equipping participants with the requisite knowledge and skills.

Critical to comprehending these improvements is the profound role of working memory. The working memory system encompasses the Phonological Loop, Visuo-Spatial Sketch Pad, and Central Executive, each intricately intertwined with cognitive tasks and, consequently, academic performance. Enhancements in these working memory components realized through the TendingPETs application translate into more efficient information processing, a foundational element of success in academic pursuits. In this regard, this study aligns with prior research conducted by Bergman Nutley S and Söderqvist Stina (2017), Studer-Luethi, B et al (2022), and Sankalaite S et al. (2023), which underscores the positive relationship between working memory enhancements and academic performance. The central role of working memory in tasks demanding attention, information retention, and complex problem-solving underscores its significance in the pursuit of educational achievements.

This study unequivocally highlights the substantial influence of the TendingPETs application on academic performance, with a particular emphasis on the subjects of mathematics and English, both foundational to adolescent education. The application's mini-games, particularly the "Last Boss," and the "Knowledge Reading Mode," collectively provide a holistic learning experience, fostering cognitive skills and delivering indispensable knowledge. This effect inherently links to working memory enhancements, which serve as a central driver of academic success. The interplay between cognitive interventions and working memory, facilitated by the TendingPETs application, forms a pivotal axis in the endeavor to enhance educational outcomes.

However, the results at the subsequent 4-month follow-up indicate a slight decrease in both Mathematics and English scores compared to the post-intervention assessment. A potential explanation for this trend could be associated with the

participants transitioning from the 9th grade to the 1st week of the 10th grade during the measurement period.

It is plausible that as students progressed to the 10th grade, the content of their academic curriculum shifted, potentially impacting their performance in both Mathematics and English. The shift to a higher grade level might have introduced new topics and challenges, requiring students to adapt their knowledge and focus accordingly. This adjustment could contribute to the observed decline in scores, reflecting the natural progression of academic content. Additionally, the decrease in time spent on the TendingPETs application over time may be a contributing factor. As students advanced to the 10th grade, the demands of their coursework and other responsibilities could have led to a reduction in the time allocated to the application. This decline in engagement might influence the application's effectiveness over the 4-month follow-up period.

Therefore, it appears that the combined effects of transitioning to a higher grade level with different academic content and a decrease in time spent on the TendingPETs application could contribute to the observed reduction in Mathematics and English scores.

5.2.3 Research hypothesis: TendingPETs application effect on risk behavior among adolescent in Phrae province, Thailand.

The study examined the impact of the TendingPETs application on risk behaviors among adolescents in Phrae province, Thailand. Notably, the application demonstrated a substantial influence on adolescent risk behaviors, particularly in the context of alcohol consumption. Over the study period, there was a significant reduction in moderate-risk behaviors related to alcoholic beverage consumption among participants in the intervention group. At the 4-month follow-up, the mean score for this group decreased to 1.04, emphasizing a meaningful decrease in risk behavior associated with alcohol consumption. In contrast, the application did not produce a statistically significant effect on the use of tobacco products. The results from the pairwise comparisons of the difference in tobacco product use between the intervention and comparison groups at different time points, including baseline, post-intervention, and the 4-month follow-up, did not reveal any significant differences.

The "TendingPETs" application, with its comprehensive design encompassing an engaging mini-game, structured knowledge within the Knowledge Reading Mode, and a strong emphasis on enhancing working memory, indeed raises intriguing questions. Surprisingly, it did not lead to a significant reduction in tobacco use among adolescents. However, several key factors can elucidate this unexpected outcome.

What adds a layer of intrigue to this scenario is the application's strong emphasis on enhancing working memory, a valuable cognitive skill. It's curious that, despite notable improvements in working memory, there was no corresponding reduction in tobacco use among adolescents. This result contradicts a study by Rosenbaum GM et al. (2017) that suggested Working Memory Training (WMT) may help mitigate risk-taking behavior in adolescents when they are being observed by their peers (106). This raises pertinent questions about the complex relationship between cognitive skills and behavioral change in adolescents, prompting us to consider whether enhancing working memory alone is sufficient to modify complex behaviors such as tobacco use.

Drawing from the Health Belief Model (115), it appears that individuals are more likely to engage in preventive actions when they perceive vulnerability to a health threat and believe in the effectiveness of these preventive measures. In the case of adolescents and tobacco use, it becomes evident that they might not have considered themselves highly susceptible to the risks associated with this habit. The application may have faced challenges in effectively communicating the severity of these risks and the benefits of reducing tobacco consumption. Consequently, adolescents might not have been adequately motivated to change their behaviors.

Furthermore, the Theory of Planned Behavior (116) underscores the significance of attitudes, subjective norms, and perceived behavioral control in shaping intentions and behaviors. In this context, adolescents' attitudes towards tobacco use, the influence of their social networks, and their perceived control over their tobacco use may have outweighed the impact of the application. The intricate interplay of peer pressure and social norms within the adolescent social milieu is a critical aspect that might not have been comprehensively addressed by the "TendingPETs" application.

Additionally, considering the phase of substantial cognitive and emotional development that adolescents are navigating, it becomes plausible that the application did not adequately account for these developmental aspects in its content and

interventions. It might not have aligned with the specific developmental stage of adolescents, which could have limited its impact.

In summation, the process of effecting behavioral change in adolescents, especially in the context of tobacco use, is undeniably multifaceted. It entails a dynamic interplay of cognitive, social, and developmental factors. While the "TendingPETs" application boasts several strengths, such as its educational content and its commitment to cognitive enhancement, the intricate and multifaceted nature of adolescent decision-making warrants a deeper understanding. This study underscores the necessity for more precise and nuanced approaches when addressing adolescent risk behaviors, particularly in the context of tobacco use.

Conversely, the "TendingPETs" application exhibited a slightly positive effect on reducing alcoholic beverage consumption among adolescents in Phrae province, Thailand. This effect warrants a comprehensive discussion, particularly in the context of the mini-game and the information provided about alcohol use within the application.

The inclusion of a mini-game within the application may have played a vital role in the observed reduction in alcohol consumption among adolescents. The interactive and engaging nature of the mini-game likely captured the attention of the target audience - adolescents - and provided a platform through which important health information was delivered. Adolescents are known to respond well to interactive and gamified learning experiences. In this case, the mini-game might have not only served as an enjoyable element but also as an effective educational tool. It may have facilitated a more profound understanding of the risks associated with alcohol consumption, making the information more relatable and memorable. Furthermore, it is plausible that the mini-game created a positive association with the application itself, potentially leading to a higher level of engagement and receptiveness to the information about alcohol use.

The information provided within the application about alcohol use is another critical element. It likely contributed to the slightly positive effect observed. Adolescents are in a stage of development where they are exploring their identity and making choices that can have long-term consequences. Access to comprehensive information on the potential risks and negative health impacts of alcohol use is a valuable resource for this age group. The application's Knowledge Reading Mode, with its structured knowledge, might have enhanced the adolescents' awareness and

understanding of these risks. Moreover, the application could have provided strategies and alternatives to alcohol use, empowering adolescents to make informed decisions about their behavior. This aligns with established health education principles that emphasize the importance of knowledge acquisition in shaping health behaviors.

Working memory skills, as emphasized in the "TendingPETs" application, also play a noteworthy role in the observed reduction in alcohol consumption among adolescents. Working memory is a cognitive function that allows individuals to hold and manipulate information temporarily. It is closely linked to executive functions, including impulse control and decision-making. Therefore, enhancing working memory skills through the application might have contributed to the adolescents' ability to resist the temptation of alcohol and exercise better decision-making when confronted with choices related to alcohol use. These research findings align with previous studies by Khemiri L et al (2018) and Mahedy L et al (2018), which also suggested an association between working memory skills and alcohol use.

Working memory is integral in processing and applying the knowledge gained from the application. It allows adolescents to retain and retrieve information about the risks of alcohol consumption when they face real-world situations that tempt them to drink. Improved working memory capacity can aid in countering impulsive behaviors, such as excessive alcohol use, by enabling more reasoned and calculated responses. Adolescents with enhanced working memory skills may exhibit improved self-regulation and be better equipped to resist peer pressure and the allure of alcohol.

In conclusion, the "TendingPETs" application demonstrated a slightly positive effect on reducing alcoholic beverage consumption among adolescents in Phrae province, Thailand. The mini-game and the information provided about alcohol use, coupled with the emphasis on enhancing working memory, appear to be key factors contributing to this effect. These elements align with established principles of health education and cognitive development, underlining the significance of engaging, informative content and cognitive skill enhancement in shaping adolescent risk behaviors, particularly concerning alcohol use. However, the nuanced nature of adolescent behavior change necessitates further investigation and a more profound understanding of the mechanisms at play.

CHAPTER 6
CONCLUSION

In this study, researcher aimed to evaluate the effectiveness of the "TendingPETs" application in addressing specific outcomes among adolescents in Phrae province, Thailand. The study focused on working memory, academic performance, and risk behaviors. This study investigation was guided by three primary research hypotheses.

6.1 Conclusion

6.1.1 Working memory skill

The "TendingPETs" application has proven to be a promising tool for enhancing working memory in adolescents, aligning with our first research hypothesis. This is a significant finding, indicating the potential for digital interventions to positively influence cognitive development in this age group.

6.1.1.1 Phonological Loop: While no substantial distinction was noted at baseline, a remarkable post-intervention and 4-month follow-up improvement in the Phonological Loop for the intervention group was evident. This sustained enhancement aligns with the application's positive influence on this critical working memory facet.

6.1.1.2 Visuo-Spatial Sketch Pad: Similar to the Phonological Loop, the Visuo-Spatial Sketch Pad exhibited a significant and sustained improvement post-intervention and at the 4-month follow-up. The noteworthy changes signify the application's impact on enhancing visual-spatial working memory in adolescents.

6.1.1.3 Central Executive: Although no significant differences were found at baseline, the Central Executive's substantial improvement post-intervention and at the 4-month follow-up highlights the enduring positive influence of the "TendingPETs" application on the cognitive processes governed by this component.

6.1.1.4 Composite Score: Initial similarity in baseline scores was followed by a significant improvement in the intervention group's composite working memory scores post-intervention and at the 4-month follow-up. This supports the notion that the

application contributes not only to specific components but also to overall working memory performance.

6.1.1.5 Processing Speed: The absence of baseline distinctions was succeeded by a significant enhancement in processing speed post-intervention and a maintained effect at the 4-month follow-up. These outcomes signify the application's role in accelerating working memory processes in adolescents.

In culmination, the "TendingPETs" application emerges as a potent tool, substantiated by statistically significant improvements across various working memory components. This aligns seamlessly with our initial hypothesis, affirming the transformative potential of digital interventions in positively shaping the cognitive landscape of adolescents. The sustained effects observed at the 4-month follow-up further underline the durability of these enhancements, presenting exciting prospects for the intersection of technology and cognitive development in this demographic.

6.1.2 Academic Performance Outcomes

Initially, the baseline assessment revealed a modest mean difference that lacked statistical significance, suggesting comparable Mathematics performance between the intervention and comparison groups. This establishes a crucial foundation for assessing subsequent improvements in both cohorts.

Following the intervention, a remarkable metamorphosis transpired, with the intervention group showcasing a substantial mean difference of 6.030 in Mathematics performance compared to the comparison group. The statistical significance of this change, coupled with a confidence interval that excludes zero, signifies a noteworthy enhancement attributable to the intervention. This post-intervention surge reaffirms the application's efficacy in fostering substantial progress in Mathematics skills among adolescents.

The persistence of a significant difference in Mathematics performance at the 4-month follow-up cements the enduring impact of the intervention. With a mean difference of 4.397, the sustained improvement further accentuates the lasting benefits accrued by the intervention group. The p-value, persistently less than 0.001, and a confidence interval that substantiates the difference from 2.782 to 6.013 underscore the stability and significance of the observed advancements.

In summation, the findings underscore the "TendingPETs" application's instrumental role in fostering a substantial and enduring improvement in Mathematics performance among adolescents. The statistical significance observed post-intervention, coupled with its sustained impact at the 4-month follow-up, positions the application as a potent catalyst for positive cognitive transformations. This aligns seamlessly with the overarching objective of leveraging digital interventions to enhance educational outcomes, presenting a compelling narrative for the integration of technology in educational practices.

Additionally, the meticulous examination of comparisons in English performance between the intervention and comparison groups has unveiled compelling evidence of the transformative impact of the intervention, "TendingPETs," on adolescent language proficiency.

Initially, the baseline assessment depicted a negligible mean difference, -0.110, signifying comparable English performance between the intervention and comparison groups. This establishes a crucial benchmark for evaluating subsequent enhancements.

In the aftermath of the intervention, a paradigm shift occurred, with the intervention group demonstrating a substantial and statistically significant mean difference of 5.856 in English performance compared to the comparison group. The robust p-value, less than 0.001, and a confidence interval ranging from 4.355 to 7.356 underscore the profound improvement within the intervention group. This post-intervention surge highlights the efficacy of the "TendingPETs" application in catalyzing significant advancements in English proficiency among adolescents.

The replication of significant findings at the 4-month follow-up serves as a testament to the enduring impact of the intervention. With a maintained mean difference of 5.593 and a p-value persistently below 0.001, the intervention group sustains the marked improvement in English performance. The confidence interval, spanning from 3.965 to 7.221, further solidifies the notion that the positive transformation observed post-intervention perseveres over time.

In summation, the findings underscore the "TendingPETs" application's instrumental role in not only instigating a significant improvement in English performance among adolescents but also ensuring the longevity of these advancements. The robust statistical significance observed post-intervention and its perpetuation at the

4-month follow-up position the application as a potent catalyst for linguistic proficiency enhancement. This aligns seamlessly with the broader educational objective of leveraging technology to optimize language learning outcomes, establishing a compelling narrative for the integration of digital interventions in language education.

6.1.3 Addressing risk behaviors

The third hypothesis investigated the "TendingPETs" application's effect on risk behaviors. It is noteworthy that the application demonstrated varying effects on reducing of alcoholic beverage use.

The result exhibited a slightly positive impact in reducing alcohol consumption. These outcomes highlight the intricate nature of addressing risk behaviors among adolescents and underline the need for tailored strategies that account for the diversity of these behaviors.

At the baseline, there was no statistically significant distinction, as indicated by a mean difference of 0.91 and a p-value of 0.910. This implies comparable alcoholic beverage use between the groups. Subsequent to the intervention, a substantial change was evident, with a mean difference of -0.784 and a p-value of 0.041, indicating a noteworthy impact. The 95% confidence interval, ranging from -2.030 to -0.461, underscores the intervention's effectiveness in influencing alcoholic beverage use. The data at the 4-month follow-up further validates the intervention's impact, with a mean difference of -1.164 and a p-value of 0.049, signifying statistical significance. The confidence interval, extending from -0.007 to 0.139, suggests a sustained effect, reinforcing the enduring influence on alcoholic beverage use.

In summary, the results highlight the intervention's efficacy in shaping alcoholic beverage use, with a substantial impact persisting post-intervention. The statistical significance observed at both assessment points underscores the intervention's potential to positively contribute to behavior change. These findings provide a compelling narrative, encouraging ongoing exploration and implementation of targeted interventions for addressing substance use behaviors within the studied population.

6.2 Strengths of the study

1. Comprehensive and Multidisciplinary Approach: The study combines elements of cognitive psychology, health education, and digital technology, offering a novel perspective on improving adolescent well-being.

2. Innovative Intervention: The "TendingPETs" application, with its gamified features and integration of health education content, provides an innovative approach that enriches the understanding of adolescent cognitive development and its influence on risk behaviors.

3. Theoretical Grounding: The research draws from established psychological and educational theories, adding depth and credibility to the study's interventions.

6.3 Limitations of the study

1. Limited Generalizability: The sample primarily represents adolescents in Phrae province, potentially restricting the generalizability of the findings to broader populations. Cultural and regional factors specific to Phrae might influence the outcomes.

2. Reliance on Specific Measurement Tools: The study relies on specific measurement tools, which, while commonly used, have sensitivity and potential for bias that should be acknowledged.

3. Potential Unaccounted Control Variables: The research may not have accounted for all potential control variables, such as external factors that could have influenced academic performance or risk behaviors during the study.

4. Lack of Biomarker for Measuring Working Memory Skill: Due to the absence of instruments like fMRI, EEG, and MRA in local hospitals, there is a lack of biomarker-supported evidence for measuring working memory skills in participants. This limitation may affect the reliability of the study results.

6.4 Implications for public health

1. Targeted Risk Behavior Interventions: Public health programs can benefit from understanding the nuances of different risk behaviors among adolescents. Tailored interventions addressing specific behaviors like tobacco and alcohol use could yield more effective results.

2. Digital Interventions: The success of the "TendingPETs" application suggests that digital interventions can be a valuable addition to public health strategies. Exploring and developing more digital tools that focus on cognitive development and well-being could be a fruitful avenue for future public health initiatives.

3. Educational Curriculum: These findings also indicate the potential for incorporating elements of cognitive development and decision-making skills within the school curriculum. Integrating such content alongside traditional academic subjects could contribute to the holistic development of adolescents.

4. Community and Family Engagement: Public health programs should involve not only schools but also families and communities. Creating a supportive environment for adolescents, where both formal education and family life contribute to their cognitive and behavioral development, is essential.

5. Policy Advocacy for Health-Enhancing Gaming Applications: The implications underscore the potential impact of the "TendingPETs" application on adolescent cognitive development and well-being. Public health policies should be crafted or revised to advocate for the integration of health-enhancing gaming applications into educational and community settings. This could involve incentivizing schools and educational institutions to adopt such applications as part of their curriculum, promoting collaborations between health authorities and gaming developers, and ensuring that policies support the positive use of technology for cognitive improvement in adolescents. This proactive approach aligns with the evolving landscape of digital tools and recognizes their potential in contributing to overall adolescent health.

6.5 Suggestions for Application and Future Research

6.5.1 Suggestions for Application

1) Teacher and Parent Involvement: Investigate the role of teachers and parents in supporting and reinforcing the effects of cognitive development interventions. Understanding how these stakeholders can contribute to the success of such interventions is crucial.

2) Collaboration with Schools and Institutions: Collaborate with educational institutions and community organizations to integrate the application into school curricula or extracurricular programs. This can facilitate a more structured and widespread use of the application among adolescents.

3) Incorporate Parental Involvement: Integrate features that encourage parental involvement and support. This could include progress tracking, regular updates on the adolescent's activities within the application, and resources for parents to reinforce positive behaviors at home.

4) Continuous Improvement: Implement a system for continuous improvement based on user feedback. Regularly update the application with new content, features, and improvements to address emerging issues and keep the intervention relevant over time.

6.5.2 Suggestions for Future Researc

1) Longitudinal Studies: Conduct long-term studies to assess the sustained impact of digital interventions like "TendingPETs" on working memory and risk behaviors as adolescents transition into young adulthood. This would help in understanding the lasting effects of such interventions.

2) Comparative Studies: Compare the effectiveness of digital interventions with traditional, non-digital approaches in addressing risk behaviors among adolescents. This can provide insights into the unique advantages of digital tools.

3) Diversity in Sample Populations: Expand the study to include more diverse demographic groups, not only in different regions but also in terms of cultural and socioeconomic factors. This would allow for a better understanding of how the intervention applies to various populations.

4) Multi-Modal Interventions: Explore the potential benefits of combining digital interventions with in-person educational and counseling approaches. A multi-modal approach might yield more comprehensive results.

5) Scaling Interventions: Develop strategies for scaling interventions like "TendingPETs" for broader use in educational institutions and families, considering factors like cost-effectiveness and ease of implementation.

6) Cross-disciplinary Research: Collaborate with experts from various disciplines, including psychology, sociology, and public health, to enrich the study's methodology and interpretation of results. A multidisciplinary approach can provide a more holistic understanding of adolescent behavior.

In summary, this study contributes to the evolving field of health education and digital interventions. It highlights the importance of customizing interventions to meet the dynamic needs of adolescents and emphasizes the intricate nature of adolescent decision-making regarding risk behaviors.

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APPENDIX

Appendix A: TendingPETs application graphic

In Appendix A, the researcher would like to present more figures of knowledge reading mode in TendingPETs application figures.

A1. Example of Mathematics infographic

Figure A1.1 Geometry Mathematics infographic

Figure A1.2 Geometry Mathematics infographic

A2. Example of English infographic

Figure A2.1 Example of English infographic

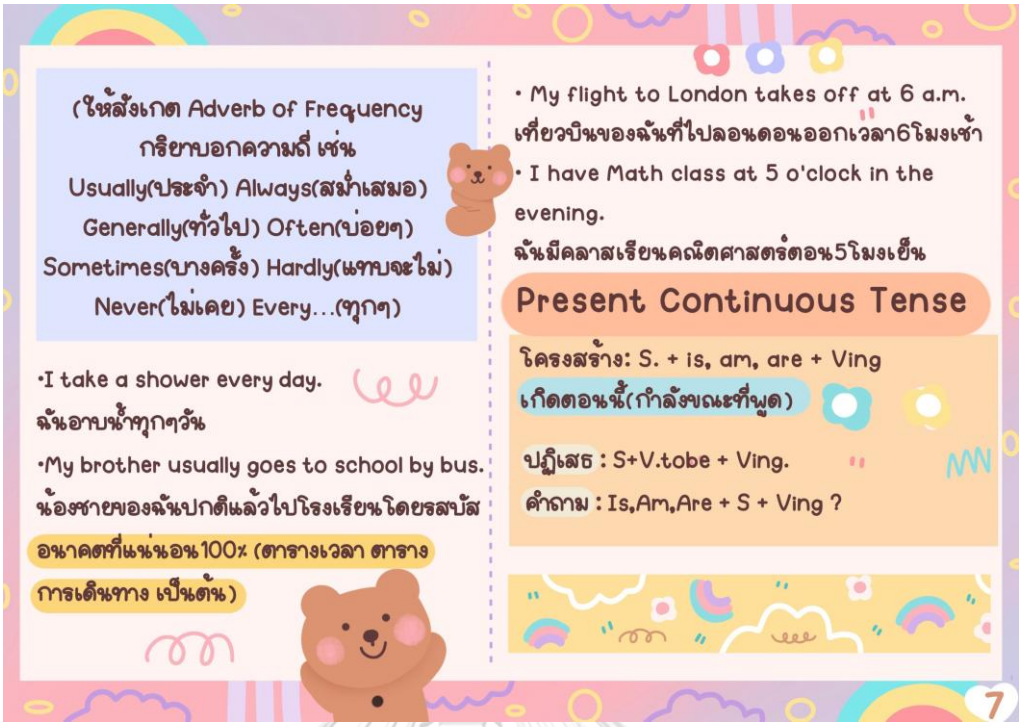


Figure A2.2 Example of English infographic

A3. Example of Tobacco infographic

Figure A3.1 Example of Tobacco infographic

Figure A3.2 Example of Tobacco infographic

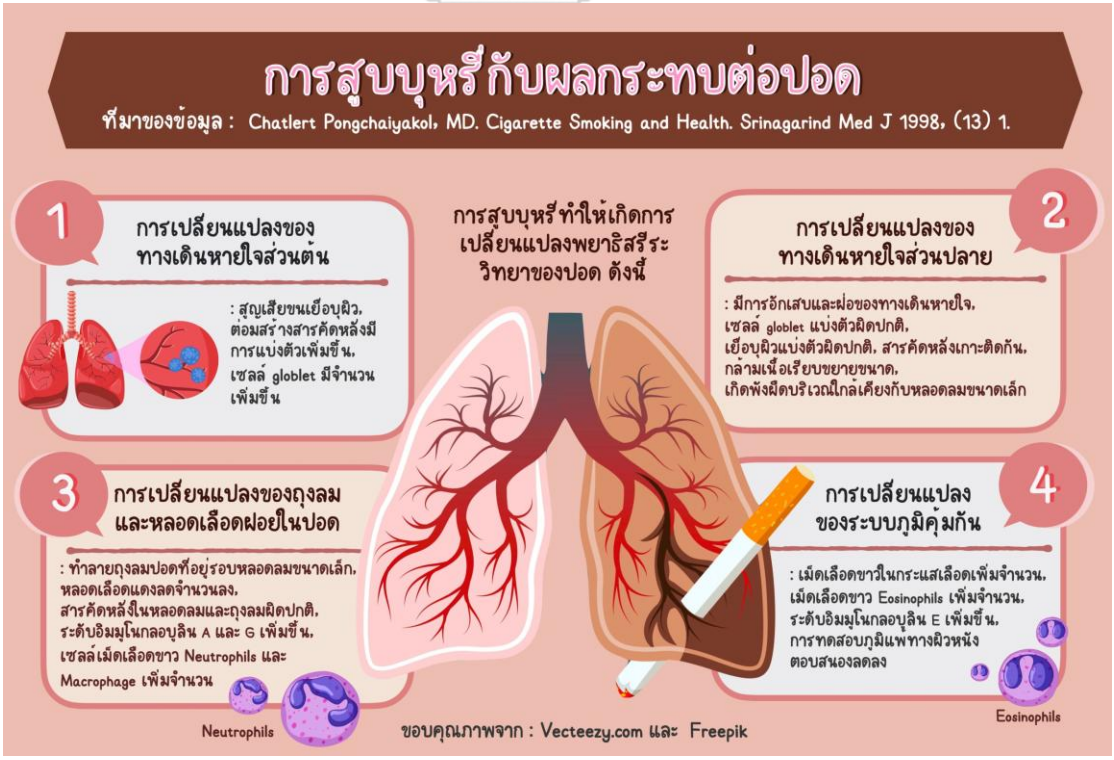


Figure A3.3 Example of Tobacco infographic

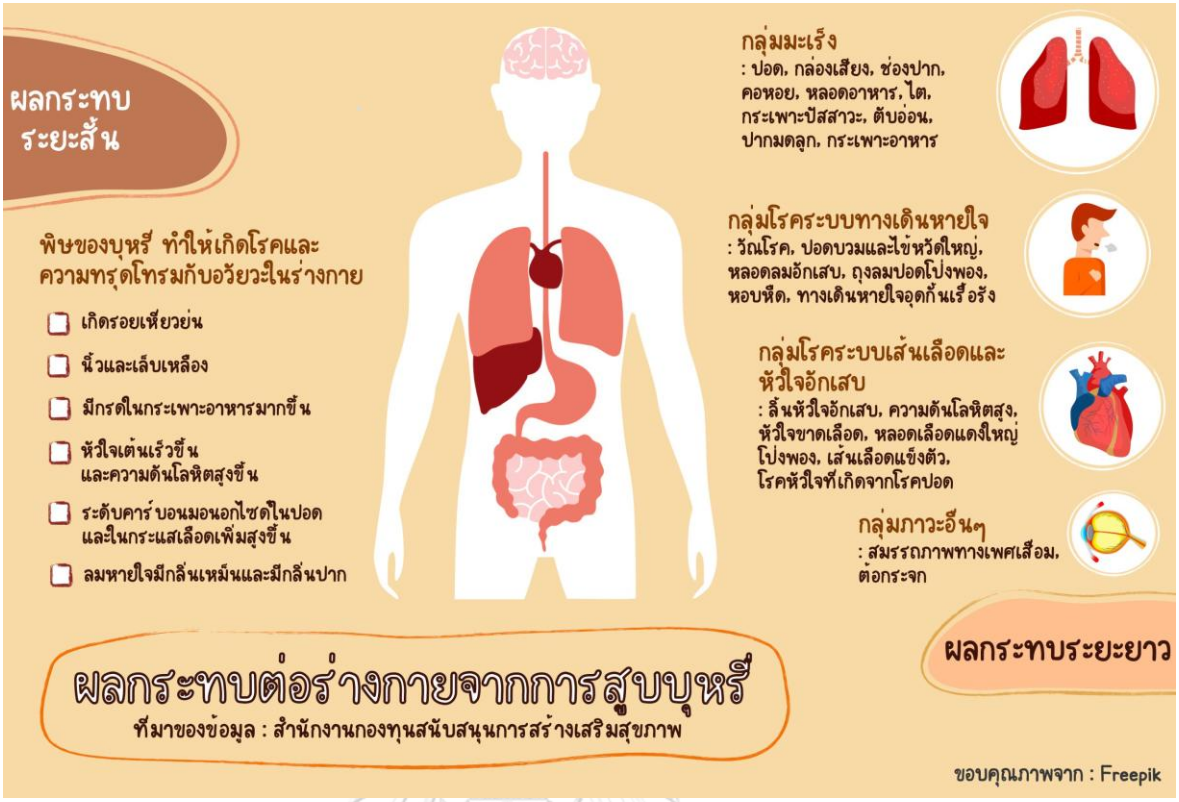


Figure A3.4 Example of Tobacco infographic

A4. Example of Alcohol infographic

Figure A4.1 Example of Tobacco infographic

Figure A4.2 Example of Tobacco infographic

Figure A4.3 Example of Tobacco infographic

Figure A4.4 Example of Tobacco infographic

Appendix B: Questionnaires

ส่วนที่ 1: ข้อมูลส่วนบุคคล

<u>คำชี้แจง</u>กลุ่มตัวอย่างอ่านข้อความแล้วเขียนเครื่องหมาย ✓ หรือตอบคำถามลงในช่องให้ตรงกับความเป็นจริงของกลุ่มตัวอย่าง

ข้อมูลส่วนบุคคลของกลุ่มตัวอย่าง

1. อายุ ..... ปี ..... เดือน
2. เพศ ( ) ชาย ( ) หญิง
3. น้ำหนัก ..... กิโลกรัม ส่วนสูง .....เซนติเมตร
   ความหนาของไขมันใต้ผิวหนัง .....
4. พฤติกรรมการรับประทานอาหาร
   4.1 ปกติท่านรับประทานอาหารกี่มื้อต่อวัน..... มื้อ
   4.2 ในแต่ละมื้อท่านรับประทานผักหรือไม่ ( ) ไม่กิน ( ) กิน
   4.3 ในแต่ละวันท่านรับประทานผลไม้หรือไม่ ( ) ไม่กิน ( ) กิน
   4.4 ท่านดื่มชา กาแฟ น้ำอัดลมหรือไม่ ( ) ไม่ดื่ม ( ) ดื่ม ..... แก้ว/วัน
   4.5 ท่านรับประทานอาหารเสริมหรือวิตามินอื่นๆ เพิ่มเติมหรือไม่
   ( ) ไม่กิน ( ) กิน จำนวน..... ชนิด อาหารเสริมที่กิน .....
5. เฉลี่ยเวลาในการนอนของท่านแต่ละวัน .....ชั่วโมง
6. ท่านมีการเคลื่อนไหวร่างกายหรือออกกำลังกายหรือไม่ ( ) ไม่ได้ทำ ( ) ทำ
   หากท่านมีการเคลื่อนไหวร่างกายหรือออกกำลังกาย (หากไม่ได้ทำให้ข้ามไป)
   6.1 ชนิดของการเคลื่อนไหวร่างกายหรือออกกำลังกาย .....
   6.2 ความถี่ของการเคลื่อนไหวร่างกายหรือออกกำลังกาย .....วัน/ สัปดาห์
   6.3 เวลาในการเคลื่อนไหวร่างกายหรือออกกำลังกาย .....นาที
7. ท่านได้เรียนพิเศษหรือเรียนเสริมนอกเวลาหรือไม่ ( ) ไม่ได้เรียน ( ) เรียน
   หากท่านได้เรียนพิเศษหรือเรียนเสริมนอกเวลา (หากไม่ได้เรียนให้ข้ามไป)
   7.1 รายวิชาที่เรียนพิเศษ .....
   7.2 เวลารวมในการเรียนพิเศษทุกรายวิชา ..... ชั่วโมง .....นาที

8. ภายในระยะเวลา 6 เดือนที่ผ่านมา ท่านเคยเล่นเกมหรือไม่ ( ) ไม่เล่น ( ) เล่น

หากท่านเคยเล่นเกม (หากไม่ได้ทำให้ข้ามไป)

8.1 เกมที่ท่านเล่นเป็นเกม (ตอบได้มากกว่า 1 ข้อ) ( ) Offline ( ) Online

8.2 ชนิดของเกมที่ท่านเล่น (ตอบได้มากกว่า 1 ข้อ)

( ) Role playing game (RPG) ( ) MMORPG

( ) Simulations ( ) Adventure

( ) Adventure ( ) Sports

( ) Educational ( ) อื่นๆ

โปรดระบุ.....

8.3 เวลารวมในการเล่นเกม ..... ชั่วโมง .....นาที

8.4 อุปกรณ์ที่ใช้ในการเล่นเกม .....

8.5 ปัจจุบันท่านยังเล่นเกมเหล่านั้นหรือไม่

( ) ไม่ได้เล่นแล้ว ( ) เล่นบางเวลา

( ) เล่นเป็นประจำ โปรดระบุเวลา ..... ชั่วโมง .....นาที

ข้อมูลส่วนบุคคลของผู้ปกครอง

ข้อมูลส่วนบุคคลของบิดา

1. อายุ ..... ปี ..... เดือน

2. ระดับการศึกษา .....

3. อาชีพ .....

4. รายได้เฉลี่ยต่อเดือน .....บาท

ข้อมูลส่วนบุคคลของมารดา

1. อายุ ..... ปี ..... เดือน

2. ระดับการศึกษา .....

3. อาชีพ .....

4. รายได้เฉลี่ยต่อเดือน .....บาท

5. เวลาเฉลี่ยที่ทำกิจกรรมหรือพูดคุยกับลูกในแต่ละวัน .....

Appendix C: Lucid Recall

1. Word Recall test

Detail of Word Recall test: child hears sequences of words through the computer speakers/ headphones. They are then required to recall the words in the same order in which they were presented, using the computer mouse to select (i.e. click on) the target words from within a 3 x 3 matrix of nine words on the computer screen.

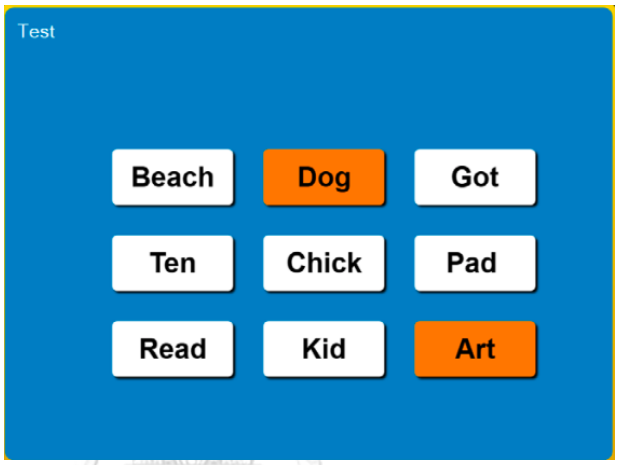


Figure C1 Example screen from the Word Recall test

2. Pattern Recall

Detail of Pattern Recall test: child sees a matrix pattern of filled (black) and unfilled (white) squares on the computer screen. When the pattern disappears they are presented with a blank matrix of all white squares and they are then required to recreate the pattern by using the computer mouse to click on the squares to be filled.

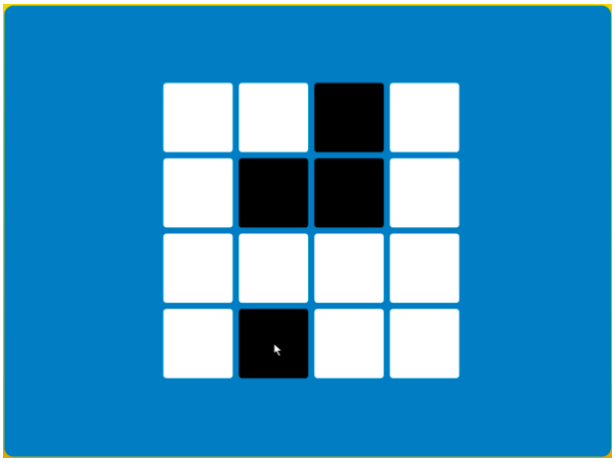


Figure C2 Example screen from the Pattern Recall

3. Counting Recall

Detail of Counting Recall test : this is a test of central executive functioning that involves carrying out a sequence of between two and six independent counting tasks whilst simultaneously remembering the results of each count in the same order. In each count the child is presented with an array of different shapes, the numbers and locations of which are randomly generated, and is required to count the number of red circles, using the computer mouse to select the correct answer at the bottom of the screen. At the end of each item (i.e. sequence) they are asked to recall the number of red circles in each counting array, in the same order in which they were presented.

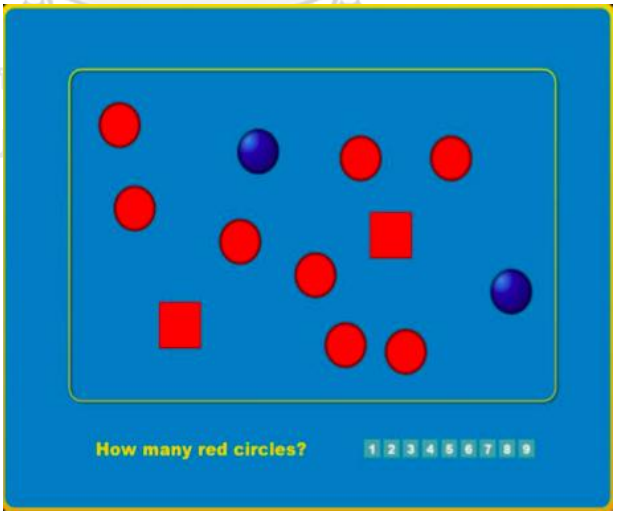


Figure C3 Example screen from the Counting recall test

* It usually takes about 20–30 minutes for most children to complete the three tests in Lucid Recall.

Appendix D: แบบคัดกรองประสบการณ์การดื่มสุรา สูบบุหรี่และใช้สารเสพติด (ASSIST)

ข้อแนะนำ (กรุณาอ่านให้ผู้รับบริการฟัง)

- คำถามต่อไปนี้เกี่ยวกับประสบการณ์ของคุณในการใช้เครื่องดื่มแอลกอฮอล์ ผลิตภัณฑ์ยาสูบ และสารเสพติดชนิดอื่นๆ ตลอดชีวิตของคุณและภายในสามเดือนที่ผ่านมา สารเสพติดเหล่านี้อาจจะใช้โดยการสูบ กลืน นัด สูดดม ฉีดหรือกินเป็นยาเม็ดก็ได้ (แสดงบัตรคำตอบ)
- คุณอาจได้รับสารเสพติดเหล่านี้บางชนิดโดยแพทย์สั่งให้ (เช่น ยากล่อมประสาท ยาแก้ปวด ในการสัมภาษณ์ครั้งนี้ เราจะไม่รวมถึงยาต่างๆ ที่คุณได้รับจากแพทย์ อย่างไรก็ตาม ถ้าคุณใช้ยาเหล่านี้ด้วยเหตุผลอื่นนอกเหนือจากที่แพทย์สั่ง หรือใช้บ่อยกว่าหรือปริมาณมากกว่าที่แพทย์สั่ง กรุณาแจ้งให้ผู้สัมภาษณ์ทราบด้วย
- คำถามเหล่านี้จะรวมถึงการใช้สารเสพติดที่ผิดกฎหมายของคุณ โปรดมั่นใจว่าเราจะเก็บข้อมูลที่เกี่ยวกับการใช้สารเสพติดของคุณเป็นความลับที่สุด

หมายเหตุ : ก่อนถามคำถาม ให้บัตรคำตอบ ASSIST แก่ผู้รับบริการ

คำถามที่ 1 (โปรดกาคำตอบในช่องของสารเสพติดแต่ละชนิด)		
ในชีวิตของคุณ คุณเคยใช้สารเสพติดต่อไปนี้หรือไม่ (การใช้นอกเหนือจากแพทย์สั่ง)		
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	เคย	ไม่เคย
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	เคย	ไม่เคย
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	เคย	ไม่เคย
d. โคเคน (โค้ก แคร็ก ฯลฯ)	เคย	ไม่เคย
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	เคย	ไม่เคย
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	เคย	ไม่เคย
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโนโซแลม ฯลฯ)	เคย	ไม่เคย
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	เคย	ไม่เคย
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟีน โคเดอีน ฯลฯ)	เคย	ไม่เคย
j. สารเสพติดอื่นๆ ระบุ.....	เคย	ไม่เคย

ถามเพิ่มเติมหากทุกข้อตอบว่า ไม่เคย: “ไม่เคยเลยแม้กระทั่งตอนที่คุณยังเรียนหนังสืออยู่หรือ”	ถ้าตอบ “ไม่เคย” ทุกข้อ จบการสัมภาษณ์ ถ้าตอบ “เคย” ข้อใดข้อหนึ่ง ถามคำถามที่ 2 ต่อสำหรับสารเสพติดแต่ละชนิดที่เคยใช้

คำถามที่ 2					
ในช่วงสามเดือนที่ผ่านมา คุณใช้สาร..... (สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ) บ่อยเพียงไร	ไม่เคย	1-2 ครั้ง	ทุกเดือน	ทุกสัปดาห์	เกือบทุกวัน
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	2	3	4	6
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	2	3	4	6
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	0	2	3	4	6
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	2	3	4	6
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	2	3	4	6
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	2	3	4	6
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	2	3	4	6
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	2	3	4	6
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟีน โคเดอีน ฯลฯ)	0	2	3	4	6
j. สารเสพติดอื่นๆ ระบุ.....	0	2	3	4	6
ถ้าตอบ “ไม่เคย” ใช้สารทุกตัวในคำถามที่ 2 ให้ข้ามไปคำถามที่ 6 ถ้าเคยใช้สารเสพติดชนิดใดชนิดหนึ่งในสามเดือนที่ผ่านมา ให้ถามคำถามที่ 3,4,5 สำหรับสารเสพติดแต่ละชนิดที่เคยใช้ไป					

คำถามที่ 3					
<u>ในช่วงสามเดือนที่ผ่านมา</u> คุณเคยรู้สึกอยากที่จะใช้สาร.... *(สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ)* อย่างรุนแรง บ่อยเพียงไร	ไม่เคย	1-2 ครั้ง	ทุกเดือน	ทุกสัปดาห์	เกือบทุกวัน
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	3	4	5	6
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	3	4	5	6
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	0	3	4	5	6
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	3	4	5	6
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	3	4	5	6
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	3	4	5	6
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	3	4	5	6
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	3	4	5	6
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟีน โคเดอีน ฯลฯ)	0	3	4	5	6
j. สารเสพติดอื่นๆ ระบุ.....	0	3	4	5	6

คำถามที่ 4					
<u>ในช่วงสามเดือนที่ผ่านมา</u> การใช้สาร....*(สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ)* ทำให้เกิดปัญหาสุขภาพ ครอบครัว สังคม กฎหมาย หรือการเงินกับคุณบ่อยเพียงไร	ไม่เคย	1-2 ครั้ง	ทุกเดือน	ทุกสัปดาห์	เกือบทุกวัน
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	4	5	6	7
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	4	5	6	7
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	0	4	5	6	7
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	4	5	6	7
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	4	5	6	7
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	4	5	6	7
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	4	5	6	7
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	4	5	6	7
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟีน โคเดอีน ฯลฯ)	0	4	5	6	7
j. สารเสพติดอื่นๆ ระบุ.....	0	4	5	6	7

คำถามที่ 5					
<u>ในช่วงสามเดือนที่ผ่านมา</u> คุณไม่สามารถทำกิจกรรมที่คุณควรจะทำได้ตามปกติเนื่องจากคุณใช้สาร...*(สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ)* บ่อยเพียงไร	ไม่เคย	1-2 ครั้ง	ทุกเดือน	ทุกสัปดาห์	เกือบทุกวัน
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	5	6	7	8
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	5	6	7	8
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	0	5	6	7	8
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	5	6	7	8
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	5	6	7	8
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	5	6	7	8
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	5	6	7	8
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	5	6	7	8
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟีน โคเดอีน ฯลฯ)	0	5	6	7	8
j. สารเสพติดอื่นๆ ระบุ.....	0	5	6	7	8
ถามคำถามที่ 6 และ 7 สำหรับสารเสพติดทุกชนิดที่เคยใช้ (สารเสพติดที่ตอบว่า "เคยใช้" ในคำถามที่ 1)					

คำถามที่ 6			
เพื่อนฝูง ญาติหรือคนอื่นเคยแสดงความกังวลหรือตักเตือนคุณเกี่ยวกับการใช้สาร... *(สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ)* ของคุณหรือไม่	ไม่เคย	เคย, ภายใน 3 เดือนนี้	เคย, ก่อน 3 เดือนนี้
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	6	3
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	6	3
c. กัญชา (กัญชาแห้ง ยางกัญชา กัญชาน้ำ ฯลฯ)	0	6	3
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	6	3
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	6	3
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	6	3
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	6	3
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	6	3
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟิน โคเดอีน ฯลฯ)	0	6	3
j. สารเสพติดอื่นๆ ระบุ.....	0	6	3
ถามคำถามที่ 6 และ 7 สำหรับสารเสพติดทุกชนิดที่เคยใช้ (สารเสพติดที่ตอบว่า "เคยใช้" ในคำถามที่ 1)			

คำถามที่ 7			
คุณเคยพยายามหยุดหรือใช้สาร...*(สารชนิดที่หนึ่ง สารชนิดที่สอง ฯลฯ)* ให้น้อยลงแต่ทำไม่สำเร็จ หรือไม่	ไม่เคย	เคย, ภายใน 3 เดือนนี้	เคย, ก่อน 3 เดือนนี้
a. ผลิตภัณฑ์ยาสูบ (บุหรี่ ยาเส้นแบบเคี้ยว ซิการ์ ฯลฯ)	0	6	3
b. เครื่องดื่มแอลกอฮอล์ (สุรา เบียร์ ไวน์)	0	6	3
c. กัญชา (กัญชาแห้ง ยากัญชา น้ำกัญชา ฯลฯ)	0	6	3
d. โคเคน (โค้ก แคร็ก ฯลฯ)	0	6	3
e. ยากระตุ้นประสาทกลุ่มแอมเฟตามีน (ยาบ้า ยาอี ไอซ์ สปีด ยาลดความอ้วน ฯลฯ)	0	6	3
f. สารระเหย (กาว ทินเนอร์ เบนซิน ไนตรัส ฯลฯ)	0	6	3
g. ยากล่อมประสามหรือยานอนหลับ (วาเลี่ยม โรฮิปนอล ดอมิกุม มาโน โซแลม ฯลฯ)	0	6	3
h. ยาหลอนประสาท (แอลเอสดี แอซิด เห็ดเมา พีซีพี ยาเค ฯลฯ)	0	6	3
i. สารกลุ่มฝิ่น (ฝิ่น เฮโรอีน มอร์ฟีน เมทาโดน บูพรีนอฟิน โคเดอีน ฯลฯ)	0	6	3
j. สารเสพติดอื่นๆ ระบุ.....	0	6	3
ถามคำถามที่ 6 และ 7 สำหรับสารเสพติดทุกชนิดที่เคยใช้ (สารเสพติดที่ตอบว่า "เคยใช้" ในคำถามที่ 1)			

คำถามที่ 8			
คุณเคยใช้สารเสพติดใดๆ โดยการฉีดหรือไม่ (การใช้นอกเหนือจากแพทย์สั่ง)	ไม่เคย	เคย, ภายใน 3 เดือนนี้	เคย, ก่อน 3 เดือนนี้
(โปรดกาที่คำตอบ)			

Appendix E: PISA

คำชี้แจง

ในแบบทดสอบชุดนี้ นักเรียนจะพบคำถามเกี่ยวกับคณิตศาสตร์

ให้นักเรียนอ่านคำถามทุกข้ออย่างละเอียดรอบคอบ แล้วตอบคำถามให้ดีที่สุดเท่าที่จะทำได้

บางคำถามจะมีคำตอบให้เลือกสี่คำตอบหรือมากกว่า แต่ละคำตอบจะมีตัวเลขแสดงอยู่ข้างหน้า คำถามประเภทนี้ ให้นักเรียนวงกลมล้อมรอบตัวเลขที่อยู่หน้าคำตอบที่นักเรียนคิดว่าถูกต้อง

บางข้อมีคำถามให้นักเรียนตอบหลายคำตอบ โดยให้วงกลมล้อมรอบคำตอบเดียวในแต่ละแถว

สำหรับคำถามอื่นๆ นักเรียนจะต้องเขียนคำตอบสั้นๆ ในที่ว่างที่เตรียมไว้ในแบบทดสอบของนักเรียน คำถามเหล่านี้นักเรียนอาจต้องเขียนคำตอบเป็นตัวหนังสือ วาดภาพ และ/หรือเขียนตัวเลข

บางคำถามต้องการให้นักเรียนอธิบายคำตอบหรือให้เหตุผลประกอบคำตอบของนักเรียน คำถามเหล่านี้มีคำตอบถูกได้หลายคำตอบ นักเรียนจะได้คะแนนจากวิธีที่นักเรียนแสดงความเข้าใจของนักเรียนที่มีต่อคำถาม และลักษณะการคิดที่นักเรียนแสดงออกมา นักเรียนควรเขียนคำตอบของนักเรียนในเส้นบรรทัดที่กำหนดไว้ให้ จำนวนเส้นบรรทัดจะเป็นตัวบอกความยาวอย่างคร่าวๆ ที่นักเรียนควรเขียนตอบ

สำหรับโจทย์คณิตศาสตร์ บางครั้งจะมีพื้นที่ว่างแทนเส้นบรรทัดสำหรับให้นักเรียนเขียนคำตอบ ให้นักเรียนใช้พื้นที่ว่างนั้นแสดงวิธีทำทั้งหมด

บางคำถาม จะมีการใช้หน่วยของเงินที่สมมติขึ้นเป็น "เซด" ซึ่งหน่วยของเงินนี้ใช้กับประเทศที่สมมติขึ้นคือประเทศ "เซดแลนด์"

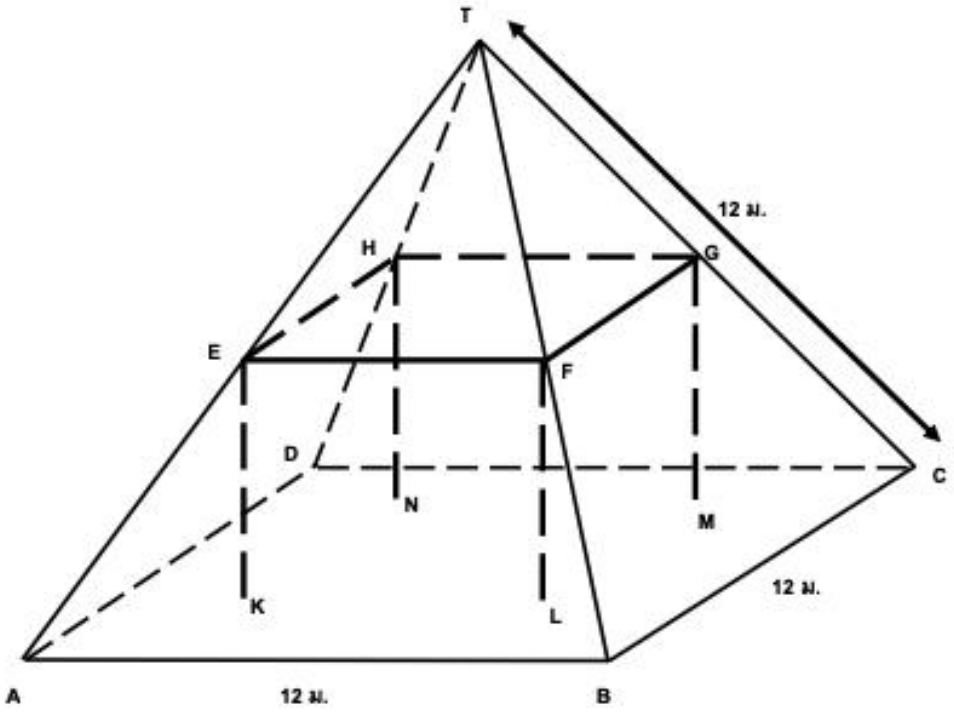
มีตารางสูตรใส่ให้ไว้ที่ด้านในของปกหน้าของแบบทดสอบ เพื่อใช้ในการทำโจทย์คณิตศาสตร์

*ข้อสอบคณิตศาสตร์เหล่านี้ เป็นข้อสอบที่เคยถูกนำมาใช้ในการประเมินของโครงการประเมินผลนักเรียนนานาชาติ (**P**rogramme for **I**nternational **S**tudent **A**ssessment หรือ **PISA**) ซึ่งบางข้อถูกใช้ในการประเมินผลจริง และบางข้อถูกใช้ในการทดลองภาคสนาม ทั้งนี้ ข้อสอบเหล่านี้ยอมให้เผยแพร่ต่อสาธารณชนแล้ว*

โรงงาน

โรงงานหลังหนึ่งมีหลังคาเป็นทรงพีระมิด ดังรูป

และข้างล่างเป็นรูปที่นักเรียนคณิตศาสตร์ ทำแบบจำลองของ**หลังคา** พร้อมกับบอกระยะกำกับไว้ด้วย



พื้นเพดาน ABCD เป็นสี่เหลี่ยมจัตุรัส คานที่รองรับน้ำหนักของหลังคา คือขอบของรูปเหลี่ยมทรงตัน EFGHKLMN (ปริซึมรูปสี่เหลี่ยม) E เป็นจุดกึ่งกลางของส่วนของเส้น AT จุด F เป็นจุดกึ่งกลางของส่วนของเส้นตรง BT จุด G เป็นจุดกึ่งกลางของส่วนของเส้นตรง CT จุด H เป็นจุดกึ่งกลางของส่วนของเส้นตรง DT สันของพีระมิดทุกด้าน ยาว 12 เมตรเท่ากัน

คำถามที่ 1 : โรงงาน

จงคำนวณพื้นเพดาน ABCD

พื้นที่ของพื้นเพดาน ABCD = _____ ตารางเมตร

คำถามที่ 2 : โรงงาน

จงคำนวณความยาวของส่วนของเส้นตรง EF

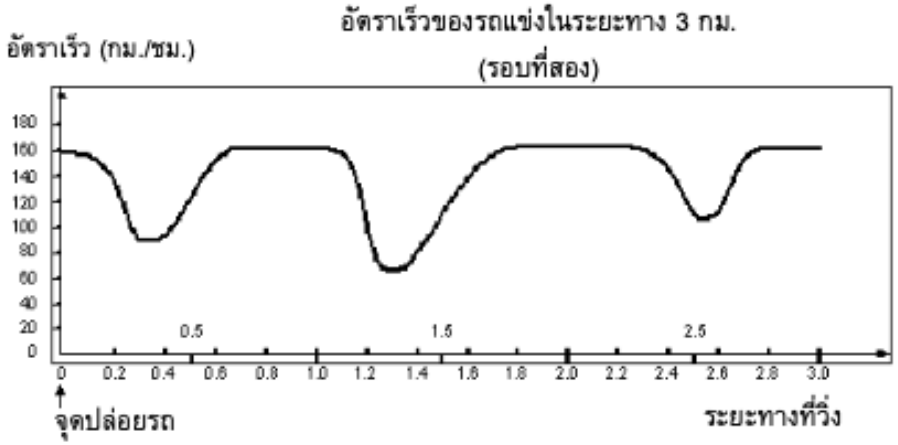
ความยาวของส่วนของเส้นตรง EF = _____ เมตร

คำถามที่ 3 : พื้นทวีป

จงหาค่าโดยประมาณของพื้นที่ของทวีปแอนตาร์กติก โดยใช้มาตราส่วนในแผนที่อธิบายวิธีการประมาณหาพื้นที่นี้ด้วย (นักเรียนสามารถลากเส้นในพื้นที่ที่กำหนดมาให้ได้ ถ้ามันจะช่วยให้การประมาณ ง่ายขึ้น)

ความเร็วของรถแข่ง

กราฟต่อไปนี้แสดงให้เห็นการเปลี่ยนแปลงความเร็วของรถแข่งคันหนึ่ง ที่วิ่งในสนามแข่งทางราบ ระยะทาง 3 กิโลเมตร



คำถามที่ 4 : รถแข่ง

ระยะทางโดยประมาณจากจุดปล่อยรถจนถึงจุดเริ่มต้นของส่วนที่เป็นทางตรงยาวที่สุดของสนามแข่งเป็นระยะทางเท่าไหร่

1. 0.5 กิโลเมตร
2. 1.5 กิโลเมตร
3. 2.3 กิโลเมตร
4. 2.6 กิโลเมตร

คำถามที่ 5: รถแข่ง

อัตราเร็วที่ต่ำที่สุดในระยะที่สองของรถแข่งคันนี้เกิดขึ้น ณ จุดไหน

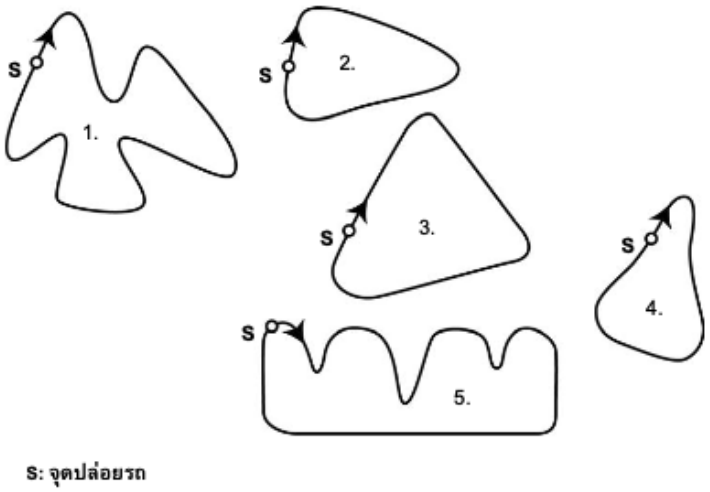
1. ที่จุดเริ่มต้น
2. ที่ประมาณกิโลเมตรที่ 0.8
3. ที่ประมาณกิโลเมตรที่ 1.3
4. ครึ่งสอบสนาม

คำถามที่ 6: รถแข่ง

อัตราเร็วของรถแข่งระหว่างกิโลเมตรที่ 2.6 และกิโลเมตรที่ 2.8 เป็นอย่างไร

1. อัตราเร็วคงที่
2. อัตราเร็วเพิ่มขึ้น
3. อัตราเร็วลดลง
4. ไม่สามารถบอกอัตราเร็วได้จากกราฟ

คำถามที่ 7: รถแข่ง



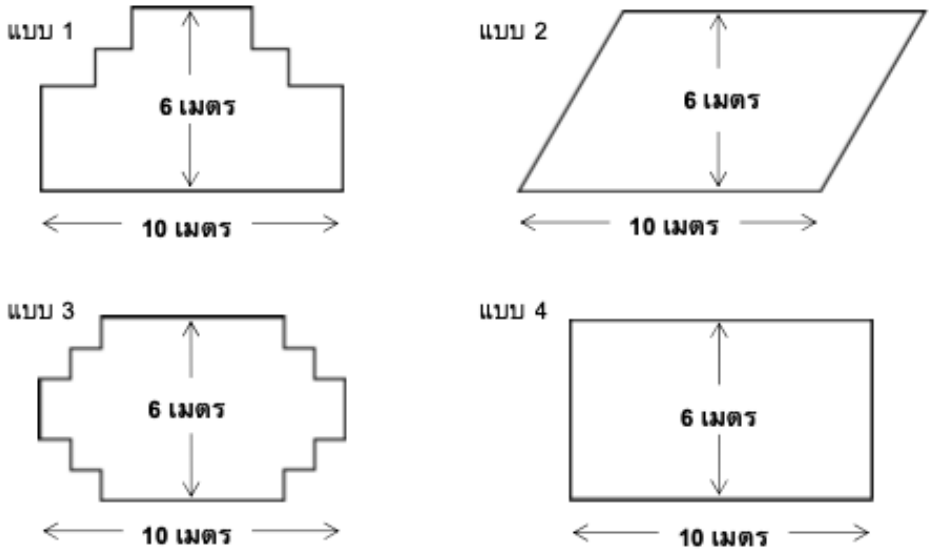
S: จุดปล่อยรถ

ภาพต่อไปนี้ คือ ทางวิ่งของสนามแข่งรถห้าแบบด้วยกัน

สนามแข่งรถที่ทำให้รถมีอัตราเร็วสอดคล้องกับกราฟข้างต้น สนามแข่งควรจะมีลักษณะอย่างไร

คำถามที่ 8: ช่างไม้

ช่างไม้มีกระดานยาว 32 เมตร และต้องการใช้ไม้นี้ล้อมกรอบสวนหย่อม
เขามีแบบสวนหย่อมที่คิดไว้ 4 แบบ ดังนี้



จงเขียนวงกลมรอบคำว่า “ใช่” หรือ “ไม่ใช่

แบบสวนหย่อม	ตามแบบนี้สามารถล้อมกรอบสวนหย่อมด้วยไม้ 32 เมตร ได้ ใช่หรือไม่
แบบ 1	ใช่ / ไม่ใช่
แบบ 2	ใช่ / ไม่ใช่
แบบ 3	ใช่ / ไม่ใช่
แบบ 4	ใช่ / ไม่ใช่

คำถามที่ 9: แบบทดสอบวิทยาศาสตร์

ครูวิทยาศาสตร์ในโรงเรียนของเหม่ย หลิง ได้ทดสอบวิทยาศาสตร์โดยมีคะแนนเต็มชุดละ 100 คะแนน เหม่ย หลิง ได้คะแนนเฉลี่ยจากแบบทดสอบวิทยาศาสตร์สี่ชุดแรก เท่ากับ 60 คะแนน ส่วนชุดที่ 5 เธอทำได้ 80 คะแนน

ค่าเฉลี่ยของคะแนนแบบทดสอบวิทยาศาสตร์ทั้งห้าชุดของ เหม่ย หลิง เท่ากับเท่าใด

ค่าเฉลี่ย : _____

เวลาในการตอบสนอง

ในการวิ่งอย่างเต็มกำลังครั้งหนึ่ง 'เวลาในการตอบสนอง' คือช่วงเวลาตั้งแต่เริ่มยิงปืนจนถึงเวลาที่นักกีฬาออกจากจุดเริ่มต้น และ 'เวลารวมสุดท้าย' คือผลรวมของเวลาการตอบสนองและเวลาวิ่ง

ตารางต่อไปนี้แสดงเวลาในการตอบสนองและเวลารวมสุดท้ายของนักวิ่ง 8 คนในการแข่งขันวิ่ง 100 เมตร

ลู่วิ่งที่	เวลาในการตอบสนอง (วินาที)	เวลารวมสุดท้าย (วินาที)
1	0.147	10.09
2	0.136	9.99
3	0.197	9.87
4	0.180	ไม่จบการแข่งขัน
5	0.210	10.17
6	0.216	10.04
7	0.174	10.08
8	0.193	10.13

คำถามที่ 10: เวลาในการตอบสนอง

จงหาผู้ที่ได้เหรียญทอง เหรียญเงิน และเหรียญทองแดง จากการแข่งขันครั้งนี้ จงเติมคำตอบลงในตารางว่าลู่วิ่งใดได้เหรียญรางวัล พร้อมทั้งเวลาในการตอบสนองและเวลารวมสุดท้าย

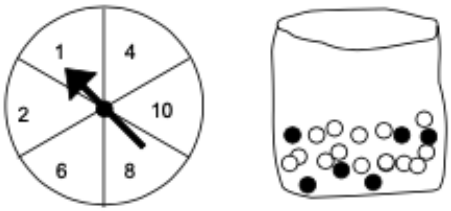
เหรียญ	ลู่วิ่งที่	เวลาในการตอบสนอง (วินาที)	เวลารวมสุดท้าย (วินาที)
ทอง			
เงิน			
ทองแดง			

คำถามที่ 11: เวลาในการตอบสนอง

ทุกวันนี้ไม่มีคนใดสามารถทำเวลาการตอบสนองได้น้อยกว่า 0.110 วินาที ถ้าการบันทึกเวลาในการตอบสนองของนักวิ่งน้อยกว่า 0.110 วินาทีแล้ว ต้องมีการพิจารณาว่ามีข้อผิดพลาดของการเริ่มวิ่งเกิดขึ้น เพราะว่านักวิ่งต้องออกวิ่งจากจุดเริ่มต้นก่อนได้ยินเสียงปืน ถ้าผู้ได้เหรียญทองทำเวลาในการตอบสนองได้เร็วขึ้น เขาจะมีโอกาสที่จะได้เหรียญเงินหรือไม่ ให้อธิบายสนับสนุนคำตอบ

คำถามที่ 12: งานวัด

ร้านเล่นเกมร้านหนึ่งในงานวัด การเล่นเกมนี้เริ่มด้วยหมุนวงล้อ ถ้าวงล้อหยุดที่เลขคู่ ผู้เล่นจะได้หยิบลูกหินในถุง วงล้อและลูกหินที่อยู่ในถุง แสดงในรูปข้างล่างนี้



ผู้เล่นจะได้รับรางวัลเมื่อเขาหยิบได้ลูกหินสีดำ สมพรเล่นเกม 1 ครั้ง ความเป็นไปได้ที่สมพรจะได้รับรางวัลเป็นอย่างไร

1. เป็นไปไม่ได้ที่จะได้รับรางวัล
2. เป็นไปได้น้อยมากที่จะได้รับรางวัล
3. จะได้รับรางวัลประมาณ 50%
4. เป็นไปได้มากที่จะได้รับรางวัล
5. ได้รับรางวัลแน่นอน

คำถามที่ 13: ขยะ

ในการทำการบ้านเรื่องสิ่งแวดล้อม นักเรียนได้รวบรวมข้อมูลเกี่ยวกับระยะเวลาการสลายตัวของขยะ ชนิดต่างๆ ที่ประชาชนทิ้งได้ดังนี้

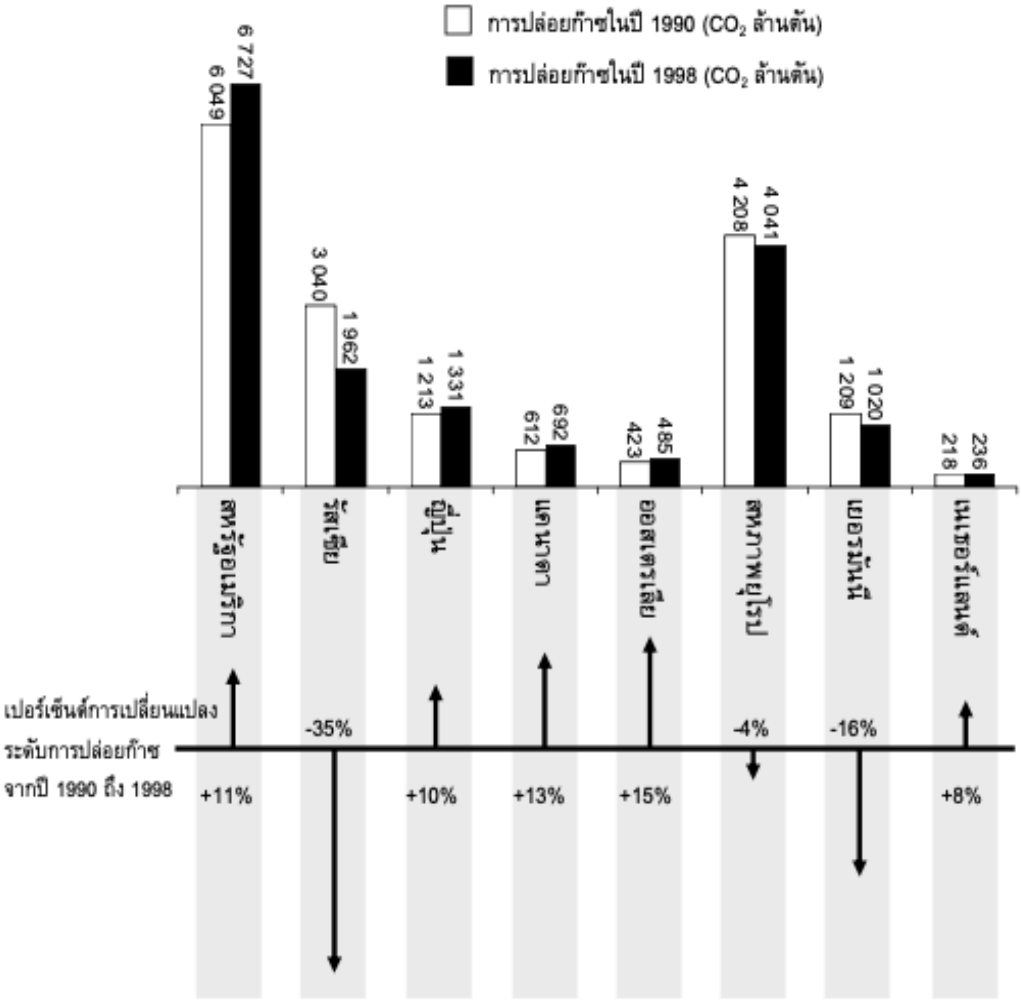
ชนิดของขยะ	**ระยะเวลาการสลายตัว**
เปลือกกล้วย	1-3 ปี
เปลือกส้ม	1-3 ปี
กล่องกระดาษแข็ง	0.5 ปี
หมากฝรั่ง	20-25 ปี
หนังสือพิมพ์	2-3 วัน
ถ้วยพลาสติก	มากกว่า 100 ปี

นักเรียนคนหนึ่งคิดที่จะแสดงข้อมูลเหล่านี้เป็นกราฟแท่ง
จงให้เหตุผลมาหนึ่งข้อว่า ทำไมกราฟแท่งจึงไม่เหมาะสมในการแสดงข้อมูลเหล่านี้

การลดระดับ CO_2

นักวิทยาศาสตร์หลายคน กลัวว่าการเพิ่มของก๊าซ CO_2 ในชั้นบรรยากาศของเรา ทำให้ภูมิอากาศเปลี่ยนแปลง

แผนผังด้านล่างแสดงระดับการปล่อยก๊าซ CO2 ในปี 1990 (แท่งไม่มีสี) ในประเทศ (หรือภูมิภาค) ต่าง ๆระดับการปล่อยก๊าซ CO2 ในปี 1998 (แท่งทึบ) และเปอร์เซ็นต์การเปลี่ยนแปลงระดับการปล่อยก๊าซ ระหว่างปี 1990 และ 1998 (แสดงด้วยลูกศร และตัวเลขเป็น %)



คำถามที่ 14: การลดระดับคาร์บอนไดออกไซด์

ในแผนผังอ่านได้ว่า การเพิ่มระดับการปล่อยก๊าซคาร์บอนไดออกไซด์ ในสหรัฐอเมริกา จากปี 1990 ถึง 1998 เป็น 11% จงแสดงการคำนวณว่าได้ 11% มาอย่างไร

คำถามที่ 15: การลดระดับคาร์บอนไดออกไซด์

มานีวิเคราะห์แผนผังและอ้างว่า เธอพบความผิดพลาดของเปอร์เซ็นการเปลี่ยนแปลงระดับการปล่อยก๊าซ “ค่าเปอร์เซ็นต์ลดลงในเยอรมัน (16%) มากกว่าเปอร์เซ็นที่ลดลงในสหภาพยุโรปทั้งหมด (ทั้งหมด 4%)” ซึ่งเป็นไม่ได้ เพราะเยอรมณีเป็นส่วนหนึ่งของสหภาพยุโรป นักเรียนเห็นด้วยกับมานีหรือไม่ว่า เป็นไปไม่ได้ พร้อมอธิบายสนับสนุนคำตอบด้วย

คำถามที่ 16: การลดระดับคาร์บอนไดออกไซด์

มานีและนพ อภิปรายกันว่าประเทศใด (ภูมิภาคใด) มีการปล่อยก๊าซคาร์บอนไดออกไซด์เพิ่มขึ้นมาที่สุด แต่ละคนลงข้อสรุปจากแผนผัง แต่ได้ข้อสรุปต่างกัน จงให้คำตอบที่น่าจะ “ถูกต้อง” สองคำตอบ และอธิบายว่าแต่ละคำตอบนั้นได้มาอย่างไร

คำถามที่ 17: การเต้นของหัวใจ

การเต้นของหัวใจ

ด้วยเหตุผลทางสุขภาพ มนุษย์ควรจำกัดการออกแรงทำสิ่งต่างๆ เช่น ระหว่างการเล่นกีฬา ทั้งนี้เพื่อไม่ให้ความถี่ของการเต้นของหัวใจสูงเกินขีดจำกัดหนึ่ง

หลายปีมาแล้วที่ความสัมพันธ์ระหว่างอัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็นกับอายุของคนให้เป็นไปตามสูตรนี้

อัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็น = 220 – อายุ

ผลการวิจัยเมื่อเร็วๆ นี้บอกว่า ควรมีการเปลี่ยนแปลงสูตรนี้เล็กน้อย สูตรใหม่เป็นดังนี้

อัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็น = 208 – (0.7 x อายุ)

บทความในหนังสือพิมพ์ระบุว่า “ผลของการใช้สูตรใหม่แทนสูตรเก่า คือ อัตราการเต้นสูงสุดของหัวใจต่อนาทีที่ควรจะเป็นในคนหนุ่มสาวลดลงเล็กน้อย และในคนสูงอายุกลับเพิ่มขึ้นเล็กน้อย” จากอายุเท่าไหร่ขึ้นไปที่อัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็นจะเพิ่มขึ้น เนื่องจากการใช้สูตรใหม่ จงแสดงวิธีทำด้วย

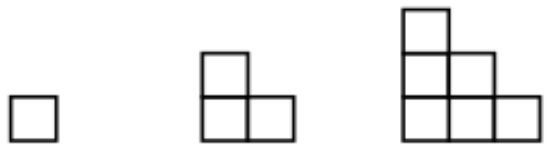
คำถามที่ 18: การเต้นของหัวใจ

สูตร อัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็น = 208 - (0.7 x อายุ) ใช้เพื่อวัดช่วงเวลาการฝึกซ้อม ที่มีประสิทธิภาพมากที่สุดด้วย ผลการวิจัยแสดงว่าการฝึกซ้อมมีประสิทธิภาพสูงสุด คือที่ 80% ของอัตราสูงสุดของการเต้นของหัวใจที่ควรจะเป็น จงเขียนสูตรสำหรับการคำนวณอัตราการเต้น ของหัวใจของการฝึกซ้อมที่มีประสิทธิภาพสูงสุด โดยให้แสดงในรูปของอายุด้วย

รูปแบบขั้นบันได

คำถามที่ 19 : รูปแบบขั้นบันได *M806Q01*

เรวัตสร้างรูปแบบขั้นบันไดโดยการใช้รูปสี่เหลี่ยมจัตุรัส ดังรูป



ขั้น 1 ขั้น 2 ขั้น 3

จะเห็นว่าเขาใช้รูปสี่เหลี่ยมหนึ่งรูปสำหรับบันได 1 ขั้น สามรูปสำหรับบันได 2 ขั้น และหกรูปสำหรับบันได 3 ขั้น

เขาจะต้องใช้รูปสี่เหลี่ยมจัตุรัสจำนวนกี่รูป เพื่อสร้างบันได 4 ขั้น

คำตอบ: ..... รูป

Appendix F: แบบทดสอบภาษาอังกฤษแบบเข้มเข้น ชั้นมัธยมศึกษาปีที่ 3

Directions: Read each situation and dialogue carefully and choose the appropriate expression to complete the dialogue.

1. Situation: In the room.

Bright: I'm afraid the radio was too loud.

Win: _____

A. OK. I'll turn it out.
B. All right. I'll turn it over.
C. Certainly. I'll turn it off.
D. I'm sorry. I'll turn it down.

2. **Situation:** Kit misses the bus and arrives at school late.

So, he says to a teacher "_____"

A. I'm so sorry.
B. I'm appreciated.
C. I'm glad to be here.
D. I'm afraid I can't study.

(3-4) Situation: On the phone

Mark: Hello! _____3_____

Jackson: I'm sorry. He's not in now. _____4_____

Mark: Of course. Please tell him "Mark" called and ask him to call me back soon.

Jackson: Ok. I will tell him when he gets back.

Mark: Thank you.

3. A. How about Bambam?
B. What is Bambam doing?
C. I want to speak to Bambam.
D. Could I speak to Bambam, please?

4. A. Can I take a message?
B. Who's calling, please?
C. Could you get the message?
D. Have you got the wrong number?

(5-8) Directions: Complete the following passage by choosing the best answer.

The Louvre was originally a royal palace. In 1516, Leonardo da Vinci came to France as a painter for the Royal Court, and ____5____ with him the painting of Mona Lisa. The King acquired it and it became a part of the royal ____6____. In the 1600s, the Louvre was a palace that contained art and rich decorations, and it only opened as a museum in 1793. The renovation of the museum in 1981 ____7____, and a pyramid was built as an entrance. Today, the Louvre is the world's largest museum and ____8____ the world's largest and richest collection of art and antiques from around the world.

5. A. brought B. was brought
   C. was bringing D. had been brought
6. A. creation B. collection
   C. invention D. construction
7. A. made it beautiful more B. it made beautiful more
   C. it made more beautiful D. made it more beautiful
8. A. produces B. becomes
   C. possesses D. belongs to

(9-10) Directions: Read the following table and choose the best answer.

Prayuth's Pet Store sells exotic and unusual pets. The chart below shows how many pets Prayuth's sold last month.

Type of Pet	Number Sold
Lizards	12
Ferrets	6
Snails	5
Fighting fish	8
snakes	9
Talking birds	11

9. According to the chart, which is **TRUE?**

A. Snails were sold the most.

B. Pimrypie sold 50 pets last month.

C. Ferrets and snails were sold less than lizards.

D. Pimrypie sold fight more than talking birds.

10. Which pet were sold more than eleven?

A. Snakes B. Lizards

C. Taking birds D. Ferrets and snails

(11-14) Directions: Read the following passages then choose the correct answer.

(11) It is very important to use water carefully. Here are some way you can use less water. First, you should be sure you turn off the faucet tightly They should not drip in the bathroom or kitchen sink. Second, you should not keep the water on for a long time. You should turn off while you are doing something else, It should be off while you are shaving or brushing your teeth, It should also be off while you are washing the dishes. Finally, int the summer you should water your garden in the evening. That way you will not lose a lot of water. During the day the sun dries up the earth too quickly.

11: Which is the best title of this passage?

A. Ways to Wash the Dishes B. Ways to Use Water Wisely

C. How to Turn off the Faucets D. How to Shave and Brush Your Teeth

12. Some words in English have the same sound, but you write them differently, and they mean different things. Take the word “won”, for example. Won has the same sound as the word “one” but it means something different ad it written differently. Another example is the word “write”. It has the same sound as the world right.

Q: Which is the best main idea of this passage?

A. Won has the same sound as the word one.

B. Write has the same sound as the word right.

C. Some English words have both the same sound and meaning.

D. Some English words have the same sound but different meaning.

(13-14) We could learn vocabulary while we are asleep. This is great new for language learners and word lovers. Researchers showed it is possible to learn new information while sleeping deeply, and recall this information later. The researchers did tests to see if a person can remember new words and their translations while they were asleep. The researchers said our sleeping brain is much more aware than we thought.

A researcher said, “language area of the brain and the…brain’s…memory were activated”after a person wakes up. These area of the brain remember vocabulary during sleep. During deep sleep, our brain is active for about half a second. It then switches off for half a second. The active state is called “up-state”. This is when our brain could learn new vocabulary. More research is needed to be sure that we can learn vocabulary while sleeping.

13. What is the purpose of the research study?

A. to confirm that our brain can learn while we are sleeping.

B. to present information how the brain works when we are sleeping.

C. to predict that the brain stops working while we are sleeping.

D. to give the evidence that our brain can learn when we are sleeping.

14. Which of following, what is **TRUE?**

A. The brain cannot remember a new word while we are sleeping.

B. The researcher proved that the brain isn’t active while we are sleeping.

C. The brain is able to remember the words while we are sleeping.

D. The researchers found that there is no evidence to support this research.

(15-20) Directions: Choose the answer which is grammatically incorrect.

15. **(1)** The period from the early 1960s to early 1980s, **(2)** when television **(3)** become more common, **(4)** is known as “New Hollywood.”

16. The Academy **(1)** Awards (or "Oscar") is **(2)** an example of an industry award-that is **(3)** to say, winners are chosen **(4)** by professionals within the film industry.

17. **(1)** Since ancient times, the benefits of applying facial masks **(2)** have been known to remove excess oil, **(3)** improve one's complexion, soften skin, and **(4)** moisturizer.

18. **(1)** American and Irish liquor producers **(2)** tend to favor the spelling whisky, while Canadian, **(3)** Scottish, and Japanese **(4)** producer tend to favor whisky.

19. Tomorrow will **(1)** probably be **(2)** cloud in the morning, the sun will come out **(3)** around midday, and **(4)** maybe it'll rain in the afternoon.

20. The **(1)** amount of water on the Earth stays **(2)** nearly the same because water is always moving and **(3)** change from liquid ti solid to gas **(4)** and then back to liquid again.

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