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Effect Of Lumosity Training Schedule On Recall Of Nonsense Syllables

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ABSTRACT

Randomized between subjects before-after experimental research design was adopted for incontestable establishment of cause-and-effect relationship between Lumosity training schedule and recall of nonsense syllables, if it exists. Learning is mainly a function of memory or recall. A random sample of 150 Tenth Grade students, each aged 15 years, was drawn for the investigation. They were randomized into five groups assigned different schedule of Lumosity Training as experimental conditions (daily 00, 06, 12, 18, and 24 minutes Lumosity training). The experimental treatment lasted for 60 days that was judged long enough for the training to cause some changes in the subjects, if at all Lumosity training could positively or negatively affect the subjects' memory or recall ability. The 60 brands of Lumosity brain enhancement games used as treatment conditions fall under seven different skills categories (8 on Problem-solving skills, 9 on Flexibility skills, 9 on Speed skills, 11 on Attention skills, 13 on Memory skills, 5 on Math skills, and 5 on Language skills). Results of data analysed with Analysis of covariance (ANCOVA) showed statistically significant effect of Lumosity training schedule on recall of nonsense syllables when the effect of the nonsense syllables Pre-test has been held constant or controlled for [$F(4, 144) = 126.725$, $p < .05$, Partial $\eta^2 = .779$]. To ascertain the pairwise mean differences that were significant statistically, Pairwise Multiple Comparisons done revealed significant Mean Difference between each pairwise means in favour of the group that had longer daily Lumosity training. Thus, Lumosity training schedule can be used to overwhelmingly improve recall or memory.

Keywords: Lumosity; Recall; Memory; Lumosity training schedule, Recall of nonsense syllables; Randomized between subjects before-after experimental design; Learning.

INTRODUCTION

Though to maximally learn in a perfectly unforgettable manner is an ultimate goal of man, no individual has been able to attain maximum learning. Research works and other efforts aimed at making man to learn in a totally unforgettable way have not yet produced the ultimately desired outcome. Recall, retrieval or memory of information previously encountered, processed and stored in the brain is critical in learning. The individual learner has total responsibility to learn, as none else can learn or recall learned information for him. Active involvement of the learner in learning process is indispensable as embedded in constructivism theory of leaning (Smorgansbord, 2011).

Great memory is necessary to learn faster, make more money, succeed better at school, work and society, and to be of much more demand in a world that is ever in need of efficient and effective services. Improvement of memory might be achieved easily chiefly by optimization of the health of the brain and by habitual adoption of good memory skills (Cherry, 2018; Elsevier, 2018). The health of the brain, like physical health, may be improved via the right online mental or brain boosting exercises. The efficacy or otherwise of Lumosity games is being experimentally tried out in the current study. Training the brain to rev up its health by daily

mental exercise may automatically improve a person's memory skills over time. As a matter of fact, brain boosting exercises that are worthy of the description or name, should have inbuilt mechanisms that can be able to typically enhance better memory skills in those who practice them over a relatively long period of time (Kpolovie, 2012). Brain training games that are indeed suitable for the purpose, must have been designed to improve memory, attention, seed, concentration, flexibility, and problem solving, math and language skills. The claim of Lumosity games in development of these skill areas for enhancement of information recall (Lumos Labs Inc., 2011; 2011a; 2011b; 2011c) is investigated in this study.

There are ways to improve recall of learned information (Human-Memory.net, 2018). They include chunking, use of mnemonic devices, encoding, rehearsal, attachment of meaning, and repetition (Todd, 2007), association of the new information with previously learnt material, and total attention. Brockis (2017) emphasized the need for use of loci method. The Loci Methodology for memory enhancement adopts visualizations via spatial memory, and familiar information within the individual's environment to very quickly recall needed information efficiently in an effortless manner. He asserted that everyone who wishes to, can immensely improve his recall or memory ability beyond the ordinary "not only can you improve your memory, you could take it all the way to the Memory Olympiad if you wanted."

Tireless research works have tried to establish Protein Kinase Mzeta (PKMzeta) as a most effective memory engine that guarantees faultless recall and totally prevents forgetting (Yong, 2011); but counter works soon disproved the claim. Kwapis and Helmstetter (2014) elaborately reviewed and outlined existing research works that are both for and against the potency of Protein Kinase Mzeta (PKMzeta) as a memory maintenance mechanism. They tried to strike a balance between pro-and-anti-PKMzeta investigations. The search for ways of making man to most efficiently learn and perfectly recall every learnt information has remained, and perhaps may continue to remain, a central focus; as the year when the desired goal will be attained is not yet at sight even in this revolutionary information communication and technology driven age (Kpolovie & Lale, 2017).

Over the last decade, scientists have found that active and unrelenting efforts are compulsory for maintaining intact memory (Kwapis & Helmstetter, 2014; Kpolovie, 2012). Information that is even encoded, rehearsed and firmly stored in the long-term memory is prone to being erased or buried so deeply beyond the point of easy recall as at when needed, if the information is not actively put into use frequently or from time to time. It is necessary to constantly create and develop the special protein that is like memory engine, called PKMzeta. PKMzeta that is the active engine of memory constantly wires each information to all others of both similar and dissimilar kinds in the brain. It is only when the memory engine (PKMzeta) is given regular boost that old memories are able to gain new lease of life. Performing of suitable brain training exercise is the sure and proven way of giving frequent boost to the memory engine. This is why it has since become very necessary to investigate the effect of Lumosity training schedule on recall, otherwise termed memory.

Kpolovie (2012) investigated the effects of Lumosity Training and Brain-Boosting Food on learning. Findings indicated that training the brain with Lumosity exercises or games significantly improved learning as the two experimental groups that received lumosity training twice a day significantly demonstrated learning more than the two groups that received brain-boosting food/supplements which in turn, learned significantly better than the two control groups in the study. As a follow-up, this current study investigates the effect of Lumosity Training Schedule on the recall or memory of nonsense syllables. A sample of Tenth Grade students of the same age was drawn for the investigation. They were randomized into five

groups that were randomly assigned different schedule of Lumosity Training (00 minute per day, 06 minutes per day, 12 minutes per day, 18 minutes per day, and 24 minutes per day) as experimental treatment conditions.

Individuals interested in realistically boosting their memory and information recall should necessarily make conscious efforts each day for improvement of recall and memory for a most successful living (Lumen Learning, 2018). Without frantic efforts in processing of information from sensory memory through short-term memory to long-term memory, information may not even get stored in the memory; and there cannot be anything like retrieval (recall) of information that was never in stored in the memory in the first place. To process novel information for long-term memory storage, a number of conscious or deliberate cognitive operations like explicit and implicit attentional capture; visual, acoustic, semantic, elaborative, chunking, organization, and mnemonic encoding as well as memory consolidation need to be done personally by each of the individuals (Lumen Learning, 2018). Different brain enhancing habits in accordance with the functional stipulations of memory-related theories and models should typically constitute their routine. Engagement in brain training games, using some of the several readily available scientifically proven online games (Kpolovie & Awusaku, 2016) such as Lumosity training (Kpolovie, 2012), Dual N-Back, NeuroNation, Happy Neuron, Sudoku, and other Increasing Brain Power (IBP) games for raising of intelligence quotient, should become part of their daily or weekly exercises.

Recall, otherwise termed retrieval, refers to the entire cognitive process of remembering or getting of information that has earlier been actively processed and stored firmly in the long-term memory out into consciousness for use as needed at the moment. The information recall process demands to be facilitated with cognitive operations such as the right information recognition, suitable retrieval cues, primacy effects, and appropriate order of information retrieval that prevents negative retroactive-cum-proactive-interference, wrong trace and the phenomenology known as tip-of-the-tongue. As part of the vigorous and enthusiastic role to be played by individuals desirous of enhancing their information retrieval, they have to actively avoid forgetting and its process (Lumen Learning, 2018b) from setting in and from affecting them in spite of the fact that memory is both fallible (may fail) and transient (may deteriorate) over time (Lumen Learning, 2018a). Regular and consistent and sustained daily mental exercises like those offered by some scientifically proven brain enhancement games might be of some help in sharpening information recall/retrieval by blocking the phenomena that threaten information retrieval from the memory. Sustained daily mental exercises may also aid in better problem solving (Lumen Learning, 2018c) and in improved recall of information from the working memory (Towse, Cowan, Hitch & Horton, 2008; Kpolovie & Akpelu, 2017).

Use of memory techniques like visualization and concretization of abstract information have been identified as likely potent information recall strategies. Douglas (2018) has branded employment of the best study skills, and growing of new brain cells with intense aerobic exercises that stimulate cortical cells growth as great ways of recall improvement. The taking of enough sleep and eating of the right brain-boosting food, those that are very rich in omega-3 essential fatty acid (salmon, mackerel, and sardines); and antioxidant (such as blueberries, mangoes, watermelon, and dark-green vegetables); as well as the several scientifically verified food supplements like folic acid and ginkgo biloba (Kpolovie, 2012) are also seen to be helpful. Consumption of the Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) diet may also be of assistance (Alban & Alban, 2018).

Each day, a person's brain has special opportunity to grow new cortical cells and form new neural connections. This process noticeably occurs for individuals who actively harness their

brains' ability to change. The process or mechanism is termed neuroplasticity. Neuroplasticity is the brain's ability for self-reorganization via development of novel neural or nerve cells connections over one's lifespan. In some, neuroplasticity may occur as compensation for brain injury or disease, and thus adjust their activities in response to marked environmental and situational changes. Alban and Alban (2018) enumerated as much as 36 proven ways that might be used by an individual for memory improvement.

It has been argued by the Harvard Medical School (2018) that "our memories shape who we are." Our genes and choices contribute to recall or memory. Healthy diet, regular exercise (be it physical, mental or the both), maintaining the right blood pressure, cholesterol and blood sugar levels, and quitting of excess alcohol and smoking may aid memory. Like body muscles that grow with physical exercise, mental exercise and mentally active life are capable of helping to tone and improve the human memory. Therefore, if the Lumosity games that the current work is investigating are indeed brain enhancement games, manipulating the Lumosity training schedule should culminate in marked differences or variations in the extent to which the subjects correctly recall processed information (nonsense syllables in this case).

White (2011) posited emphatically that with the use of the right filling system that the brain adopts to store information, recall of memory of the stored information can be improved beyond imagination. Several lists of 100 digits can be memorized and retrieved at will after hearing or seeing them just once.

Recall of information tends to be the most important of the three core processes of memory – information recall, information storage, and information encoding. Information recall could be done in either of three forms, each of which is a type of information recall, namely – free recall, serial recall, and cued recall. Every of these information recalls is done in accordance with certain specifications by the two-stage theory and the encoding specificity theory (Wikipedia Foundation, 2018).

The two-stage theory holds that search for and retrieval of information is the first process of recall of memory. The second process of recall is decisive recognition that the retrieved information is correct. Encoding specificity theory rather posits that memory is the utilization of information from the situation in which it was learnt, from the memory trace, and from the circumstance or environment in which the information is being retrieved. Improvement of memory requires availability and similarity or association of both encoding condition at the point of learning and the retrieval circumstance at the point of recalling the information. The needed similarity or association principle is what underlies truly brain enhancement games that make it possible for a person who has exercise consistently enough to have improved memory or recall of information that he is exposed to in real life setting.

At each time in every situation, how one learns tends to be impacted by his capacity to recall sensory information. Positive behaviour is greatly reinforced by one's recall of victories from winning strategies, as such recall increases dopamine for confidence that tends to guarantee the person's making of quick clear decisions when faced with similar situations subsequently (Reynolds, 2017). This automatically makes the person to typically learn more of his successes than failures. Memory successes recorded in Lumosity training or other brain training games are expected to be brought to bear in similar recall situations in real life setting. Evidence of success in genuine brain training games may make the individual to put more right effort in the recall of information. This is much in line with Reynolds (2017) who concluded that people learn more effectively from their successes than their failures.

> *The dopamine release with positive reinforcement increases the chance of 'learning' to occur and behavioural change to stick. The more often you win, the greater your confidence and desire to risk. The brain needs evidence of success to support ongoing effort. The brain's primary purpose is to protect you from harm, including feeling shame.*

Lumosity is said to be one of the most effective online tool for cognitive enhancement that offers brain training exercises which strategically target brain areas such as memory, attention, processing speed, flexibility, problem solving, math, and language skills to make the individual, irrespective of age, smarter and better fit mentally. Lumosity is the owner of Lumos Labs Inc. that was developed by popular neuroscientists and cognitive psychologists for the enhancement of brains and lives. The official website of Lumos Lab Inc. is www.lumosity.com, and can be accessed at will for brain training exercises. Lumosity games have been tried in Lumos laboratories and found to improve visual attention, working memory, fluid and crystalized intelligence (Kpolovie, 2003; 2016a), executive functions, and creativity, health, flexibility, self-confidence, problem-solving skills, and learning (Lumos Labs Inc., 2011).

Lumosity has adapted age-old techniques of mental training into very easy-to-learn exercises for profound relaxation and maximum focus. With a team of experts, leading researchers and mindfulness teachers, Lumosity has developed great exercises that limitlessly train concentration, mental clarity, memory or recall, and total brain functions. Even with daily short, quick and simple sessions that last for just 3-5 minutes can very easily be used by anyone who is desirous of his brain training and enhancement to achieve reasonable improvement (Lumos Labs Inc., 2011).

The Lumos Labs Inc. also "partners with researchers at Stanford, UCSF, Harvard, and Columbia, among other prestigious universities. We also work with numerous health care organizations to provide cognitive training services" Lumos Labs, Inc., 2011). Scientists, users, medical doctors, corporate organizations, and opinion leaders have praised Lumos Labs Inc. since its inception. The Lumos Labs Inc. has even been incorporated into the European Space Agency's Mars500 programme for the simulated trip to the planet, Mars.

Neuroscientists and cognitive psychologists engaged in revolutionary research have since found that the human brain can organize and reorganize itself fundamentally when confronted with novel challenges, irrespective of age. With engagement in the right mental exercises, the brain can most actively reshape itself to become much more efficient, a mechanism that is considered as neuroplasticity. New ways to improve brain's health and performance are continuously discovered to leverage on neuroplasticity by neuroscientists and researchers particularly at this revolutionary information and communication technology age. The foremost of such discoveries is the development of several scientifically proven online brain improvement games. The Lumosity training which the efficacy of its schedule is being investigated in this study is one of such games. If found to be effective, the information on the effect of Lumosity training schedule could be used to better design personalized brain training exercises to enable the individual attain cognitive peak performance and to more effectively combat possible cognitive decline occasioned by age, injury, or other neurophysiological traumatic conditions.

The human brain may definitely require regular and consistent mental challenges to better function excellently, just like the human muscle that needs regular physical exercise and practice to excel in any sporting activity or skill. The Lumosity memory or brain enhancement games are designed to provide the human brain with novel and ever-increasing in difficulty

mental challenges to rev up the various areas of brain skills. In this investigation, 60 different types of brain enhancement exercises, each of which cannot be exhaustively accomplished by an individual, and yet it optimally strengthens the brain's ability to recall, remember details, solve novel problems, pay attention, and perform higher-order tasks are used as the experimental treatment conditions.

Works that entail incredible memory, attention and intelligence; executive function; mental fitness; cognitive acuity; high creativity; problem-solving speed; mental fitness; flexibility; curiosity; mathematics and language skills; as well as persistence, could be executed more easily with regular and consistent brain exercises such as those provided by Lumos Labs Inc. (Kpolovie, 2012). While persistence is the indomitable willpower, unshakable determination, irrepressible commitment, absolute dedication, relentless pursuit, continuous and ever-increasing confidence and resolute action in the direction of one's goal until it is exceptionally accomplished; self-discipline is the ability to and the actual commitment to make oneself do what one should do, exactly how and when he should do it, irrespective of whether he feels like doing it or not (Kpolovie, 2010; 2016).

Hardy (2011) found that Lumosity training can significantly enhance cognitive function and change the way that the brain processes mathematics. Kesler (2011) applied Lumosity Math Tutor that is designed for improvement of processing speed, cognitive flexibility and number sense in Stanford University. Results showed significant improvement in math skills, speed of processing, flexibility and attention after six weeks of exercise. The Math Tutor was also found to significantly enhance both cognitive and math skills even in girls with the genetic disorder of Turner's syndrome. In another investigation that used 93 'brain dead' students in Pennsylvania University, it was found that subjects who completed Lumosity training improved twice in math and reading as much as their counterparts in the control group that did not use Lumosity exercise (Lumos Labs Inc., 2011c).

Advantages of exercising the brain with Lumosity mental enhancement games seem to be endless as concluded by Hardy (2011) and Lumos Labs Inc. (2011a; 2011b; 2011c) that analyzed data of all those who use Lumosity brain games. Up to 97% of those who train for at least 10 hours had overwhelming increase in their Brain Performance Indexes (BPIs). Their BPIs measure improved in brain areas such as memory, attention, problem-solving, fluid intelligence, and the ability to recall and process information speedily. The improved scores were also found to translate into real world benefits. For instance, as few as 20 days of working memory training was capable of improving more complex reasoning and problem-solving abilities that are collectively termed fluid intelligence. Even people who engage in as few as 4 hours of cognitive training enhanced their ability to creatively solve novel problems (Hardy, 2011).

The Lumos Labs Inc. (2011a; 2011b) has shown incredible innate neuroplasticity to enhance memory and attention by engaging in Lumosity training. Lumosity greatly increase dopamine, the neurochemical that is very crucial for many bran functions. Dopamine is a neurotransmitter, a special chemical used for communication between brain cells, and it is particularly important for signaling reward. Each release of dopamine is like activating the brain internally by saying 'good job, do that again' that propels the brain to recall more and more information, and to process the information better and better, deeper and deeper in an ever-increasing form to guarantee much better memory.

The critical necessity is that most of the findings on the effectiveness of Lumosity in brain or cognitive enhancement are done and reported by Lumos Labs team. There has ever remained

an urgent demand for neutral persons to independently investigate the effect of Lumosity training on cognitive function. The demand for independent investigation of the claims by Lumosity compelled the execution of the work, "Lumosity training and brain-boosting food effects on learning" Kpolovie (2012); and the current work that has examined the 'effect of Lumosity training schedule on recall of nonsense syllables.' Thus, this current experiment was executed to further fill the existing great knowledge gap.

RESEARCH QUESTIONS

Eleven (11) research questions, 1 omnibus and 10 pairwise, that were answered at the end of the study with respect to the effect of Lumosity training schedule on recall of nonsense syllables when the Pre-test effect is covaried are follows:

1. What is the effect of Lumosity training schedule on the subjects' recall of nonsense syllables when the influence of the pre-treatment test has been covaried out as measured by their means and standard deviations?
   In other words, the omnibus research question is – do the five groups differ in their means and standard deviations on the recall of nonsense syllables when the influence of the Pre-test has been held constant (controlled for)?
2. What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 6 minutes Lumosity training per day (06minpd) when the Pre-test is covaried?
3. What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?
4. What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?
5. What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?
6. What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?
7. What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?
8. What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?
9. What is the difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?
10. What is the difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?
11. What is the difference between recall of nonsense syllables by those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?

NULL HYPOTHESES

Eleven corresponding null hypotheses (1 omnibus and 10 pairwise) were postulated and tested at .05 alpha thus:

1. There is no significant effect of Lumosity training schedule on recall of nonsense syllables when the Pre-treatment test (Pre-test) influence has been covaried (held constant or controlled for).
2. There is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 6 minutes Lumosity training per day (06minpd) when the Pre-test is covaried.
3. There is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried.
4. There is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried.
5. There is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried.
6. There is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried.
7. There is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried.
8. There is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried.
9. There is no significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried.
10. There is no significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried.
11. There is no significant difference between recall of nonsense syllables by those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (12minpd) when the Pre-test is covaried.

METHODOLOGY

Randomized between subjects before-after experimental research design was adopted for incontestable establishment of cause-and-effect relationship, if it exists, in this investigation. The research design allowed for the subjects in all the groups to receive both Pre-treatment test and Post-treatment test on the dependent variable, recall of nonsense syllables. The beauty of the employed research design is that the entire effect, if any, of the Pretest was statistically removed or controlled for with the use of Analysis of Covariance (ANCOVA) from affecting the Posttest nonsense syllables scores. The exact design used is illustrated in *Figure 1*.

Group	Membership means	Pretest	Treatment Condition	Posttest
1	Randomization	O1	00MLTPD	O2
2	Randomization	O3	06MLTPD	O4
3	Randomization	O5	12MLTPD	O6
4	Randomization	O7	18MLTPD	O8
5	Randomization	O8	24MLTPA	O10

Figure 1: Randomized before-after experimental design

A random sample of 150 Tenth Grade students, each aged 15 years, was drawn for the investigation. They were randomized into five groups that were randomly assigned different schedule of Lumosity Training as experimental conditions. Each of the five groups had 30 students. The Lumosity Training Schedule for the groups were as follows:

Group 1 00 minute of lumosity training per day
Group 2 06 minutes of lumosity training per day
Group 3 12 minutes of lumosity training per day
Group 4 18 minutes of lumosity training per day
Group 5 24 minutes of lumosity training per day.

Before the commencement of the experimental training, which was first day, they were presented with a list of 200 nonsense syllables on a projector screen for 20 minutes. After which the list was removed. Then, they were given a valid and reliable test that required them to individually recall the nonsense syllables as much as possible and write them out clearly on their answer scripts. The test lasted for 30 minutes. Each subject's number of correct recalls of the nonsense syllables was recorded as the person's pre-treatment test (pre-test, in short) score.

Then for the next 60 days, while group 2 received 06 minutes lumosity training each day; group 3 received 12 minutes lumosity training daily; group 4 received 18 minutes lumosity training per day; and group 5 did lumosity training for 24 minutes each day. In each case, the training began in the morning at 6.30am before their breakfast at 7.30am. Subjects in group 1, the control group, were not exposed to the lumosity training. The experimental treatment lasted for as long as 60 days that was judged long enough for the training to cause some changes in the subjects, if at all lumosity training could positively or negatively affect the subjects' memory or recall ability; and the 60-day period was long enough for the subjects to have forgotten the nonsense syllables as well as the pre-test that they took. This measure was to reduce possibility of carry-over and test-wise effects.

For equality of computer speed and network accessibility, each subject was provided the same type of newly installed laptop with the same specifications; and a 120G router. Power supply was guaranteed throughout the training period though each laptop had good new battery. Effective mechanism was put in place that prevented possibility of any subject from

performing Lumosity training beyond or outside the specified training period for the various experimental groups all through the duration of the experiment (60 days).

After the last day of the experimental exposition, the entire 150 subjects were presented the same 200 nonsense syllables for 20 minutes after which the nonsense syllables were removed. Then, the same test on the nonsense syllables that required the subjects to recall and write out as much of the nonsense syllables as possible was administered to them. At the end of 30 minutes that the test lasted, the number of correct responses made by each of the subjects was recorded as his/her post-treatment test (post-test) score. The following coding was used in the recording of the scores for data analysis.

Nonsense syllables pre-test = NSPre
Nonsense syllables post-test = NSPost
Lumosity training schedule = LumosityTS (1 = 00minpd; 2 = 06minpd; 3 = 12minpd; 4 = 18minpd; 5 = 24minpd).

As stated earlier, the administration of the treatment lasted for 60 days. The treatment administration was done such that in the first day, subjects in each experimental group must have performed one exercise in each of the six Lumosity games. Thus, by the 10th day, they must have performed all the 60 Lumosity games for the first time. The process of administrated was repeated such that by the 20th day, the four experimented groups must have each been exposed to all the 60 Lumosity games the second time. By the 30th day, each of the experimental groups must have been exposed to all the 60 Lumosity games three times. The process continued until the 60th day when members of the experimental groups must have all performed all the 60 Lumosity games six times. The 60 brands of Lumosity games used as experimental treatment conditions fall under six different skills categories as follows – 8 for enhancement of Problem-solving skills, 9 for enhancement of Flexibility skills, 9 for improvement of Speed skills, 11 for enhancement of Attention skills, 13 for improvement of Memory skills, and 5 each for improvement of Math skills and Language skills. How the treatment conditions were administered daily for the first 10 days is tabulated for illustration in *Table 1*. The same daily treatment administration was repeated at the second, third, fourth, fifth and sixth 10 days that make up the 60 days which the experiment lasted.

Table 1: Daily Lumosity Training exercises for the first 10 day that the four experimental groups were exposed to

Day	S/No	No	Mental Exercises	Skill area	Instructions
	SPEED				
1st	1	1	Highway Hazards	Information processing	Requires very swift dodging of obstacles in a race through the desert. The rapid manoeuvres challenge your information processing skills: your ability to process and analyse incoming information
2nd	2	2	Penguin Pursuit	Spatial orientation	Elicit use of spatial orientation, ability to adjust perspective in a mental map for guiding a penguin through a maze. When the maze rotates, you must rotate your mental map of the maze and recalibrate the directions to get to the fish.
3rd	3	3	River Ranger	Information processing	Demands quickly spotting animals in a river and picking the same animal twice in a row. It challenges very quick information processing skills, and the ability to rapidly process and analyse information
4th	4	4	Splitting Seeds	Information processing	Elicits even division of seeds. To do this quickly, you'll need your subsidisation skills. Subsidization is your ability to quickly discern the number of items in a small group without having to count
5th	5	5	Speed Pack	Visualization	Requires you to fit the last item into an already filled suitcase. You must imagine what the suitcase would look like when folded. This mental folding challenges visualization, your ability to imagine how objects fit together and interact
6th	6	6	Speed Math	Information processing	Demands quick decision on whether a flashcard symbol matches the one shown directly before it. This rapid analysis challenges information processing skills, your ability to process and analyse incoming information.
7th	7	7	Spatial Speed Match	Information processing	Demands quick decision on whether a flashcard symbol matches the one shown directly before it. It tests the ability to very quickly analyse information processing skills of incoming information
8th	8	8	Speed Match Overdrive	Information processing	Demands mastery of Speed Match and payment of keen attention to both colours and shapes as guide to the correct response
9th	9	9	Penguin Pursuit	Spatial orientation	Compels you to race against a rival penguin in a spinning icy maze while ensuring not getting disoriented
	MEMORY				
10th	10	1	Tidal Treasures	Working memory	Requires you to quickly decide whether a flashcard symbol matches the one shown directly before it. This rapid analysis

					challenges information processing skills, your working memory ability to process and analyse incoming information
1st	11	2	Memory Matrix	Spatial recall	Demands swift memorization of a group of tiles on a grid; remembering their location, and shapes they create. Thus, testing your short-term memory's spatial recall ability to track location and position within an environment
2nd	12	3	Pinball Recall	Working memory	Demands memorization of the locations of several bumpers before they disappear. You then visualize how the ball will bounce off them, and determine where it will go. You must also analyse your temporary memories in order to answer correctly
3rd	13	4	Rotation Matrix	Working memory	It challenges you to track a pattern as it rotates, and gain much more self-control or discipline and direction.
4th	14	5	Memory Match	Working memory	It challenges your working memory to very quickly determine whether a flashcard symbol matches the one presented 2 times previously.
5th	15	6	Memory Match Overdrive	Working memory	This is a much more complex game designed specifically for the talented few who have already mastered Memory Match
6th	16	7	Follow that Frog	Working memory	Trains the memory not to lose track of events or series of learning information by demanding you to follow the orange frog and remembering every of its path as it gets farther away
7th	17	8	Familiar Faces	Face-name recall	Compels you to play the role of a waiter and remember your customers' names and orders in order to earn higher tips and job promotions
8th	18	9	Face Memory Work	Working memory	Trains the individual's rhythm skills by playing the series of drums on the computer keyboard as indicated by the provided instructions and illustrations.
9th	19	10	Memory Lane	Working memory	The working memory is generally used for temporarily storing and processing, organising and manipulation for information. Memory lane demands remembering the windows and letters from the houses you pass, while remaining very sharp in recalling and using the information as at when needed.
10th	20	11	Moneycomb	Spatial recall	Overall, spatial memory is uniquely used for tracking location and position within any given space or environment. Moneycomb exercise is for improvement of the ability to recall visual patterns by collecting coins in order of value. The amount of daily payment depends on volume or magnitude of coin collected per day.

1st	21	12	Monster Garden	Working Memory	Demands remembering where monsters were in a garden; and very quickly navigating through the garden without stepping on any of the monsters.
2nd	22	13	Rhyme Workout	Working memory	Demands matching successive rhymes as the clock ticks in order to work out improvement in one's working memory.
	ATTENTION				
3rd	23	1	Assist Ants	Divided attention	Demands diligence in simultaneously assisting different ants reach their destinations as they move through diverse paths in opposite directions while avoiding falling prey to other animals.
4th	24	2	Feel the Beat	Timing	Trains the ability for synchronization of activities and accurate time keeping. Requires bodybuilding of your rhythm skills by playing several drums on the keyboard in accordance to swiftly indicated pattern or order.
5th	25	3	Eagle Eye	Field of view	Compels you to photograph birds accurately from around the world and watch your visual field abilities take flight
6th	26	4	Trouble Brewing	Divided attention	Challenges you to fill multiple coffee orders at once. The more orders you take on, the harder it becomes to fill them successfully. Thus, challenging you to divide your attention and ability to simultaneously respond to multiple tasks with accuracy
7th	27	5	Train of Thought	Divided attention	Requires you to simultaneously guide many trains that are increasing in number to their stations. You must divide your highly limited attention to guide all of them simultaneously.
8th	28	6	Star Search	Selective attention	Demands you to sift through space fragments and swiftly find the unique object. That means processing many types of stimuli shape, colour, motion, and texture. Sorting through all this information challenges selective attention, your ability to focus on relevant information while ignoring distractions
9th	29	7	Lost in Migration	Selective attention	Requires you to determine the direction of the bird at the centre of the flock. Your attention needs to be given only to specific bird at the centre all the time by ignoring all the other birds. This way, attention concentration is developed for better memory enhancement.
10th	30	8	Playing Koi	Divided attention	Trains the ability to respond simultaneously to multiple demands, stimuli or tasks. Demands your feeding a school of fish that rapidly move around a pond in such a careful way that each fish is feed only once by remembering and

					exempting those of the fish that you have already fed. Thus, you must keep track of all the fish always (those you have fed and the ones that you are yet to feed) no matter the direction and speed with which each fish move in the pond. Your attention is therefore divided, but you must simultaneously respond accurately to the multiple tasks.
1st	31	9	Eagle Eye	Field view	Field view refers to the totality of the area over which one absorbs visual information without eyes movement.
2nd	32	10	Space Junk	Field of view	Requires one to work as an astronaut with the specific duty of cleaning the galaxies excellently within the shortest possible time. It demands accurate counting of swift rolling questions as they appear and clearing them away thoroughly.
3rd	33	11	Observation Tower	Field of view	Demands you to speedily construct the tallest tower by remembering the order of building blocks appearance; and using them to build your visual processing skills the best possible manner.
	FLEXIBILITY				
4th	34	1	Disillusionment	Task switching	Task switching trains effective and efficient adaptation to changing circumstances by switching from one goal to another as at when necessary without letting procrastination play any role. Disillusionment demands instant matching of tiles in accordance to constantly changing rules between matching of colours and of shapes to ensure development of balancing of cognitive process for correct interpretation of confusing shapes and colours in a mistake-free manner.
5th	35	2	Ebb and Flow	Task switching	Demands switching of your focus between where given leaves point and how they actually move. The ability to skilfully shift between two cognitive process in opposite direction and detail is measured and developed. Very frequently requires switching of the brain power between interpretation movements and colours such that when attending to one form, the other is held constant by suppression or selective attention to complexly avoid both retrospective (backward)-and prospective (forward)-interference.
6th	36	3	Robot Factory	Response inhibition	Response inhibition is the mental ability for suppression of inappropriate responses that could have interfered with or slowed down actions that are aimed at goal-attainment. Robot Factory demands building you to build the highest possible

					number and kinds of robots without allowing any room for inhibition to set in by your completely ignoring every of the numerous incorrect parts.
7th	37	4	Brain Shift	Task switching	Demands shifting of focus between vowels and numbers by rapidly switching from cognitive processes that process vowels to the cognitive processes for processing quantitatives or numbers as instantly as prompted without making any mistake. One must answer each question very quickly as it appears and accurately in order to build the individual's task switching skills.
8th	38	5	Colour Match	Response inhibition	Demands instant determination of the correct colour of each written word as it is flashed in milliseconds while suppressing the natural impulse to respond to the meaning of the word. Thus, the ability to effectively suppress the ever-ready impulsive responses that interfere or inhibit painstaking provision of the right answer to each specific task at hand.
9th	39	6	Brain Shift Overdrive	Task switching	This demands application multiple tasks switching skills simultaneously between three or more challenging tasks in accordance to rapid prompting. It is a much more complex tasks switching skills development training.
10th	40	7	Disillusion	Task switching	Demands more complex matching of tiles with rapidly changing circumstances to better develop tasks switching skills. The circumstances could be different complex images, each composed of several units that only a blend of effective comprehension, analysis, synthesis, evaluation, and application will allow for the needed correct matching.
1st	41	8	Word Bubbles	Verbal fluency	Guarantees development of verbal fluency by improving the ability for rapid retrieval of countless words from mental vocabulary. Taking correct recall each word as a bubble, Word Bubbles demands one to most speedily come up with as many words as possible that begin with three initial alphabets that are provided in rapid succession.
2nd	42	9	Word Bubbles Rising	Verbal fluency	A much more challenging verbal fluency ability development task that demands instant typing of all words in the long-term memory on the basis of rapidly changing stems, prefixes, or suffixes that are provided.
	PROBLEM SOLVING				
3rd	43	1	Pirate Passage	Planning	Demands the individual to sale and avoid

					pirates on his path to a given treasure. It instructs him to select a shape and use it to draw the path from the ship to the treasure without getting close to pirates infested points. This way, planning skills via thinking ahead, evaluation and choosing of the best course of action.
4	44	2	Masterpiece	Spatial reasoning	Spatial Reasoning is the unique skills for the visualization of spatial associations or relationships, analysing, and synthesizing them for the drawing of the most utilitarian conclusions. The Masterpiece demands a person to accurately fit pieces of a mosaic together in a novel or creative manner.
5	45	3	Organic Order	Logical reasoning	Demands the individual to cultivate several seeds in the best possible order as evidence of well-developed logical reasoning.
6	46	4	Fuse Clues	Logical reasoning	Optimally challenges logical reasoning by demanding the individual to logically order scattered fuses in order to connect electricity to a room that the absence the fuses has cut off power supply.
7	47	5	Pet Detective	Planning	Demands the individual to search for and rescue every lost pet via application of planning skills (construction of possible solutions, evaluation of all the possibilities, and choosing and execution of the best or most likely solution) in determination of the most efficient routes that the lost pets might have taken to get missing so as to most easily recover them.
8	48	6	By the Rules	Logical reasoning	Requires the individual to demonstrate evidence of better recognition and utilization of patterns by looking at cards and determining the secret rule that govern the process of eliminating them in order to be left with only the needful. It develops the skills for problem solving by elimination of the causes on the principle that “there is no problem without causes; and elimination of the causes is a sure way of likely solving it (Kpolovie, 2016, 3).”
9th	49	7	Route to Sprout	Planning	Planning is the special ability for thinking prospectively with the right foresight, and evaluate decision alternatives based on needs assessment, and choose the best course of action in every situation. The Route to Sprout demands the individual to plan ahead, find the most efficient route, provide the best guide for each seed to its planting whole, water it, and prone it like a great farmer till all the seeds grow fully and produce bumper harvest.
10th	50	8	Word Sort	Logical	Logical Reasoning deals with improvement

				reasoning	of the mental ability for combination of multiple cognitive processes required for accurate recognition of patterns, drawing of deductive and inductive conclusions, and the making logical generalizations and decisions. The Word Sort demands the individual to figure out covert or hidden rules and appropriately place every given word in the form of Q-sought in the most suitable pile. It best allows for improvement of pattern recognition and word sorting skills as necessitated by the dramatically changing world.
	LANGUAGE & MATH				
		LANGUAGE			
1st	51	1	Contextual	Reading comprehension	Reading Comprehension is the ability for fluent reading, processing, and understanding of a particular written language. The Contextual demands the individual to exhibit reading comprehension by identifying and replacing words that are used wrongly in the context and position where they appear.
2nd	52	2	Word Snatchers	Vocabulary proficiency	Vocabulary Proficiency trains the ability to understand and use words correctly. Demands comprehension and accurate use of words by unravelling and decoding the contextual meaning of words and utilizing it proficiently.
3rd	53	3	Taking Root	Vocabulary proficiency	Requires the individual to demonstrate vocabulary mastery via combination of roots to constitute words and apply them.
4th	54	4	Continuum	Vocabulary proficiency	Demands the individual's demonstration of vocabulary sufficiency and mastery through accurate ordering of words in accordance to the meanings of the words.
5th	55	5	Editor's Choice	Vocabulary proficiency	Demands a person to exhibit vocabulary proficiency and fluency by instantaneous identification synonyms via correctly picking them out from an evenly distributed list of distractors (distracting words). Success largely depends on the extent to which the individual has processed enormous or vast number of words and saved in his long-term memory, and the speed with which he retrieves the words for use with ease.
		MATH			
6th	56	6	Magic Chance	Probabilistic reasoning	Probabilistic Reasoning trains the ability to analyse and evaluate the likelihood of events. The Magic Chance demands the individual to improve his probability skills by setting up card tricks for a stage magic show with the goal of selecting cards on

					the basis of the probabilities that each trick needs.
7th	57	7	Halve Your Cake	Probabilistic reasoning	Aimed at improving a person's ability to compare and contrast quantities across different ratios and representations.
8th	58	8	Top That	Numerical estimation	Trains the individual's numerical estimation by demanding the person to choose a prize and exchange it for more expensive prizes. The current prize always needs to be topped.
9th	59	9	Raindrops	Numerical calculation	Trains numerical calculation by improving the individual's ability to execute simple arithmetic operations that include addition, subtraction, division, and multiplication.
10th	60	10	Chalkboard Challenge	Numerical estimation	For improvement of the individual's numerical estimation via his ability to approximate numerical relationships very quickly or with incomplete information. It mainly demands the person to use his quantitative reasoning skills in the determination of which value that is greater than each of the presented values.

RESULTS AND DISCUSSION

Based on the analysed data, the findings are as tabulated in *Table 2*.

Table 2: Output of the Effect of Lumosity training schedule on recall of nonsense syllables

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
LumosityTS	1.00	00minpd	30
	2.00	06minpd	30
	3.00	12minpd	30
	4.00	18minpd	30
	5.00	24minpd	30

Descriptive Statistics

Dependent Variable: NSPost-test

LumosityTS	Mean	Std. Deviation	N
00minpd	30.0000	4.82808	30
06minpd	35.2667	5.07144	30
12minpd	43.6000	5.64831	30
18minpd	51.0667	5.18575	30
24minpd	54.1000	4.38925	30
Total	42.8067	10.42821	150

Levene's Test of Equality of Error Variances[a]

Dependent Variable: NSPost-test

F	df1	df2	Sig.
1.436	4	145	.225

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + NSPre + Lumosity

Tests of Between-Subjects Effects

Dependent Variable: NSPost-test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12655.377[a]	5	2531.075	102.726	.000	.781
Intercept	5647.176	1	5647.176	229.197	.000	.614
NSPre	137.617	1	137.617	5.585	.019	.037
Lumosity	12489.509	4	3122.377	126.725	.000	.779
Error	3548.017	144	24.639			
Total	291065.000	150				
Corrected Total	16203.393	149				

a. R Squared = .781 (Adjusted R Squared = .773)

Estimated Marginal Means

LumosityTS

Estimates

Dependent Variable: NSPost-test

LumosityTS	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
00minpd	30.010[a]	.906	28.219	31.802
06minpd	35.296[a]	.906	33.505	37.088
12minpd	43.578[a]	.906	41.787	45.370
18minpd	51.025[a]	.906	49.234	52.817
24minpd	54.123[a]	.906	52.332	55.915

a. Covariates appearing in the model are evaluated at the following values: NSPre-test = 29.5867.

Pairwise Comparisons

Dependent Variable: NSPost-test

(I) LumosityTS	(J) LumosityTS	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
00minpd	06minpd	-5.286*	1.282	.001	-8.940	-1.632
	12minpd	-13.568*	1.282	.000	-17.222	-9.914
	18minpd	-21.015*	1.282	.000	-24.670	-17.361
	24minpd	-24.113*	1.282	.000	-27.767	-20.459
06minpd	00minpd	5.286*	1.282	.001	1.632	8.940
	12minpd	-8.282*	1.282	.000	-11.936	-4.627
	18minpd	-15.729*	1.282	.000	-19.384	-12.074
	24minpd	-18.827*	1.282	.000	-22.481	-15.173
12minpd	00minpd	13.568*	1.282	.000	9.914	17.222
	06minpd	8.282*	1.282	.000	4.627	11.936
	18minpd	-7.447*	1.282	.000	-11.101	-3.793
	24minpd	-10.545*	1.282	.000	-14.199	-6.891
18minpd	00minpd	21.015*	1.282	.000	17.361	24.670
	06minpd	15.729*	1.282	.000	12.074	19.384
	12minpd	7.447*	1.282	.000	3.793	11.101
	24minpd	-3.098	1.282	.169	-6.752	.557
24minpd	00minpd	24.113*	1.282	.000	20.459	27.767
	06minpd	18.827*	1.282	.000	15.173	22.481
	12minpd	10.545*	1.282	.000	6.891	14.199
	18minpd	3.098	1.282	.169	-.557	6.752

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

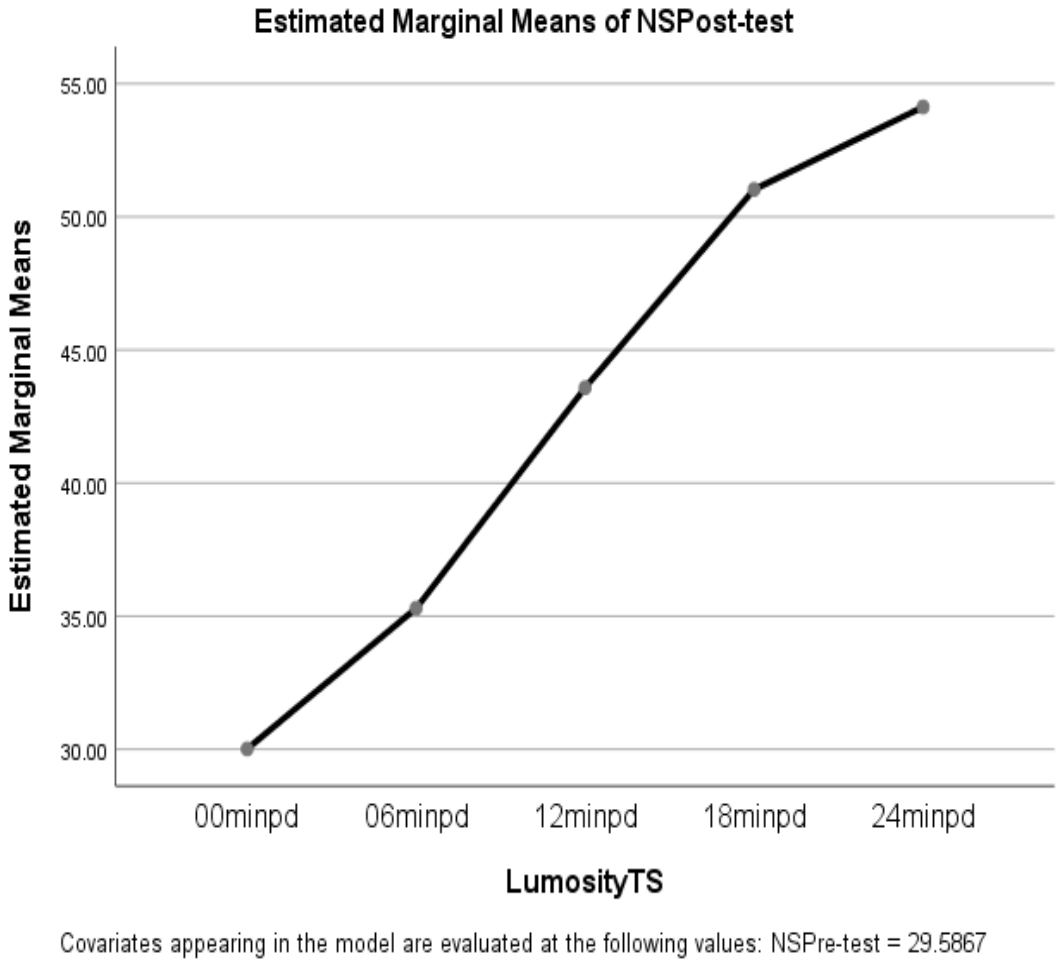
Univariate Tests

Dependent Variable: NSPost-test

	Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	12489.509	4	3122.377	126.725	.000	.779
Error	3548.017	144	24.639			

The F tests the effect of LumosityTS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.

Profile Plots



There are 8 sub-tables (Univariate Between-Subjects Factors, Descriptive Statistics, Levene's Test of Equality of Error Variances, Tests of Between-Subjects Effects, Estimated Marginal Means, Pairwise Comparisons, Univariate Tests, and Profile Plots) in the results, showing the effect of Lumosity training schedule on recall of nonsense syllables. Each of these segments of the output is very briefly interpreted.

Univariate Analysis of Variance Between-Subjects Factors:
This table merely lists the Value Label (00minpd, 06minpd, 12minpd, 18minpd and 24minpd) respectively for the five levels of LumosityTS (1.00, 2.00, 3.00, 4.00 and 5.00). The N (number of cases) for each of the five levels is 30.

Descriptive Statistics:
The Descriptive Statistics table has presented the nonsense syllables post-test (NSPost-test) Mean, Std. Deviation and N for each of the five levels of LumosityTS. The table could serve as part of the answers to the research questions. There is equal N of 30 for each level of the independent variable. The recall of nonsense syllables has a Mean and Std. Deviation respectively of 30.0000 and 4.82808 for 00minpd, 35.2667 and 5.07144 for 06minpd, 43.6000 and 5.64831 for 12minpd, 51.0667 and 5.18575 for 18minpd, and 54.1000 and 4.38925 for 24minpd. The total has 150 N, 42.8067 Mean and 10.42821 Std. Deviation.

Levene's Test of Equality of Error Variances:

This table has indicated that the assumption of equality of error variances is met (not violated) because the ***F*** of **1.436** has **.225 Sig.** that is greater than the chosen .05 alpha. In other words, the null hypothesis that the error variances are significantly equal across the five groups is retained. That is, the Levene's Test of Equality of Error Variances that the null hypothesis that the error variances of the dependent variable is equal across the groups (the five levels of LumosityTS) is sustained. Thus, meeting the important requirement for ANCOVA test. The Levene's Test of Equality of Error Variances was based on "Intercept + NSPre + Lumosity" design.

Tests of Between-Subjects Effects:

The Tests of Between-Subjects Effects table presents the core results of the ANCOVA statistical test for rejection or otherwise of the tenability of the omnibus null hypothesis. The main concern of the investigation which is summarised in this ANCOVA table is whether the five levels or treatment conditions of Lumosity training schedule (LumosityTS) produce significantly different scores on the dependent variable (recall of nonsense syllables at the post-test). Information in the row in the table for the independent variable (Lumosity) takes adequate care of the main concern of the investigation. The Lumosity row has shown 12489.509 Type III Sum of Squares, 4 df, 3122.377 Mean Square, 126.725 ***F***, .000 (read as less than .0005) Sig., and .779 Partial Eta Squared (Partial $\boldsymbol{\eta^2}$). The .000 Sig. is less than the classically chosen alpha level of .05. Therefore, the omnibus null hypothesis which is the first null hypothesis of the experimental study that "there is no significant effect of Lumosity training schedule on recall of nonsense syllables when the Pre-treatment test (Pre-test) influence has been covaried (held constant)" is rejected. Thus, the alternate hypothesis that indeed "there is a significant effect of Lumosity training schedule on recall of nonsense syllables when the Pre-treatment test (Pre-test) influence has been covaried (held constant)" is sustained. In other words, there is preponderance of overwhelming evidence that the five LumosityTS groups (00minpd, 06minpd, 12minpd, 18minpd, and 24minpd) significantly differ in their means and standard deviations on the recall of nonsense syllables after controlling for the effect of the Pre-test. The Pairwise Comparisons that will be discussed in a short while will reveal the specific pairs of Lumosity training schedule that have statistically significant difference.

The **Effect Size**, measured with **Partial Eta Squared (Partial $\boldsymbol{\eta^2}$)** is as large as **.779**. This **Partial Eta Squared** or **Effect Size** practically means that Lumosity training schedule (LumosityTS) accounts for as much as 77.9% of the variance in recall of nonsense syllables (NSPost-test) when the influence of nonsense syllable Pre-test (NSPre-test) is removed, eliminated or controlled for.

Another important finding, though not really the concern of this study, is contained in the row that presents results for the covariate, the Nonsense Syllables Pre-test (NSPre); showing 137.617 Type III Sum of Squares, 1 df, 137.617 Mean Square, 5.585 ***F***, .019 Sig., and .037 Partial Eta Squared. This row specifies whether there is a significant association between the dependent variable, recall of nonsense syllables post-treatment test scores (NSPost-test) and the covariate, recall of nonsense syllable pre-treatment test scores (NSPre-test) when the effect of the independent variable Lumosity training schedule (LumosityTS) is statistically controlled. The Sig. for the covariate is .019 that is smaller than the .05 alpha; therefore, association between the dependent variable and the covariate is statistically significant when Lumosity training schedule is held under control.

In all, the Tests of Between-Subjects Effects has presented the Type III Sum of Squares, df, Mean Square, ***F***, Sig., and Partial Eta Squared (each of these serving as a column) for each of the sources of variation, namely: Corrected Model, Intercept, NSPre, and Lumosity. The ***F*** for each of these sources is significant as the Sig. for it is lower than the .05 classical level of significance. The table has equally displayed the Type III Sum of Squares (SSTIII), df, and Mean Square for Error to be 3548.017, 144 and 24.639, respectively. While the Total has 291065.000 SSTIII and 150 df, the Corrected Total has 16203.393 SSTIII and 149 df, respectively.

Estimated Marginal Means for LumosityTS NSPost-test:

This table is very useful as it presents information for partly answering the research questions. Furthermore, the Estimated Marginal Means serve as the basis for Pairwise Comparisons. The Estimated Marginal Means table has displayed the Nonsense Syllables Post-test (NSPost-test) Mean, Std. Error, and 95% Confidence Interval Lower Bound and Upper Bound for the five levels of Lumosity training schedule, LumosityTS, (00minpd, 06minpd, 12minpd, 18minpd, and 24minpd). For instance, 00minpd and 06minpd respectively have 30.010 and 35.296 Mean, .906 and .906 Std. Error, 28.219 and 33.505 Lower Bound, and 31.802 and 37.088 Upper Bound at 95% Confidence Interval. The Covariates appearing in the model are evaluated at the following values: NSPre-test = 29.5867.

Pairwise Comparisons of NSPost-test:

This Pairwise Comparisons table has presented the Nonsense Syllables Post-test (NSPost-test) Mean Difference (I-J), Std. Error, Sig., and 95% Confidence Interval for Difference Lower Bound and Upper Bound. The Pairwise Comparisons of NSPost-test is crucially important in ANCOVA because each of the other null hypotheses beside the omnibus one is tested with information in this table. That is, the null hypotheses 2, 3, 4, 5, 6, 7, 8, 9, 10, and 11 are tested with information in the appropriate rows of the Pairwise Comparison of NSPost-test table.

On the whole, every Pairwise Comparison Mean Difference that is statistically significant, has an asterisk attached to it, with Sig that is less than .05, and both the Lower Bound and Upper Bound 95% Confidence Interval for Difference completely fall either below zero or completely above zero. A Pairwise Mean Difference that is not significant statistically, has no asterisk, Sig. that is greater than .05, and the Lower Bound and Upper Bound 95% Confidence Interval for Difference has one side below zero and the other side of it is above zero. Whenever the NSPost-test Mean of (I) LumosityTS is smaller than the NSPost-test Mean of the (J) LumosityTS, the Mean Difference has a negative sign as a prefix because the Mean (J) is subtracted from the Mean (I).

The null hypothesis 2 that "there is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 6 minutes Lumosity training per day (06minpd) when the Pre-test is covaried" is rejected because the -5.286* Mean Difference has Sig. of .001 that is less than .05 chosen alpha. There is a significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 6 minutes Lumosity training per day (06minpd) when the Pre-test is covaried in favour of the latter.

The null hypothesis 3 that "there is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried" is rejected because the Mean Difference of -13.568* has .000 Sig. (read as less than .0005) that is smaller than .05 classically chosen alpha. Therefore, there is indeed a significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day

(00minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried in favour of the latter.

The null hypothesis 4 that "there is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried" is rejected. Reason for the rejection is that the Mean Difference of -21.015* has .000 Sig. (read as less than .0005) is smaller than the chosen alpha of .05. Therefore, there is a significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried in favour of those who received 18 minutes Lumosity training per day.

Null hypothesis 5 that "there is no significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried" is rejected. Reason for the rejection is that the Mean Difference of -24.113* has Sig. of .000 that is less than the .05 chosen alpha. Therefore, there is a significant difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried in favour of the experimental group (those who received 24 minutes Lumosity training per day).

Null hypothesis 6 that "there is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried" is rejected. The rejection is because the Mean Difference of -8.282* has .000 Sig. that is less than .05 alpha. There is therefore a significant difference between recall of nonsense syllables by those who receive 6 minutes Lumosity training per day (06minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried. The difference is in favour of 12minpd (those who received 12 minutes per day Lumosity training).

The null hypothesis 7 that "there is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried" is rejected. Reason for rejecting null hypothesis 7 is that the Mean Difference of -15.729* has Sig. of .000 that is less than the classically chosen alpha of .05. There is therefore a statistically significant difference between recall of nonsense syllables by those who receive 6 minutes Lumosity training per day (06minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried. The difference favours those who received 18 minutes Lumosity training per day (18minpd).

The null hypothesis 8 that "there is no significant difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried" is rejected. This rejection is because the Mean Difference of -18.827* has .000 Sig. (read as less than .0005) that is lower than .05 classically chosen alpha. Therefore, there is a significant difference between recall of nonsense syllables by those who receive 6 minutes Lumosity training per day (06minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried. The difference is in favour of those who received 24 minutes Lumosity training per day (24minpd).

Null hypothesis 9 that "there is no significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried" is rejected. The reason for rejecting it is that the Mean Difference of -7.447* has Sig. of .000 (read as less than .0005) which is smaller than the chosen alpha of .05. Therefore, there is indeed a statistically significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried. The difference is in favour of the latter (those who had 18minpd Lumosity training).

The null hypothesis 10 that "there is no significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried" is rejected. This rejection is because the Mean Difference of -10.545* has Sig. of .000 which is less than the classically chosen alpha of .05. Therefore, there is a significant difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried. The significant mean difference is in favour of those who had 24 minutes Lumosity training per day.

The null hypothesis 11 that "there is no significant difference between recall of nonsense syllables by those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (12minpd) when the Pre-test is covaried" is retained (failed to reject). Reason for the failure to reject null hypothesis 11 is that the Mean Difference of -3.098 has Sig. of .169 that is greater than the classically chosen alpha of .05. Thus, the alternate hypothesis that "there is a significant difference between recall of nonsense syllables by those who receive 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (12minpd) when the Pre-test is covaried" is discarded. What seems to be like a mean difference between the two levels of Lumosity training (18 minutes per day and 24 minutes per day) with regard to the post-test scores on recall of nonsense syllables when the pre-test is controlled for, is merely a function of chance that is not consistent; and cannot qualify for a significant difference.

In addition to testing ten of the null hypotheses, information in the Pairwise Comparison of NSPost-test table can also be used to answer the research questions. The Pairwise Mean Difference in each situation, is an answer to the corresponding research question as tabulated here, *Table 3*. Each significant difference is in favour of the group with more minutes of exposure to LumosityTS per day.

Table 3: Answering of the research questions

S/No	Research Question	Answer	Corresponding Ho Decision
1	What is the effect of Lumosity training schedule on the subjects' recall of nonsense syllables when the influence of the pre-treatment test has been covaried out as measured by their means and standard deviations? In other words, the omnibus research question is – do the five groups differ in their means and standard deviations on the recall of nonsense syllables when the influence of the Pre-test has been held constant?	***00minpd*** M=30.010 SD=4.82808 ***06minpd*** M=35.296 SD=5.07144 ***12minpd*** M=43.578 SD=5.64831 ***18minpd*** M=51.025 SD=5.18575 ***24minpd*** M=54.123 SD=4.38925	Significant $F(4, 144) = 126.725$, $p < .05$, $\eta^2 = .779$
2	What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 6 minutes Lumosity training per day (06minpd) when the Pre-test is covaried?	-5.286	Significant $p < .05$
3	What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?	-13.568	Significant $p < .05$
4	What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?	-21.015	Significant $p < .05$
5	What is the difference between recall of nonsense syllables by those who did not receive Lumosity training any day (00minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?	-24.113	Significant $p < .05$
6	What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 12 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?	-8.282	Significant $p < .05$
7	What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?	-15.729	Significant $p < .05$
8	What is the difference between recall of nonsense syllables by those who received 6 minutes Lumosity training per day (06minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?	-18.827	Significant $p < .05$
9	What is the difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those	-7.447	Significant $p < .05$

	who received 18 minutes Lumosity training per day (18minpd) when the Pre-test is covaried?		
10	What is the difference between recall of nonsense syllables by those who received 12 minutes Lumosity training per day (12minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is covaried?	-10.545	Significant p < .05
11	What is the difference between recall of nonsense syllables by those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (12minpd) when the Pre-test is covaried?	-3.098	Not significant p > .05

Univariate Tests:

The Univariate Tests table presents the NSPost-test Sum of Squares, df, Mean Square ***F***, Sig., and Partial Eta Squared for Contrast and Error. The ***F*** is 126.377 with .000 Sig. (read as less than .0005), and is statistically significant as p < .05; and the Partial Eta Squared is .779. That is, tenability of the omnibus null hypothesis tested by the Univariate Tests is rejected **[F(4, 144) = 126.725, p < .05, Partial η^2 = .779]**. This ***F*** indicates the effect of LumosityTS on the basis of linearly independent pairwise comparisons among the estimated marginal means.

Profile Plots:

The Profile Plots serve as pictorial illustration of answers to the research questions. The Plots indicate the Estimated Marginal Means of Post-test recall of Nonsense Syllables as a function of the Lumosity training schedule of 00minpd, 06minpd, 12minpd, 18minpd, and 24minpd. The covariates appearing in the model on which the Profile Plots is base was evaluated at the following values: NSPre-test = 29.5867.

CONCLUSIONS

The experiment that lasted for 60 days sought to establish the effect of Lumosity training schedule, if any, on the recall of the memory of nonsense syllables. A sample of 150 subjects, randomized into 5 groups was used. The 60 Lumosity games used as experimental treatment covered Problem solving (8 games), Flexibility (9 games), Speed (9 games), Attention (11 games), Memory (13 games), Math (5 games) and Language (5 games). ANCOVA was performed to test the 11 null hypotheses and answer the 11 research questions on the effect of Lumosity training schedule (LumosityTS) on recall of nonsense syllables Post-test (NSPost-test) when the effect of the nonsense syllables Pre-test (NSPre-test) is covaried, controlled for or held constant. The assumptions for execution of ANCOVA were met as the Levene's Test of Equality of Error Variances was not significant (p > .05) and the covariate (NSPre-test) had significant linear relationship with the dependent variable (NSPost-test) **[*F*(1, 144) = 5.585, p < .05, Partial η^2 = .037]**. The ANCOVA of the main concern in the study showed a statistically significant effect of LumosityTS on recall of nonsense syllables when the NSPre-test is controlled for **[*F*(4, 144) = 126.725, p < .05, Partial η^2 = .779]**. To ascertain the pairwise mean differences that were significant statistically, Pairwise Comparisons done revealed significant Mean Difference (MD) between 00minpd and 06minpd **[MD = -5.286, p < .05]**; 00minpd and 12minpd **[MD = -13.568, p < .05]**; and 00minpd and 18minpd **[MD = -21.015, p < .05]**; 00minpd and 24minpd **[MD = -24.113, p < .05]**. There were also statistically significant Mean Difference (MD) between 06minpd and 12minpd **[MD = -8.282, p < .05]**; 06minpd and 18minpd **[MD = -15.729, p < .05]**; 06minpd and **24minpd [MD = -18.827, p < .05]**; as well as 12minpd and 18minpd **[MD = -7.447, p < .05]**; and 12minpd and 24minpd **[MD = -10.545, p < .05]**. In each of the Pairwise Comparisons, the Mean Difference was in favour of the group that had higher minutes of Lumosity training per day. The Mean Difference (MD) between 18minpd

and 24minpd was not significant **[MD = -3.098, p > .05]**. Profile Plots was drawn to pictorially illustrate the recall of nonsense syllables Means across the five levels of LumosityTS. Conclusively, Lumosity training schedule can be used for improvement of memory recall of learnt information.

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