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Fluid Intelligence and Lumosity Training Schedule – Any Effect?

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Abstract: *The most needed asset in the ever-competitive 21st century and beyond is an extraordinarily enhanced intelligence and unlimited memory. Cognitive science application to real-world learning is undergoing new unquenchable technological fire. Results of investigations that online brain training can improve fluid intelligence in healthy individuals is debated fiercely by neuroscientists, psychologists, geneticists, dietitians, ICT specialists, researchers and experts in various works of life. Theories that underlie brain features and intelligence are critically re-examined with a view to better understand the phenomena of behavioural training and the diverse electrical stimulations that are being proposed as a function of the radically changing world of information and communication technology. The current experiment investigated the effect of Lumosity training schedule on fluid intelligence, measured with Culture Fair Intelligence Test. In all, 60 Lumosity brain enrichment games, covering seven skills (attention, memory, problem solving, flexibility, processing speed, math and language), served as experimental intervention conditions. The experiment lasted for 60 days with 150 healthy 15-year old students randomized into 4 experimental and 1 control groups. Surprisingly, results showed a significant effect of Lumosity training schedule on fluid intelligence [F(4, 144) =3.1777, p< .05, partial η2 = .081], a reflection of difference between the groups that received 12 minutes and 24 minutes daily Lumosity training in favour of the former. Results of the 9 other pairwise multiple comparisons showed lack of significant effect of the online Lumosity brain training schedule on fluid intelligence. Fluid intelligence in the main, remained stable in corroboration of the Fluid (gf) and Crystallized (gc) Theory of Intelligence that unlike the gc which is environmentally determinable (reported in another study), the gf becomes stable or flattens out from age 15, is genetically dependent and is the general mental ability for abstract thinking, novel problems solving, and learning of new things.*

Keywords: *Fluid intelligence, Lumosity training schedule, Lumosity, Brain training, Intelligence, Experiment.*

1. INTRODUCTION

Conscious enhancement of brain performance and brain health to maximally adapt to new challenges and situations across one's life span, is a dear necessity in the radically changed and changing world with unimaginable wide range of increasingly abstract and interconnected problems. Online brain enhancement training that could best make the brain fit for the swiftly changing world has long become indispensable (Jausovec & Pahor, 2017). Just as it may take thousands of hours of physical training to become the best international golf player, footballer, or boxer; concerted hours of regular and sustained online brain training is required for attainment of overwhelming brain enhancement. The earlier one starts such training, the better for his overall brain capabilities to grow or improve exponentially. As training schools and gyms are for development and improvement of physical skills, so shall special schools and laboratories flourish over time for the development and enhancement of different cognitive skills such as attention, memory, flexibility, problem solving, language, and mathematics skills; if the potency claimed by online brain training vendors gets confirmed experimentally.

"Intelligence refers to general mental ability to learn, solve novel problems, educe relationships, quickly process information accurately, think rationally, act purposefully, originate useful ideas and effectively adapt to one's environment" (Kpolovie, 2016: 157). Intelligence, an all-important and central trait around which all other psychological attributes revolve, needs to be dispassionately investigated with regard to online brain training with Lumosity games. Each individual has some

intelligence, a capacity which underlies his ability to adjust to the new and to appropriately utilize the old information. It enables him to actively initiate cognitive interaction with his environment, to search for and respond to it in the most suitable form. It is responsible for a person's consistent search for the best fit, the most efficient, economic, and integrated fit of information and experience that is accessible to him with information which he had already internalized, assimilated and organized. That is, the intellectual power of an individual determines the magnitude of assimilation and organization of already internalized material and the extent to which this is relevant to the attainment of goals subsequently undertaken by him.

Cattell (1963), for purpose of clarity and accuracy of measurement, theorized that intelligence which is the basis of all other human characteristics is composed of two general factors: fluid intelligence (*gf*) and crystallized intelligence (*gc*). The *gf* is general to many different fields and is for adaptation to new situation. It depends on heredity; and its peak of development is at 14 to 15 after which it flattens. The *gf* can best be measured with culture fair test of intelligence (i.e., a test that is equally novel or equally common for all examinees, irrespective of their cultural backgrounds). The *gc* is specific to certain fields and is for maintaining developed habits. It is a function of environment such as school, training and cultural experiences, and it keeps developing rapidly up to the age of 28 to 30. A culturally loaded test like the Standford-Binet or Wechsler intelligence scales is appropriate for measuring *gc* of individuals from the same culture in which the test was developed and standardized. Crystallized general mental ability indicates the extent to which an individual has appropriated the collective intelligence of his culture for his own use; and of course, this is largely dependent upon that person's fluid intelligence (the *gf*), for he must have the basic capacity to appropriate that which at one time must have been novel to him. The current work that is concerned with the effect of Lumosity training schedule on Fluid Intelligence which is validly and reliably measured adequately with Culture Fair Intelligence Test (CFIT), developed by Raymond B. Cattell, published by IPAT (Institute for Personality and Ability Training) in the United States. The Scale 2 of the CFIT used in this study has four subtests – Sequence, Classification, Matrix, and Condition. The test was revalidated and standardized by Kpolovie (1999; 2003; 2003a) for use.

Online brain training programmes have progressed very quickly (Jaeggi, Buschkuehl, Jonides & Perrig, 2008) from inception to become a multibillion-pound spinning business within just 15 years (Evans, 2018). The sharp geometric progression is still sustained largely, and will most probably continue to be so in this radical information and communication technology age (Kpolovie & Lale, 2017). Jaeggi, Buschkuehl, Jonides and Perrig (2008) showed that brain training with Lumosity not only enhanced short-term memory ability, but equally boosted IQ up to one point per hour of training. Kpolovie (2012) found significant positive effect of Lumosity training and brain-boosting food on human learning; and in 10 years later, Kpolovie (2018a) discovered that recall of nonsense syllables significantly improved with longer minutes of Lumosity training schedule.

A number of studies have questioned the workability and effectiveness of online brain training programmes (Day, 2013; Smith, 2018; Tsausides, 2018; Robbins, 2016; Hummeluhr, 2012; Owen, Hampshire, Grahn, Stenton, Dajani, Burns, Howard & Ballard, 2010; Lewis, 2014). Redick, Shipstead, Harrison, Hicks, Fried, Hambrick, Kane and Engle (2013) asserted on the basis of their experiment that there is no evidence of intelligence improvement after working memory training. They found that despite great improvement on both the dual *n*-back programme and visual search tasks that subjects in the experimental groups practiced, there was no positive transfer of the training gains to any of the cognitive ability tests such as fluid intelligence, multitasking, working memory capacity, crystalized intelligence, and perceptual speed.

In a study that experimented with Lumosity training for 10 weeks of training and a sample of 128 (71 male and 57 female), Kable, Caulfield, Falcone, McConnell, Bernardo, Partasarathi, Cooper, Ashare, Audrain-McGovern, Hornik, Diefenbach, Lee and Lerman (2017) found that there is no effect, positive or negative, of the commercial cognitive training on brain activity, choice behaviour, or cognitive performance. Although the assertion that the brain is malleable is definitely undoubtable; exercising the brain by playing Lumosity brain training games, and perhaps other similar online games, for a few hours in some weeks will most probably not make anyone smarter. For healthy young persons, playing the online brain training games has no evidence of making any trustworthy cognitive difference (Gallegos, 2017). The silver bullet for improvement of cognitive ability is yet to be firmly found in online brain training games beyond the specific training tasks (Gaines, 2014).

The disturbing question has been and continues to be whether brain training by major companies like Lumosity (Kpolovie, 2012; 2018a), Dual N-Back, NeuroNation, Happy Neuron, Fitbrain, Sudoku, Nintendo, CogniFit, CogMed, Elevate, and Jungle Memory brain training games actually increase intelligence quotient (IQ) of the masses who engage in the brain-training exercises (Resnick, 2016; Cherry, 2018a; Katsnelson, 2013). While Katsnelson (2013) concluded that there are not enough objective scientific evidence of any reliable gain from brain training, Lewis (2014) contends that brain training development and operations are pseudoscience rather than neuroscience. Gallegos (2017) avers that brain-training do not train the brain; and Gaines (2014) asserts that the apps for brain training merely make the trainees better in playing the games rather than improving their overall cognitive ability like IQ. The United States has even launched the tracking down of Brain Training firms like Lumosity for making false claims of efficacy of the programme without adequate independent scientifically verifiable evidence (Robbins, 2016).

The essence of brain training is the transfer of the skills acquired in the training to new and different situations or task performances. But this so much desired transfer does not occur and the trainees more likely get disappointed (Katsnelson, 2013). All that the training produces is improvement in the performance of the same task under the same scenario with the training. The exercises are not able to culminate in IQ improvement or in general improvements in brain function (Smith, 2018). It was on the basis of the failure of brain training to transfer the exercised skills from one situation or task to another that Owen, Hampshire, Grahn, Stenton, Dajani, Burns, Howard and Ballard (2010) declared that there is a total lack of effects of brain training because the expectation that practising a wide range of brain training that covers many cognitive skill areas will make the individual smarter intellectually completely lack support. Thus, brain training games are ineffective, and do not work. They do not make the brain to undergo any real exercise that is positively impactful on the practitioner's IQ and general cognition as claimed by the developers and owners of the said games.

For the healthy elderly, cognitive interventions such as online brain training games do not seem to correct, prevent, or delay the setting in of Alzheimer's and Dementia diseases (Papp, Walsh & Snyder, 2008), but educational attainment and lifelong participation in cognitively stimulating activities like brain-training could have preventive effect. They very strongly asserted that investigations on the topic are highly limited and inconclusive, and that there is great need for much more studies to be done on the phenomenon: "we found no evidence that structured cognitive intervention programs delay or slow progression to AD in healthy elderly. Further works that accounts for the limitations of past efforts … will help the elderly make informed decisions about range of potential preventive lifestyle measures including cognitive intervention."

SharpBrain (2013) and SharpBrain (2013a) outlined and discussed five necessary conditions that a brain training game must meet before its effect can be transferred to real-life setting. The conditions are core brain training identity, performance bottleneck target, adaptability to performance difficulty, minimum of 21 hours weekly training, and sustained consistency of training. Online brain training gains cannot be transferred effectively to real life IQ situations without meeting the five basic conditions for such transfer. The investigations that do not show significant effects of online brain training were most likely conducted in a hurry in such a manner that did not meet the necessary requirements for establishment of the gains of brain training. The needed conditions that are indispensable for effects determination are as enumerated.

- Core brain training identity with real-life setting. The brain training games have to sufficiently elicit exercise of core brain-based capacity that has neural circuits that are directly identical with real-life outcomes.
- Hit the right performance bottleneck target. Brain training games need to exactly target the trainee's performance bottlenecks within the core neural circuits such as IQ, emotional regulation, decision making, realistic working memory, and real-life-like processing speed.
- Adaptability to performance difficulty. Each online brain training session should be adaptable to performance increases in difficulty to guarantee that the training continually challenge the individual trainee enough as he improves with practice to a much more fully attention absorbing tasks that typify real-life settings.
- Minimum of 21-hour weekly training. A brain training game should take at least 3 hours of the trainee's total commitment every week that is considered necessary for real improvement

in cognitive task performance (SharpBrain, 2013; 2013a). Merely exerting very few hours training across broad variety of brain functions is never likely to result in meaningful transfer of skills to the real-world with all its complex complications. This is analogical to going to the gym and having less than three hours physical exercise on all possible skills per week which cannot produce any meaningful results. A successful sportsman trains on just one or very few skills for several hours per week long ever before, during and after been judged to be successful in the given skill.

- Sustained consistency in training. Exercising the brain with online brain training games must be done in a manner that is sustained consistently over a long enough period of time for it to trigger transfer benefits of the training to real-life settings.

Regular, continued, and sustained practice with the Lumosity brain training games might be a necessary condition before positive effect of the exercises could produce significant effect on the IQ of the trainee. Thus, Lumosity training like every good online brain training, must be targeted at specific core brain circuits that are identified to be having bottlenecks; the training must be most suitably adapted to increasing difficulty with practice. There is equally great need for Lumosity brain training to be practiced several hours per week; and sustained for long enough period of time before its gains could positively affect IQ dramatically.

Smith (2018a) pointed out that "scientific evidence" for efficacy of online brain training games that emanated from in-house research (those done by the developers); conference talks (those either unpublished or under review articles); and single peer-reviewed works in published journals (those research publications that have not been confirmed via replications) should never be taken too seriously, and crucially important decisions should not be taken based on them without evidence of replications of the investigations by others to arrive at the same results. It is only the brain training efficacy that emanate from published research articles that have been objectively replicated by several other researchers, verified to be the true situation, and are now published in the form of meta-studies that demand according serious attention, and life-changing decisions should rightly be based upon.

In-house research works are those executed by the developers of the games or by the companies that are either promoting them or selling the games. Reports from such investigations have high tendency of been doctored in favour of the brain games. Reports of this nature do not have external checks that have confirmed their genuineness, accuracy, trueness, authenticity, and generalizability. They are usually not even peer-reviewed. More so, in-house reports are not independent and might have been biased subjectively (Smith, 2018a). Each of the companies that develop and distribute brain training games such as Lumosity, base most of efficacy claims of their games on their in-house research works. This accounts for why significant majority of publications that online brain training improve cognitive functions and IQ were done by the companies that produced the games, and exist by promoting and selling the games, Lumos Labs Inc. for instance.

Conference talks are in the main, not based on meticulously executed research reports that have been thoroughly peer-reviewed by other experienced scholars in the relevant disciplines. Thus, they lack the requisite checks for unquestionable confirmations of the internal cum external validity, and for the scientific rigor with which the investigations were done. Some of the conferences where such papers or talks are presented are even cosponsored by the brain training companies, perhaps with the hope of getting seeming scientific evidence for the efficacy of their brain training games (Schwandt, 2018).

Single peer-reviewed research works are independently done and have each been peer-reviewed by the reviewers and editors who are independent experts of one international journal in a particular discipline, found as a publishable scientific work and published accordingly. Single peer-reviewed research works are indeed very good scientific evidence, but the validity of the results or effects becomes higher when they have independently been replicated (repeated) by other scientists who found the same results as conclusive evidence of the significance of the effects. Such conclusive evidence means that when different scientists at different times, locations, and laboratories executed the same experiment with similar or different populations, they independently arrived at the same findings of the effects of a given independent variable (an online brain games for instance) on a dependent variable (such as a cognitive skills enhancement). Such conclusive findings are incomparably better to rely on than those from in-house research and conference talks.

The findings of meta-studies of multiple peer-reviewed journal articles are exceptionally good evidence of the effects of any particular online brain training games. Meta-research studies investigate the findings of research works on a phenomenon that have been severally replicated by different scientists in different laboratories that found similar results and published the findings independently in different peer-reviewed journals. Meta-research studies independently investigate and report multiple scientific studies that found the same effects of a particular experimental intervention or treatment conditions on a dependent variable. Such meta-evidence found on any brain training games can and should be validly relied on unquestionably.

Self-quantification is a supportive evidence for the efficacy of the claims of a given online brain training games (Smith, 2018a). It is incumbent for every good company that develops or produces brain training games to provide independent measures that are neurologically and scientifically valid for assessment and evaluation of the cognitive functions or performances that the brain training covers before and after the entire training exercises. "These measures should be scientifically valid, and developed in the field of cognitive neuroscience. They should enable you to objectively track your cognitive gains across a full spectrum of cognitive abilities relating to memory, attention, and learning – as well as IQ"

Self-quantification refers to personally taking the neurologically valid cognitive test before engagement in the brain training exercises consistently in a sustained manner for a long enough time (a good number of months); and taking the same cognitive test after the entire training period; to ascertain the magnitude of difference, if any, between the pre-test and the post-test scores. If there is a great difference between the two scores on the cognitive functions in line with the claims of the specific online brain training games, then a self-quantification support of the evidence claimed by the games exists. Where there is no overwhelming difference between your personal cognitive capacities before and after the long-enough brain training interventions, then self-quantification is not confirmed as a supportive evidence for engagement in practicing the games. The results of the self-quantification is supposed to be in consonance with or corroborate findings of both the single peer-reviewed journal articles and the meta-studies or multiple peer-reviewed journal articles on the brain training games.

Seitz (2017) discussed issues of effective evaluation of brain training and attributed the criticisms leveled by some studies that failed to reveal significant brain gains in the transfer of the cognitive skills exercised to poor validity, unsuitable reliability and insufficient rigor of the real-life setting tests of cognitive abilities. In a perceptual learning for instance, Watanabe, Nanez Sr., Koyama, Mukai, Liederman and Sasaki (2002) noted that there is plasticity at the lower-level than the higher-level visual motion process in a given learning task in both brain training and transfer to the real-world setting. Therefore when brain training is done at the lower-level visual motion perceptual processing, a valid real-world task tested must also be at the lower-level visual motion perceptual processing skill. If a high-level visual motion processing task is rather tested in the real-world scenario, the test is definitely an invalid criterion. Based on systematic reviewed findings, Seitz (2017) suggested integration of cognitive testing into the brain-training games and a better alignment of evaluation activities regarding the expected and the actual learning objectives. Use of continuous evaluation in the course of brain training as against the existing seeming norm of pre-test-post-test was also emphasized.

In an investigation of effect of working memory training on fluid intelligence (*gf*), Jaeggi, Buschkuehl, Jonides & Perrig (2008) and Au, Sheehan, Tsai, Duncan, Buschkuehl & Jaeggi (2014) in their meta-analysis inquiries found a significant improvement as greater amount of training of the working memory accounted for greater fluid intelligence improvement. The *gf* which is the general mental ability to reason, adapt and solve novel problems independent of previously acquired knowledge, and is mainly got via nature or heredity was demonstrated to improve with consistently sustained training with highly demanding working memory tasks. Learning and a wide variety of cognitive tasks depend on the *gf*, which is highly related to professional and educational success, particularly in environments that are complex, challenging and very demanding. A long history of cognitive training has previously shown that in spite of the fact that performance on trained tasks increase dramatically with training, transferring the learning to other tasks that depict *gf* have remained poor. Available smart drugs too have not been able to increase the *gf* in healthy adults (Elliott, Sahakian, Matthews, Bannerjea, Rimmer, & Robbins, 1997; Kimberg, D'Esposito & Farah, 1997). But with training, using computer games that function like the *n-back* tasks employed by

Jaeggi, Buschkuehl, Jonides & Perrig (2008), improvement in the *gf* has been demonstrated.The gain in *gf* in instances like this is strictly training-based and not due to preexisting individual differences in intelligence and or memory. Lawlor-Savage and Goghari (2016) executed similar study and found that dual n-back working memory training may not express or transfer training gains to other working memory areas and to fluid intelligence.

Although factors (heredity for instance) other than working memory capacity contribute to individual differences in *gf*, it has been proposed and confirmed that with suitable training interventions that strongly relies on binding processes and control of attention, transfer effects of the training to other reasoning tasks in which performance relies largely on the same process is possible (Ritchie, 2016; Jaeggi, Buschkuehl, Jonides & Perrig, 2008). Training on working memory of healthy adults could lead to effects that are beyond the specific training as evidence of transfer of the training gains to IQ components like the fluid intelligence (*gf*) and crystalized intelligence (*gc*) (Olesen, Westerberg & Klingberg, 2014; Westerberg & Klingberg, 2007).

Wai (2013) observed what tends to reflect transfer of brain training gains in other cognitive areas and with IQ to the extent that he suggested that the online brain training games scores are beginning to function as IQ tests. This was in line with his findings that Lumosity training scores highly correlate both with SAT, r = .85 and with ACT, r = .84 in a study that used scores of 89,699 young adults aged 17 to 25. The correlations between Lumosity and SAT as well as ACT performances are almost as high as the correlations between IQ scores and performances in these examinations. This suggests that brain training with Lumosity games is tending to replicate what IQ does. I am of strong opinion that the high correlations found by Wai (2013) might have been due to influence of some covariates like IQ that correlates with both the predictor and the criterions. If in that study, Wai had collected data on IQ as well and partialed its effect out with Partial Correlation, or covaried the effect of the IQ out with ANCOVA (Analysis of Covariance), the observed high correlations between Lumosity training scores and SAT as well as ACT could have been much less.

Fluid intelligence entails so much that it is never expected to easily be improved by online brain games because even the performance on the exercises that the games elicit are to an extent determined by the persons' fluid intelligence (Kpolovie, 2016a; 2016; 2018a). It is little wonder that Ritchie (2016) asserted that it is bullshit to claim that an experiment of brain-training for just some hours boosted fluid intelligence by 5 points. The world would indeed be a better place for many reasons if we all become smarter. For instance, people with superior intelligence tend to live longer, have better health, enjoy greater well-being across lifetimes, perform relatively better in school, at work and all-round, and are even more protected from automobile crashes. The desire to become smarter persons has made online or computer-based brain training to boom as a billion-dollar industry. However, such training do not likely work in terms of improving fluid intelligence; though persons who trained consistently in a sustained manner for a long period of time (several months) may notice improvement in memory recall of certain information or certain levels of cognitive task performance (Kpolovie, 2018a; Ritchie, 2016; Resnick, 2016; Cherry, 2018; Cherry, 2018a).

Online brain training has significant effects on working memory (Jaeggi, Buschkuehl, Jonides & Perrig, 2008). Working memory is the ability to store and manipulate information for limited periods of time. Working memory considerably predicts scholastic aptitude but it tends to block higher-order cognitive functions or processes such as reasoning and controlled attention (Au, Sheehan, Tsai, Duncan, Buschkuehl & Jaeggi, 2014) that typify fluid intelligence. Brain training games with the exercises that they elicit as interventions that target working memory have firmly demonstrated plasticity of the working memory systems as both the directly trained as well as the untrained working memory tasks like recall of nonsense syllables increase with greater hours of sustained consistent training (Kpolovie, 2018a; 2016). For instance, the correct recall of nonsense syllables steadily improved with increased Lumosity training schedule from 06 minutes per day through 12 minutes per day, and 18 minutes per day, to 24 minutes per day of consistently sustained training for 60 days (Kpolovie, 2018a). But unlike the working memory that improved with increasing Lumosity training schedule, overall intelligence quotient (IQ) and the fluid intelligence in particular, measured validly and reliably with Culture Fair Intelligence Test (CFIT) (Kpolovie, 2003; 2003a; 1999) did not improve with the increased Lumosity training schedule (Kpolovie, 2018a). The findings lend support for the Fluid (*gf*) and Crystallized (*gc*) Theory of Intelligence. Theory holds that while the *gf* is genetically determined, increase with age to 14 or 15 years and flattens out thereafter, is used for

abstract thinking, solving of novel problems and learning new things; the *gc* is influenced by nurture, based on prior learning, past experiences, acquired facts, and it increases with education/training and environments that are challenging to a much older age (30 years) before flattening out and much latter reducing gradually as a person ages (Cattell, 1963; Elsevier, 2018; Cherry, 2018b; Kpolovie, 2003).

In a publication titled "cognitive-training can result in long-term improvement", Cherry (2018) noted that for the elderly, brain training leads to lasting rewards. This suggests the need for pursuing cognitive training as a viable intervention that might aid in maintaining mental abilities of older people. It is hoped that by the year 2050, mental training could have helped to improve cognitive function of older adults by as much as 38 percent. Individuals who received long enough brain training experienced improvement in their daily activities that involved cognitive abilities in which they had received training. Such effects last for as long as 5 to 10 years.

Ossola (2017) asserted that though one's intelligence is a trait that is fixed and seems to stick with the person for life, hinting his potentials for success in this world, intelligence is highly dynamic and capable of amplification, if the individual truly wants to and tries hard enough via the right cognitive training. Research over the decades have concluded that a person's IQ score can change over the course of his life. The IQ is a result of complex interaction of genetics and the environment. Non-genetic factors like childhood at-home intellectual environment and the level of exposure to toxic chemicals such as lead affects the child's IQ. But because the brain is like a muscle that the more it is used, the stronger it gets; a person can and should constantly work hard to upgrade his intelligence all through life (Flynn, 2007).

Globally, IQ has undergone the Flynn Effect (Flynn, 2013) which denotes that over the course of generations, people have on the average performed better in IQ tests. There has been a global increase in IQ over the course of generations, such that the IQ today is better than the IQ five, three or two generations ago. There has been massive IQ gains over time. In each succeeding generation, people get far more questions right on IQ. In every succeeding generation, people are able to confront, analyze and deal with a much more complex world. The vehicles typically used for transportation a 100 years ago are not necessarily the same that are used today in terms of complexity, speed, safety, and comfort. The percentage of people who have obtained university degree today is far higher than the percentage of persons who had acquired it 50 years ago. In every succeeding generation, more flexible and user-friendly information and communication gadgets are manufactured. The Flynn Effect is in every sphere of life. The world is radically changing for better all-round (Kpolovie & Lale, 2017). The implication is that the world is indeed a training ground on its own for cognitive enhancement.

To improve the human brain, ten training hacks that enhance capacity of the brain neurons could be used according to Schwandt (2018). They are – learning by writing, reasoning backward, listening to audio books, learning by teaching, smarter reading, use of online brain training apps, learning of new languages, think-try-learn (TTL), mastery of quick and easy math tricks, and physical exercise. These 10 brain hacks recommended by Schwandt (2018) are derived from the 150 brain building exercises much earlier proposed by Savant (1990) and 60 mind hacker tips by Hale-Evans and Hale-Evans (2011). Brain Metrix (2018) also listed similar skills that brain training covers, and truly need to be trained. With cognitive training that uses exercises for rapid development of the brain power, a person's IQ, attention, focus and creativity skills improve as the gains of brain training. The brain training exercises are typically self-motivational, and could propel the practitioner to do more and more training, progressing from less difficult to much more difficult challenges that make the brain neurons most active in performing cognitive functions (Kpolovie, 2012; 2016a).

In another experiment on enhancement of cognitive abilities with comprehensive online training, Hardy, Nelson, Thomason, Sternberg, Katovich, Farzin and Scanlon (2015) with a sample of 4715 participants that used 49 Lumosity training exercises that targeted a variety of cognitive abilities at 15 minutes daily training, 5 days per week for 10 weeks found the following:

- Subjects in the experimental group improved significantly more on outcome measures (an aggregate measure of neuropsychological performance) than their counterparts in the control group – effect size of .255 at 95% confidence interval.
- The group that received the training showed greater improvements than the control group with regard to processing speed, short-term memory, working memory, problem solving, and fluid reasoning.

- The experimental group equally showed greater improvements on self-reported measures of cognitive functioning (concentration in particular) than those in the control group – .249 effect size at 95% confidence interval.
- Thus, varied brain training programme composed of a number of tasks targeted to different cognitive functions are effective in transfer of training gains to a wide range of untrained measures of cognitive performance.

In one investigation, Smith (2015) found that in comparison with engagement in cross-word puzzles, 10 weeks of Lumosity training results in a 1.7 point IQ gain. In another investigation, this time on IQ tests and how to join Mensa, Smith (2015a) posited that brain training may aid an individual to become part of the top 2% IQ that is necessarily required for membership of Mensa. Getting into Mensa requires ample preparation and brain training because one must first have an IQ score that is at or above 98th percentile (i.e., be part of the top 2%) on a standardized, professionally administered IQ test. The typical IQ score that qualifies for this is 130 and above.

Maximum learn in a perfectly unforgettable manner is an ultimate goal of man. But yet, 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 the 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 cognitive or brain boosting exercises. The efficacy or otherwise of Lumosity games in boosting of fluid intelligence is being experimentally tried 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 fluid intelligence (Lumos Labs Inc., 2011; 2011a; 2011b; 2011c) is investigated in this study.

There are ways to improve IQ, though the fluid intelligence is theoretically stable and not easily malleable to positive change after age of 14 (Human-Memory.net, 2018). Such ways may 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 working memory ability, and by extension his IQ, 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 and fluid IQ from the age of 15 and beyond (Kwapis & Helmstetter, 2014; Kpolovie, 2012). Information that is even encoded, rehearsed and firmly stored in the long-term memory is occasionally prone to being erased or buried so deeply beyond the point of easy recall and use 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 fluid intelligence. 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 brain should necessarily make conscious efforts each day for the purpose (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 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; 2018a; 2018b; 2018c). 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.

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 mechanism is termed neuroplasticity. Neuroplasticity is the brain's ability for self-reorganization via development of novel neural 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 IQ. Like body muscles that grow with physical exercise, brain training exercise and mentally active life are capable of helping to tone and improve brain capacity and IQ. 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 subjects' fluid intelligence (White,2011; Wikipedia Foundation, 2018).At each time in every situation, how one learns novel information tends to be impacted by his fluid intelligence (Reynolds, 2017). Success in brain training causes release of dopamine that tends to motivate fluid intelligence to be more active in subsequent novel learning scenario.

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 brain enhancement. 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 intelligence and crystalized intelligence (Lumos Labs Inc., 2011; 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 on fluid intelligence 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. It is already known neurologically that the greater the bran is used, the more powerful it become (Kpolovie, 2012; 2016a; 2018a). 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 remember details, solve novel problems, pay attention, and perform higher-order cognitive 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; Lumos Labs Inc., 2011a; 2011b).

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 dispassionately 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); 'effect of Lumosity training schedule on recall of nonsense syllables' (Kpolovie, 2018); and this current study of Lumosity training schedule effect on fluid intelligence. Thus, this current experiment was executed to further fill the existing great knowledge gap.

1.1. Research Questions

One omnibus research question and ten (10) pair wise research questions were answered at the end of the study with respect to the effect of Lumosity training schedule on Fluid Intelligence (*gf*) when the *gf* Pre-test effect is controlled for or held constant:

- What is the effect of Lumosity Training Schedule on the subjects' Fluid Intelligence (*gf*) when the influence of the Pre-treatment IQ test (the *gf*) has been controlled for or held constant as measured by their means? (That is: Do the five Groups differ in their Fluid Intelligence means when the influence of the *gf* pre-test has been held constant?)
- What is the difference between the Fluid Intelligence (*gf*) of 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 controlled for?

- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf*of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of 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 controlled for?
- What is the difference between the *gf* of those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is controlled for?

1.2. Null Hypotheses

Eleven corresponding null hypotheses (1 omnibus and 10 pairwise) were postulated and tested at .05 alpha regarding the effect (if any) of Lumosity training schedule on Fluid Intelligence (*gf*), simply referred to here as IQ, because the Fluid Intelligence was measured with Culture Fair Intelligence Test in the study as follows:

- There is no significant effect of Lumosity training schedule on the subjects' Fluid Intelligence (*gf*) when the pre-treatment test (Pre-test) influence has been controlled for (held constant).
- There is no significant difference between the fluid Intelligence (*gf)* of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.

- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of 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 controlled for.
- There is no significant difference between the fluid intelligence of those who received 18 minutes Lumosity training per day (18minpd) and those who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is controlled for.

2. METHODOLOGY

Randomized between subjects before-after experimental research design (Kpolovie, 2010; 2011; 2016; 2018) 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, fluid intelligence. The beauty of the employed research design is that the entire effect, if any, of the Pre-test was statistically removed or controlled for with the use of Analysis of Covariance (ANCOVA) from affecting the Post-test fluid intelligence 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

Figure1. *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 given the Culture Fair Intelligence Test (CFIT) that validly and reliably measures Fluid Intelligence (*gf*). Each subject's score was recorded as the person's pre-treatment *gf 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 the Lumosity training could positively or negatively affect the subjects' Fluid Intelligence (*gf*); and the 60-day period was long enough for the subjects to have forgotten the CFIT pre-test items 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 Culture Fair Intelligence Test that measures fluid intelligence. At the end of the test, the score got by each of the subjects was recorded as his/her post-treatment test (post-test) *gf*score.

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, depending on who many exercises that the time for the group allowed to be done. Thus, by the 10th day, they must have performed all the 60 Lumosity games for the first time. The process of administration was repeated such that by the 20th day, the four experimental 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 processing 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.

Table1. *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 informat ion 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 ind icated 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 reasoning	Logical Reasoning deals with improvement 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.

Fluid Intelligence (*gf*) was measured with the Culture Fair Intelligence Test (CFIT), Scale 2, which is suitable for both children from the age of 8 to adults of any age. The Culture Fair Intelligence Test was professionally developed by Raymond B. Cattell, published by IPAT (Institute for Personality and Ability Training) in the United States; and was revalidated and standardized by Kpolovie (1999; 2003; 2003a) for use. The Scale 2 of the CFIT used in this study has two forms (Form A and Form B), each of which is composed of four subtests (Series, Classifications, Matrices and Conditions). Each of the two Forms has 46 items to be answered in 12 ½ minutes. That is, the complete test (Forms A & B) has 92 items to be answered in 25 minutes:

- ***Series*** – is the first subtest and it requires the examinee to select from among choices provided, the answer that best continues an incomplete progressive series presented.
- ***Classifications*** – is the second subtest, it presents the examinee with five figures of which he must select the one that is different from the other four.
- ***Matrices*** – is the third subtest. It requires an examinee to correctly complete a design or matrix presented at the left of each row from one of the options in the row.
- ***Conditions***(also referred to as***Topology***) – is the fourth subtest. It requires the examinee to select from five options provided, the one which best duplicates conditions contained in the far left box of each row.

Reliability of the CFIT instrument as reported by IPAT (1973, 1973a; 2000; 2002) and Kpolovie (1999; 2003; 2003a; 2016) on the basis of several works done range from .80 to .93 for the various types of reliability(test-retest, parallel forms, split-half, and internal consistency via KR20 and KR21).The test has construct validity that range from .79 to .87 from different sources of evidence (subtest-total correlation, item-total correlation), concurrent validity that range from .77 to .85 for direct correlations with the pure intelligence factor via correlations with other tests of general intelligence (Progressive Matrices, Otis, WAIS, WISC and Stanford-Binet). Other forms of construct validity established for the Culture Fair Intelligence Test are hypothesis testing evidence from 4 different cultures [$F(3, 982) = 1.4540$, $p>.05$] denoting that people from different cultures do not significantly differ in their *gf* ; and developmental changes evidence from persons of different ages [$F(8, 977) = 31.7780$, $p< .05$] denoting that the fluid intelligence (gf) significantly increased with age from 9 to 15 and flattened out thereafter in line with the Fluid and Crystallized Theory of Intelligence as summarized in Table 2.

Table2. *Post hoc multiple comparisons test for the gf ANOVA*

Age		**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17+**
Age	$\bar{X}$									
9	**46.7182**									
10	**50.5856**	*								
11	**55.4727**	*	*							
12	**57.4455**	*	*	*						
13	**59.2818**	*	*	*	*					
14	**61.1000**	*	*	*	*	*				
15	**63.7364**	*	*	*	*	*	*			

16	**63.1635**	*	*	*	*	*	*			
17+	**63.4955**	*	*	*	*	*	*			

*Pairs of age groups which are significantly different at .05 or less alpha.

Source: Peter James Kpolovie (2016). *Excellent Research Methods*. IN, USA: Partridge. Pp166

3. RESULTS

Based on the data analysed, the findings of this investigation are comprehensively presented in *Table 3*. Note that IQ as found in SPSS output in the Table refers to fluid intelligence (the dependent variable of this study).

Table3. *ANCOVA output on the effect of Lumosity training schedule on fluid intelligence*

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

Levene's Test of Equality of Error Variances[a]			
Dependent Variable: Post-test IQ			
F	df1	df2	Sig.
1.870	4	145	.119
Tests the null hypothesis that the error variance of the dependent variable is equal across groups.			
a. Design: Intercept + IQPre + Lumosity			

Tests of Between-Subjects Effects						
Dependent Variable: Post-test IQ						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	15133.284[a]	5	3026.657	234.466	.000	.891
Intercept	58.408	1	58.408	4.525	.035	.030
IQPre	14831.644	1	14831.644	1148.963	.000	.889
Lumosity	164.025	4	41.006	3.177	.016	.081
Error	1858.856	144	12.909			
Total	1760765.000	150				
Corrected Total	16992.140	149				
a. R Squared = .891 (Adjusted R Squared = .887)						

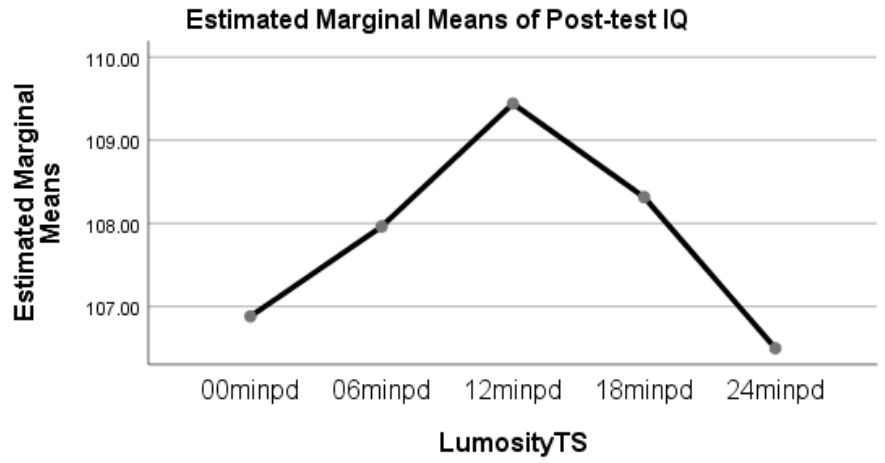
Estimated Marginal Means Lumosityts

Estimates				
Dependent Variable: Post-test IQ				
LumosityTS	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
00minpd	106.882[a]	.656	105.586	108.179
06minpd	107.963[a]	.658	106.664	109.263
12minpd	109.440[a]	.656	108.144	110.737
18minpd	108.316[a]	.658	107.015	109.617
24minpd	106.498[a]	.662	105.190	107.806
a. Covariates appearing in the model are evaluated at the following values: Pre-test IQ = 105.9667.				

Pairwise Comparisons						
Dependent Variable: Post-test IQ						
(I) LumosityTS	(J) LumosityTS	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
					Lower Bound	Upper Bound
00minpd	06minpd	-1.081	.929	1.000	-3.731	1.569
	12minpd	-2.558	.928	.066	-5.203	.087
	18minpd	-1.433	.930	1.000	-4.085	1.218
	24minpd	.384	.931	1.000	-2.269	3.038

06minpd	00minpd	1.081	.929	1.000	-1.569	3.731
	12minpd	-1.477	.929	1.000	-4.126	1.172
	18minpd	-.352	.928	1.000	-2.997	2.292
	24minpd	1.465	.937	1.000	-1.206	4.137
12minpd	00minpd	2.558	.928	.066	-.087	5.203
	06minpd	1.477	.929	1.000	-1.172	4.126
	18minpd	1.125	.930	1.000	-1.526	3.775
	24minpd	2.942*	.931	.019	.287	5.597
18minpd	00minpd	1.433	.930	1.000	-1.218	4.085
	06minpd	.352	.928	1.000	-2.292	2.997
	12minpd	-1.125	.930	1.000	-3.775	1.526
	24minpd	1.818	.938	.547	-.858	4.493
24minpd	00minpd	-.384	.931	1.000	-3.038	2.269
	06minpd	-1.465	.937	1.000	-4.137	1.206
	12minpd	-2.942*	.931	.019	-5.597	-.287
	18minpd	-1.818	.938	.547	-4.493	.858
Based on estimated marginal means						
*. The mean difference is significant at the .05 level.						
b. Adjustment for multiple comparisons: Bonferroni.						

Univariate Tests						
Dependent Variable: Post-test IQ						
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**	**Partial Eta Squared**
Contrast	164.025	4	41.006	3.177	.016	.081
Error	1858.856	144	12.909			
The F tests the effect of LumosityTS. This test is based on the linearly independent pairwise comparisons among the estimated marginal means.						



Profile Plots

4. Interpretation of the Findings

The results in *Table 3* has 7 parts that indicate the effect of Lumosity training schedule on fluid intelligence. They are the:

- Univariate Between-Subjects Factors
- Levene's Test of Equality of Error Variances
- Tests of Between-Subjects Effects
- Estimated Marginal Means for LumosityTS
- Pairwise Comparisons
- Univariate Tests
- Profile Plots

Each of these segments of the results in Table 3 is very briefly interpreted herein.

4.1. 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.

4.2. Levene's Test of Equality of Error Variances

This sub-table has indicated that the assumption of equality of error variances is met (not violated) because the ***F*** of **1.870** has **.119 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 (Intelligence Quotient) 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 + IQPre + Lumosity" design.

4.3. Tests of Between-Subjects Effects

The Tests of Between-Subjects Effects sub-table has presented the main 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 sub-table is whether the five levels or treatment conditions of Lumosity training schedule (LumosityTS) produce significantly different scores on the dependent variable (Fluid Intelligence at the post-test) when the pre-test IQ (i.e. the pre-test *gf*) is controlled for. 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 164.025 Type III Sum of Squares, 4 df, 41.006 Mean Square, 3.177 ***F***, .016 Sig., and .081 Partial Eta Squared (Partial η^2). The .016 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 fluid intelligence whenits pre-test (IQPre-test) influence has been controlled for (held constant)" is rejected. Thus, the alternate hypothesis that "there is a significant effect of Lumosity training schedule on the subjects' Fluid Intelligence when the pre-treatment test (Pre-test) influence has been controlled for (held constant)" is sustained. In other words, there is a statistically significant evidence that the five LumosityTS groups (00minpd, 06minpd, 12minpd, 18minpd, and 24minpd) significantly differ in their means and standard deviations on fluid intelligence after controlling for the effect of the IQ (*gf*) pre-test. The Pairwise Comparisons that will be discussed in a short while from now will reveal the specific pair or pairs of Lumosity training schedule that have statistically significant difference.

The **Effect Size**, measured with **Partial Eta Squared (Partial η^2)** is **.081** that falls within "medium effect size" as recommended by Cohen (1988) is from ".0588 to .1378." This **Partial Eta Squared** or **Effect Size** practically means that Lumosity training schedule (LumosityTS) accounts for 8.1% of the variance in fluid intelligence (IQPost-test) when the influence of the fluid intelligence Pre-test (IQPre-test) is held constant, removed, eliminated or controlled for.

In all, the Tests of Between-Subjects Effects table 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, IQPre, and Lumosity (each of which serves as a row). 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 1858.856, 144 and 212.909, respectively. While the Total has 1760765.000 SSTIII and 150 df, the Corrected Total has 16992.140 SSTIII and 149 df, respectively.

4.4. Estimated Marginal Means for LumosityTS Post-test IQ

This sub-table is very useful as it presents information that answers the research questions. Furthermore, the Estimated Marginal Means serve as the basis for Pairwise Comparisons as well as the Profile Plots. The Estimated Marginal Means table has displayed the Fluid Intelligence Post-test (Post-testIQ) 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 106.882 and 107.963 Means, .656

and .658 Std. Errors, 105.586 and 106.664 Lower Bounds, and 108.179 and 109.263 Upper Bounds at 95% Confidence Interval. While 12minpd of Lumosity training schedule has the highest mean (109.440), 24minpd Lumosity training schedule has the lowest estimated marginal mean (106.498). Pairwise comparisons will soon reveal that the difference between these two estimated marginal means (the highest and the lowest) is statistically significant in favour of 12minpd training. The Covariates appearing in the model are evaluated at the following values: Pre-test IQ = 105.9667.

4.5. Pairwise Comparisons of Post-test IQ

This Pairwise Comparisons sub-table has presented the Post-test Intelligence Quotient (Post-test IQ) Mean Difference (I-J), Std. Error, Sig., and 95% Confidence Interval for Difference Lower Bound and Upper Bound. The Pairwise Comparisons of Post-test IQ is crucially important in the 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 the Post-test IQ 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, the Sig. 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 Post-test IQ Mean of (I) LumosityTS is smaller than the Post-test IQ 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 the Fluid Intelligence of 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 controlled for" is retained (not rejected) because the -1.081 Mean Difference has Sig. of 1.000 that is more than .05 chosen alpha. There is indeed, no significant difference between the *gf* of 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 controlled for.

The null hypothesis 3 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained (not rejected) because the Mean Difference of -2.558 has .066 Sig. that is higher than .05 classically chosen alpha. Therefore, there is indeed no significant difference between the Fluid Intelligence of 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 controlled for.

The null hypothesis 4 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained (failed to reject). Reason for the retention is that the Mean Difference of -1.433 has 1.000 Sig. is greater than the chosen alpha of .05. Therefore, there is no significant difference between the Fluid Intelligence of 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 controlled for.

Null hypothesis 5 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is rejected. Reason for the retention is that the Mean Difference of .384 has Sig. of 1.000 that is greater than the .05 chosen alpha. Therefore, there is indeed is no significant difference between the Fluid Intelligence of those who did not receive Lumosity training any day (00minpd) and their counterparts who received 24 minutes Lumosity training per day (24minpd) when the Pre-test is controlled for.

Null hypothesis 6 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained. The retention is because the Mean Difference of -1.477 has 1.000 Sig. that is greater than the chosen .05 alpha. There

is therefore no significant difference statistically between the Fluid Intelligence of 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 controlled for.

The null hypothesis 7 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained. Reason for retaining the null hypothesis 7 is that the Mean Difference of -.352 has Sig. of 1.000 that is greater than the classically chosen alpha of .05. There is therefore no significant difference between the Fluid Intelligence of 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 IQ is controlled for.

The null hypothesis 8 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained (failed to reject). This non-rejection is because the Mean Difference of 1.465 has 1.000 Sig. that is higher than .05 classically chosen alpha. Therefore, there is, indeed, no significant difference between the Fluid Intelligence of 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 controlled for.

Null hypothesis 9 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained (failed to reject). The reason for retaining the null hypothesis is that the Mean Difference of 1.125 has Sig. of 1.000 which is greater than the chosen alpha of .05. Therefore, there is indeed no statistically significant difference between the Fluid Intelligence of 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 IQ is eliminated or held constant.

The null hypothesis 10 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is rejected. This rejection is because the Mean Difference of 2.942* has Sig. of .019 which is less than the classically chosen alpha of .05. Therefore, there is a statistically significant difference between the Fluid Intelligence of 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 controlled for. The significant mean difference is in favour of those who had 12 minutes Lumosity training per day. You can see that the mean difference has asterisk attached to it as a sign that it is significant at the .05 alpha level. Furthermore, the 95% Confidence Interval for Difference Lower Bound and Upper Bound are both above zero, indicating significance of the mean difference. It can quickly be noted that of all the pairwise mean difference comparisons, this is the only one that is significant statistically. The significant difference in the observed between the Fluid Intelligence of those receive 12 minutes per day Lumosity Training schedule and their counterparts who do Lumosity brain training for 24 minutes per day must have been responsible for the rejection of the overall null hypothesis (i.e. the Hypothesis 1).

The null hypothesis 11 that "there is no significant difference between the Fluid Intelligence of 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 controlled for" is retained (failed to reject). Reason for the failure to reject null hypothesis 11 is that the Mean Difference of 1.818 has Sig. of .547 that is greater than the classically chosen alpha of .05. Thus, the alternate hypothesis that "there is a significant difference between the Fluid Intelligence of 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 controlled for" 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 Fluid Intelligence 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 10 of the 11 null hypotheses, information in the Pairwise Comparisons of Post-test IQ table can very suitably be used to answer the research questions. The Pairwise Mean

Difference in each comparison, is an answer to the corresponding research question. For research questions 2 and 3 for instance, the Mean Difference of -1.081 and -2.558, respectively, could serve as the answers as illustrated in *Table 4*.

Table4. *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' Fluid Intelligence (*gf*) when the influence of the Pre-treatment *gf* test has been controlled for or held constant as measured by their means and standard deviations? (That is: Do the five Groups differ in their *gf* means and standard deviation when the influence of the *gf* pre-test has been held constant?)	***00minpd***M=106.882 SD=11.02875 ***06minpd*** M=107.963 SD=11.30334 ***12minpd*** M=109.440 SD=11.10328 ***18minpd*** M=108.316 SD=11.20247 ***24minpd*** M=106.498 SD=10.67901	Significant $F(4, 144) = 3.177$, $p < .05$, $\eta^2 = .081$
2	What is the difference between the *gf* of 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 controlled for?	-1.081	Not significant $p > .05$
3	What is the difference between the *gf*of 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 controlled for?	-2.558	Not significant $p > .05$
4	What is the difference between the *gf* of 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 controlled for?	-1.433	Not significant $p > .05$
5	What is the difference between the *gf* of 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 controlled for?	.384	Not significant $p > .05$
6	What is the difference between the *gf* of 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 controlled for?	-1.477	Not significant $p > .05$
7	What is the difference between the *gf* of 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 controlled for?	-.352	Not significant $p > .05$
8	What is the difference between the *gf* of 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 controlled for?	1.465	Not significant $p > .05$
9	What is the difference between the *gf* of 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 controlled for?	1.125	Not significant $p > .05$
10	What is the difference between the *gf* of 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 controlled for?	2.942	Significant $p< .05$ in favour of 12m inpd Lumosit y training schedule.
11	What is the difference between the *gf* of 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 controlled for?	1.818	Not significant $p > .05$

4.6. Univariate Tests

The Univariate Tests table presents the Post Test IQ Sum of Squares, df, Mean Square *F*, Sig., and Partial Eta Squared for Contrast and Error. The *F* is 3.77 with .016 Sig. The *F* of 3.177 is statistically significant as the Sig. of .016 is less than .05 alpha; and the Partial Eta Squared (Effect Size) is .081. That is, the overall null hypothesis tested by the Univariate Tests is rejected [$F(4, 144) = 3.177$, $p < .05$, Partial $\eta^2 = .081$]. This *F* indicates the effect of LumosityTS on the basis of linearly independent pairwise comparisons among the estimated marginal means.

4.7. 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 Fluid Intelligence 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 based was evaluated at the following values: Pre-test IQ = 105.9667.

5. CONCLUSIONS

The experiment that lasted for 60 days sought to establish the effect of Lumosity training schedule, if any, on fluid intelligence. 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), processing Speed (9 games), Attention (11 games), Memory (13 games), Math (5 games) and Language (5 games).

ANCOVA was executed for the effect of Lumosity training schedule (LumosityTS) on Fluid Intelligence Post-test (Post-test IQ) when the effect of the Fluid Intelligence Pre-test (Pre-test IQ) is controlled for, held constant or eliminated. 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 (Pre-test IQ) had significant linear relationship with the dependent variable (Post-test IQ) [$F(1, 144) = 1148.963$, $p < .05$, Partial $\eta^2 = .889$]. The ANCOVA of the main concern in the study showed a statistically significant effect of LumosityTS on Fluid Intelligence when the Pre-test *gf* is controlled for [$F(4, 144) = 3.177$, $p < .05$, Partial $\eta^2 = .081$]. To ascertain the pairwise mean differences that were significant statistically, Pairwise Comparisons done revealed significant Mean Difference (MD) for only one pair, 12minpd and 24minpd, [MD = 2.942, $p < .05$]. All theother Pairwise Comparisons showed total lack of significant Mean Difference (MD). For instance, between 00minpd and 06minpd [MD = -1.081, $p > .05$]; 00minpd and 12minpd [MD = -2.558, $p > .05$]; and 00minpd and 18minpd [MD = -1.433, $p > .05$]; 00minpd and 24minpd [MD = .384, $p > .05$]; between 06minpd and 12minpd [MD = -1.477, $p > .05$]; 06minpd and 18minpd [MD = -.352, $p > .05$]; 06minpd and 24minpd [MD = 1.465, $p > .05$]; 12minpd and 18minpd [MD = 1.125, $p > .05$]; and between 18minpd and 24minpd [MD = 1.818, $p > .05$]. Profile Plots was drawn to pictorially illustrate the Fluid Intelligence clustered Mean Differences across the five levels of LumosityTS.

Of the eleven null hypotheses tested, the first indicated that brain training with Lumosity schedule has significant effect on fluid intelligence with a medium effect size; the tenth showed significant effect that 12 minutes per day training is better than 24 minutes per day training; and all the nine other null hypotheses revealed lack of effect of Lumosity training schedule on fluid intelligence. The lack of significant difference in fluid intelligence of all these nine pairwise comparisons is a clear indication that fluid intelligence is indeed not a mental capacity that is environmentally determined, and so could not be easily altered or chanced by a few hours of brain training online. Since none of the experimental groups showed greater fluid intelligence than the control group, the gains of Lumosity brain training games have not been transferred effectively to real life *gf*situations as indicated by fluid intelligence, measured with Culture Fair Intelligence Test. This could be because first, the fluid intelligence (*gf*) is theoretically proven to be determined genetically or by nature and not by nurture or environment that brain-training could have easily affected. The fluid intelligence, unlike crystallized intelligence that is environmentally dependent, is not easily amenable by online brain training of healthy young persons.

Fluid intelligence entails so much that it is never expected to easily be improved by online brain games because even the performance on the exercises that the games elicit are to an extent determined by the persons' fluid intelligence (Kpolovie, 2016a). It is little wonder that Ritchie (2016) asserted

that it is bullshit to claim that an experiment of brain-training for just some hours boosted fluid intelligence by 5 points. The world would indeed be a better place for many reasons if we all become smarter. For instance, people with superior intelligence tend to live longer, have better health, enjoy greater well-being across lifetimes, perform relatively better in school, at work and all-round, and are even more protected from automobile crashes. The desire to become smarter persons has made online or computer-based brain training to boom as a billion-dollar industry. However, such training do not likely work in terms of improving fluid intelligence; though persons who trained consistently in a sustained manner for a long period of time (several months) may notice improvement in memory recall of certain information or certain levels of cognitive task performance (Kpolovie, 2018; Ritchie, 2016; Resnick, 2016; Cherry, 2018; Cherry, 2018a).

Other reasons for the lack of effect of Lumosity trainingschedule on fluid intelligence might be that second, the games do not sufficiently exercise core brain-based capacity that has neural circuits that are directly identical with real-life cognitive outcomes that are due to fluid intelligence. Third,some of the games may not be fully targeting the trainee's performance tailbacks within the core neural circuits that constitute fluid intelligence, emotional regulation,decision making, realistic working memory, and real-life-like processing speed. Fourth, some Lumosity brain training schedule might not have been adaptable to performance increases in difficulty because the training does not continually challenge the practitioner enough as he improves with practice to a much more fully attention absorbing tasks that typify the swift complexities of real-life settings that fluid intelligence deals with. Fifth, the Lumosity online brain training games did not take up to even 3 hours of total commitment per week that is considered necessary for real improvement in cognitive tasks performance. Merely exerting very few hours training across broad variety of brain functions (problem solving, attention, speed processing, flexibility, memory, language, and math) is not likely to result in meaningful transfer of the trained skills beyond the exercises themselves to the real-world with all its multifaceted complications. This is analogical to going to the gym and having less than three hours exercise on all possible skills per week that is not meant to produce any meaningful results. A successful sportsman trains on just one or very few skills for several hours per week ever before, during and after been judged to be successful in the given skill. Sixth, exercising the brain with Lumosity brain training games might not have been done in a manner that is sustained consistently long enough to trigger transfer of the benefits to real-life settings that are dependent on fluid intelligence. Alteration of fluid intelligence of healthy young adults is akin to genetic modification by training. A much more regular, continued, and sustained practice with the Lumosity brain training games might be a necessary condition before positive effect of the exercises could produce significant effect on the fluid intelligence of the trainee. Thus, Lumosity training for instance, must be targeted at specific core brain circuits that are identified to be having logjams; the training must be most suitably adapted to increasing difficulty with practice. There is need for Lumosity brain training to be practiced several hours per week; and sustained for long enough period of time before its gains could positively affect IQ significantly.

Redesigning of the needful aspects of the Lumosity online brain training exercises to better reflect fluid intelligence-based real-life wide range of ever increasingly abstract and highly interconnected real-world problem-solving scenarios is strongly suggested. For instance, this will overcome probable issues of perceptual cognitive training of the eyes and the testing of some others skills (say finger dexterity) instead in the real-world setting. Conclusively, Lumosity training schedule with the necessary modifications may be used for improvement of fluid intelligence in healthy young adults.

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