PXL EDUCATION

BACHELOR OF EDUCATION
SECONDARY EDUCATION

Bachelor Thesis

How Can Spaced Repetition Software Improve Pupils' Memory and Processing?

PROMOTOR
MICHEL JANSSENS
LECTOR ECONOMY

JOCHEM BROODHUYS
ENGLISH & ECONOMICS
ACADEMIC YEAR 2016-2017

Preface

You're looking at an ambitious bachelor thesis that seeks to improve pupils' memory and processing. Most students see their bachelor thesis as a cumbersome obligation. I, on the contrary, would have done the research out of natural curiosity. The subject is practicable and pioneering which is why I enjoyed writing the ensuing research.

This project is the result of countless hours of reading and software testing at home, at school and in public libraries. I didn't perform any study myself because this wasn't feasible due to a teaching practice in Peru. Nevertheless, I corroborated my statements by adding, to my bachelor thesis, results of professional studies which should be enough to make up for this loss.

I would like to thank my economics lecturer, Michel Janssens, who was always available and willing to answer my queries. It's thanks to his guidance and expertise that this project was attainable. I also wish to express my gratitude to my English lecturer, Lieve Cuypers, who helped me with any language concerns and contributed to this project with views of her own.

Conclusively, I also wish to thank all the people who appraised the apps and the people who were willing to discuss the topic with me, especially Patrizio. Thank you for your insights. Finally, I want to take the opportunity to thank my family for supporting me both emotionally and financially.

I hope you enjoy reading this bachelor thesis as much as I did writing it.

Jochem Broodhuys
As, June 2017

Table of Contents

Introduction

For years there have been debates about the relevance of exams. The main concern is that pupils tend to forget what is learned in schools, too rapidly. The chief objective of education is to prepare the pupils for the workplace and for a place in our society. Flemish schools accomplish this by teaching them the right set of knowledge, skills and attitudes that they believe are preeminent. Especially knowledge, out of the trinity, is forgotten rather quickly after graduating. Some people may argue that that is fine, because information is omnipresent and the right set of skills and attitudes is what is needed in today's society, and therefore, more important than knowledge. Besides, today we have electronics, and soon even robots (Hamilton, 2017), that can bestow us with information. The previous statements make sense up to a certain degree, but picture this: A doctor who passed the bar, but with little knowledge, would you put your trust in him? Or maybe a teacher, he is great in teaching but he cannot answer the pupils' questions without browsing on the internet first, would you send your children there? A sales representative who does not know the first thing about his product, would you buy from him?

It is clear that, no matter what today's trend is, and no matter how important skills and attitudes are, we cannot go without knowledge. In a later stage, information about how the human brain works will prove that knowledge is the foundation which we build upon. Knowledge is paramount because, without this foundation, lifelong learning becomes impossible. Lifelong learning is, without a doubt, one of the most important skills in our society (Vanweddingen, 2008). We need to be able to adapt to our rapidly evolving environment. Luckily, in the age of information, information is readily available. So much so, that it has become too much for a single human being to handle. That pile of information still grows progressively and we should make good use of it. Yet, the problem remains, people forget.

The argument that pupils forget most of what they learned at school, is an argument frequently quoted in debates about shortening the summer break.

> *Vooral voor kans- en taalarme kinderen is 9 weken zomervakantie te lang. Na verloop van tijd vergeten ze wat ze het voorbije schooljaar geleerd hebben. Laten we de zomervakantie met 2 weken inkorten, stelt Wim Vermeersch. (Vermeersch, 2015)*

Vermeersch pleads to shorten the summer break by two weeks. He argues that underprivileged- and language poor children's progress is mainly undone after the break.

Although the article is about language deficiency of Dutch in Flanders, the same is true for all languages. (BBC Magazine, 2014). It does not stop with languages, forgetfulness counts for all subjects learned at school (Thalheimer, How Much Do People Forget?, 2010). Vermeersch could have a point in his argument.

When one pleads to repeal exams the same argument is used: pupils forget too much of the information they learned, too quickly.

> *Internationaal onderzoek toont aan dat hoogstens 20 procent van de leerstof die één keer voor een examen werd ingestudeerd, blijft hangen. (Renson, 2014)*

The quote says only 20 percent of what is learned once, before an exam, lingers.

Shortening the summer break or abolishing the exams are interesting discussions. However, The focus of this bachelor thesis is on neither. This bachelor thesis will inquire whether there are ways to help the pupils remember longer, for the pupils' sake as well as everyone else's. Imagine all pupils remembering what they have learned before. This would mean the end of stressful exams for the pupils, and teachers could bid their biggest frustration goodbye. If that does not trigger you, then imagine your own incentive, you could benefit from the same solution, you could finally forget about forgetting.

1 The Human Brain

The holy grail of this quest is finding a way to improve pupils' memories. We will have some challenges en route, as is the case in all quests. Before anything else, we need to have a better understanding about how our memory works. How else can it be improved? In the same way, to be able to learn about our memory, we need to have at least an elementary understanding of our brain, and above all, awe for its complexity.

Humans are on the top of the food chain but it has little to do with our strength. Few human beings are able to fight lions, bears and other strong animals and live to talk about it. No, the reason we, humans, are the dominating species is because our brain is highly evolved. We might not be able to fight a bear in a one-to-one combat, but we might outsmart the bear. We can set traps, create weapons, and more.

In the western world, we no longer hunt, be it for sports. Those days have long passed and we now have to face other extinction threats. We have yet to resolve the environmental issues, to give just one example. The world develops at a dazzling speed. A hundred years ago nobody had a computer, nor a phone. Today we cannot imagine our world without one of these devices. It is hard to comprehend the evolutions we have been through. Yet, at times, it is even harder to understand that we are in fact highly evolved.

The human brain is ridiculously complex. Although we still do not know all there is to know about the human brain, scientists are already trying to build an A.I. based on the human brain (WHITE, 2016). Several movies are dedicated to this very subject and are not soothing. In fact, rather apocalyptical. These ideas frighten us because it still is undiscovered terrain.
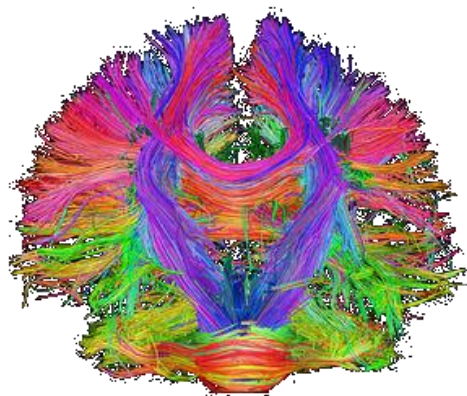

Figure 1: Human Brain

Our brain hugely interacts. Because it is still believed that one side is responsible for creativity and the other for logic it is worth mentioning that the previous idea is simply put not true (Jarrett, 2012). We can, however, identify three major components: the cerebrum, cerebellum and the brain stem.
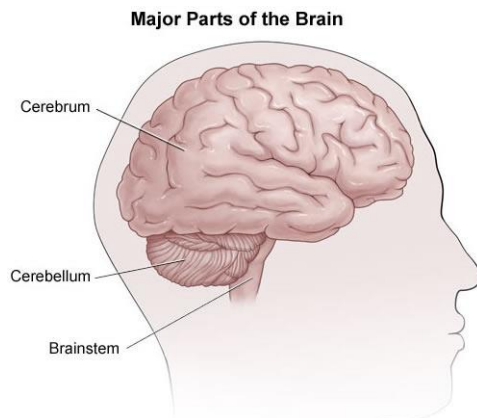
Major Parts of the Brain

Figure 2: Major Parts of the Brain

The brainstem connects the brain with the spinal cord and the rest of the body. It contains the medulla, the pons and the midbrain. The brainstem is responsible for breathing, blood pressure, digestion, heart rate and other autonomic processes.

The cerebellum mainly controls balance, motor control, muscle tone and some cognitive functions, such as attention, language, emotional functions and the processing of procedural memories. The cerebrum, which represents 75% of the brain, is divided into two hemispheres by the longitudinal fissure. The left hemisphere, which is left for the owner's point of view, is largely responsible for the right side of the body, and the right hemisphere for the left side. They are linked by the corpus callosum and other commissures. The hippocampi and the temporal lobes are also to be found in the cerebrum, or forebrain. Although there are two hippocampi and temporal lobes, they are conventionally referred to as hippocampus and the temporal lobe, in the singular. The cerebral cortex, or neocortex, covers the cerebrum and includes the thalamus, the hypothalamus and the pituitary gland.

The cerebral cortex is important for this bachelor thesis because it plays a key role in memory. Other than in memory it also plays a vital part in attention, perceptual awareness, thought, language and consciousness. The cerebral cortex can be separated into four regions: the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe:
▪ frontal lobe: conscious thought, higher mental functions, processing short-term memories, retaining long-term memories which are not task-based;
▪ parietal lobe: integrating sensory memory, spatial sense and navigation;
▪ temporal lobe: senses of smell and sound, processing of semantics in speech and vision, processing of complex stimuli and formation of long-term memory;
▪ occipital lobe: the sense of sight.
The inner part of the temporal lobe, the medial temporal lobe, is involved in declarative and episodic memory. The limbic system, inside the medial temporal lobe, includes the hippocampus, amygdala, cingulate gyrus, thalamus, hypothalamus, epithalamus, mammillary body and others. Most of these organs play vital roles in the processing of memory.
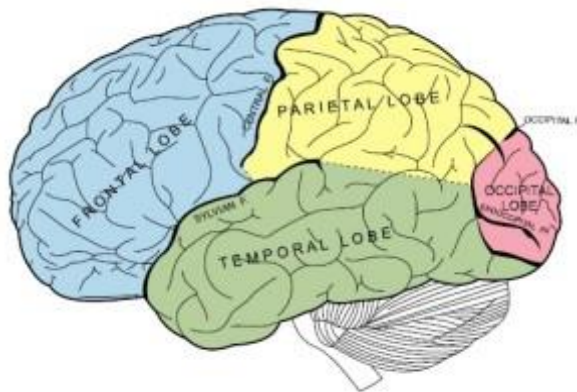
Figure 3: Cerebrum

The hippocampus or, like mentioned before, hippocampi transfers short-term to long-term memory. It also controls spatial memory and behaviour. There are only a few areas capable of growing new neurones, the hippocampus is one of them. The amygdala also performs an important role in the processing of memory of emotional reactions and social and sexual behaviour. The amygdala also regulates the sense of smell. Finally, the basal ganglia, another sub-cortical system, with the striatum, or neostriatum, is important in the formation and retrieval of procedural memory.
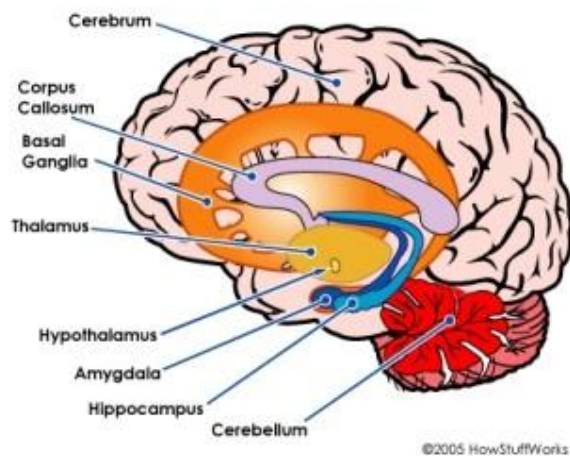

Figure 4: Basal Ganglia

Bear in mind that these two pages by no means cover all we know about the human brain. It is only a very basic summary to provide the reader with a basic understanding of the brain and its organs, in order to understand the development of this bachelor thesis.

2   Our Memory

2.1   Introduction

"Memory is like a spiderweb that catches new information. The more it catches, the bigger it grows. And the bigger it grows, the more it catches."
— Joshua Foer, Moonwalking with Einstein: The Art and Science of Remembering Everything

Joshua Foer's quote makes it sound obvious. The opposite is true: years of research has been spent on discovering the secrets of our memory. We have come a long way with today's technology, but still much is left a mystery.

In 1939 Piaget made a systematic study of cognitive development. He was the first psychologist to do so. Before Piaget's development theory, the common assumption in psychology was that children were merely less competent thinkers than adults. But Piaget proved that young children simply think in different ways compared to adults. According to Piaget children are born with a very basic mental structure, genetically inherited and evolved, on which all subsequent learning and knowledge are based. The goal of the theory was to explain the mechanisms and processes a child uses to develop into an adult. Piaget's Cognitive Theory basically proved that our minds work like semantic networks. Endless clusters of information connected with one another. Hence knowledge is the foundation we build upon. Ausubel claimed that: "The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly." (Ausubel, 1978)
Piaget together with Van Parreren, Ausubel, Gagné and others, gave birth to 'cognitivism'. This was a huge step forward. Before cognitivism, we had behaviourism, think of B.F. Skinner and Ivan Pavlov. Researchers never paid much attention to underlying mental progress, they simply looked at external behaviour, e.g. classical conditioning and the Skinner box.

Cognitive science: The study of thought, learning, and mental organization, which draws on aspects of psychology, linguistics, philosophy, and computer modelling. (Oxford Dictionary)

2.2   Learning Theories

The cognitive theory seeks to explain the process of knowledge acquisition and the subsequent effects on the mental structures within the mind. The learning process depends on what the learner already knows and the way in which he acquires new knowledge. The theory suggests that the student must be an active participant in their own learning process. Cognitivism gave insight into the way people process information. It brought about the realisation that memory plays a major part in what and how we learn. This was a huge milestone and a leap forward.

The cognitive theory typically seeks logical statements for behaviour while minimising impulsive, spontaneous learning behaviour. But, now we know learning does not always take place in an educational setting, quite the contrary: most of what we learn, we learn spontaneously and unconsciously through experiences in our daily lives. A new theory was born: constructivism.

Learning is now the result of the learner's own activities. The learner processes information by giving meaning to external inputs. Personal experience is important because that's where knowledge is rooted. Knowledge is not transmitted by instruction but by its own construction.

Knowledge is thus constructed by every human being in its own way, influencing strongly the reactions and perceptions in the social environment. Constructivism emphasises the importance of social environment and, along these lines, learning in groups.

A more recent theory, Connectivism, claims that earlier theories have limitations regarding the influence of technology on our lives, the way we communicate and on the way we learn. It faces plenty of criticism and is not embraced by all as a new theory. Therefore, Connectivism will not be elaborately explained in this bachelor thesis. One part of Connectivism does have to be addressed in order to prevent confusion. Connectivism relies on other people's, or artificial intelligence's, knowledge which is why the memory's role in Connectivism is rather minor. This whole bachelor thesis would become obsolete if we would accept the statement that learning is pointless if one can google it. Can we outsource our knowledge and still reach our mind's full potential? Of course not. Prior knowledge helps us take in new information, prior knowledge allows us to think and reason more effectively, prior knowledge leads us to retain more of what we learn. The question for the future of education is not whether we should build knowledge, it's how. (Richert, 2017)

2.3   How Our Memory Works

Memory is the process in which information is encoded, stored, and retrieved. There are three main stages in making and retrieving memory:
- encoding or registration: receiving, processing and combining of received information;
- storage: creation of a permanent record of the encoded information in short term or long term memory;
- retrieval, recall or recollection: the information existing in our memory, is called upon, reactivated and comes back in our consciousness as a memory.

Figure 5: Stages of Memory

Memory can fail when something goes wrong in one of these stages. It is also possible that certain information was stored, but that one forgets this information after a short or a longer period of time. Lastly, it is also possible that the information is present, but that the memory cannot be called upon. With some help or some hints, one is, nevertheless, able to retrieve this information. This is called the tip-of-the-tongue phenomenon.

Remembering starts with sensory memory. Sensory information can be remembered for no longer than a second. We perceive a huge amount of stimuli, but only a few items make it to the short-term memory. As is the case when paying attention.
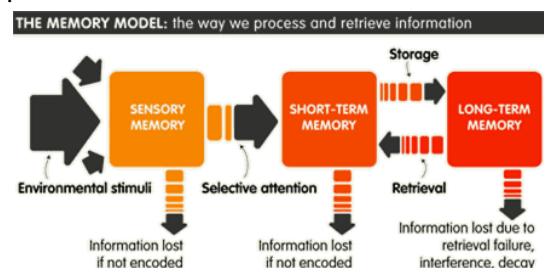

Figure 6: Memory Model

The short-term memory is also known as the working memory. It can remember items for several seconds up to a minute without rehearsal. Just like the sensory stage, its capacity is limited. In computer terms, our working memory is our RAM. It holds the information we are currently working with or are using for thinking, e.g. a chess player calculating his next move. The information can be either new, delivered by our senses, or retrieved from our long-term memory. This event takes place in the pre-frontal lobe, the front of our brain. The pre-frontal lobe of the brain is highly developed in humans.

Humans can, therefore, use information by holding on to it for a short period of time. This is also the reason why humans have an upright forehead.

How much the short-term memory can hold on to depends on a number of variables. George A. Miller (1956) conducted experiments that showed the magical number for storing short-term items is seven. Nowadays, researchers like Nelson Cowan, believe 4 or 5 may be better still. Trying to store a telephone number, for example, would be challenging. However, the memory capacity can be increased by 'chunking', chunking 9 digits into three meaningful groups is far more effective. That could be why, in some countries, telephone numbers are written in chunks of three or four digits.

To summarise: in this stage, the information is either forgotten, remembered for several seconds, or transferred to our long-term memory. It is worth noting that both attention and repetition play a vital part in transferring items from short-term to long-term memory. Outdated views thought that only repetition could lead to long-term memory, but evidence has revealed that we do not always have to repeat information to be able to remember something (Heshmat, 2015). An extreme example would be a shocking experience like a car accident. Emotions are therefore also critical factors in creating patterns. It colours the memory and makes it stick.

Unlike the sensory and short-term memory, long-term memory's storage capacity is immeasurable. Long-term memory can store large quantities of information for potentially a lifetime. If the short-term memory is the RAM, the long-term memory would be the hard drive.

Short-term memory is supported by temporal patterns of neuronal communication dependent on regions in the frontal lobe and the parietal lobe. Long-term memory, then, is maintained by more stable and permanent changes in neural connections widely spread throughout the brain. The neurones make new physical connections and synapses with each other when a new long-term memory is formed. This connection endures whether it's being used or not. Each of the one hundred billion neurones in our brains is connected to approximately seven thousand kilometres of nerve fibres. To put this in perspective: the earth's radius measures 6.371 km. This web plays an essential part in our memory. This means the only way to remove one's memory entirely is to remove the brain as a whole. These connection patterns form into a mechanical progress. "Neurones that fire together wire together". This principle called the law of Hebb, explains how we are able to remember. It is an abstract and abstruse concept. Maybe the best way to visualise it is by comparing it to the internet, which is also a network made out of information spread all across the planet and accessed via countless connections.

It may sometimes seem as if long-term memories have disappeared. There are many things one forgets after all, e.g. previous addresses, passwords, old phone numbers, …
In these cases, the problem is not that it has disappeared, but rather that it cannot be recalled. It is somewhat like those socks that magically seem to disappear. They are still in the house somewhere, but they cannot be used anymore.

The hippocampus is essential to the consolidation of information from short-term to long-term memory, in other words: for learning new information. Although it does not seem to store information itself, or according to current theories, only during the day (Yassa, 2016). Without the hippocampus, new memories are unable to be stored into long-term memory. The reason we know this is because of a man named Henry Molaison and the people who examined- and wrote about him: Scoville and Brenda Milner (1957).
What Henry had is known as 'anterograde amnesia', which basically means he could not form new memories anymore. The doctors were not going to be able to give his memory back, but for the rest of his life, and longer, they tried to learn as much as humanly possible.

The doctors discovered that the hippocampus plays a vital part in the formation and retention of certain kinds of memory. They also learned that there are multiple kinds of long-term memory, controlled by different parts of the brain. There are two kinds of long-term memories: declarative, or explicit and non-declarative, or implicit.

Declarative, or explicit, memories are memories that require conscious progressing and the kind that Henry Molaison lost the ability to form. These include semantic memories; facts and ideas, as well as episodic memories such as; one's 11th birthday. Episodic memories are more personal memories, such as the sensations, emotions, and personal associations of a particular place or time.

Nondeclarative memories or implicit memories, then, are memories of habit like riding a vehicle or tying one's shoes. After Molaison's surgery, he could not remember new facts or remember new events. He would meet a person and forget about him as soon as he walked out the door. Molaison could still form non-declarative, or procedural, memories e.g. learning new motor skills. So the different kinds of long-term memory had to depend on different brain structures.

For the rest of Molaison's life, he was examined and referred to as H.M. After his death his brain was removed and flash-frozen before being cut into 2401 microsections. These sections were used to make a 3D recreation of his brain in 2014. Thanks to him and others like Clive Wearing, we are still learning about memory and the human brain.

2.4   Memory Stimulating Environment

There are ways to enhance one's memory to make sure it's in its best condition. One can use all kinds of techniques and still make no progress if one's memory is not properly nurtured.

Sleep

Sleep, for one, plays a tremendous part in storing memory. The neural connections in the brain are strengthened during a night's rest. As memory is consolidated during sleep (Yina Wei, 2016) it is highly advisable to get enough sleep to have one's memory working best. The ever popular learning technique: cramming, in which a student offers his sleep up for a night of devouring as much of information as possible, is therefore not very effective in the long run (Reichelt, 2016). The memory does not get the chance to consolidate the information well.

Believe

> *"We all have potentially an amazing memory." — Chris Day, World Memory Sports Council*

An excuse often used is "I am not gifted with a good memory". These negative thoughts make a person believe that they are not in control of their memory. These people are therefore less likely to work at maintaining and improving their memory skills and as a consequence, they will indeed experience cognitive decline. Positive self-fulfilling prophecies are beneficial in this case. Learning about the human brain and its memory can have a wonderful impact on a person's belief in himself and can influence the actions he will take afterwards to improve his memory. An excellent example is Joshua Foer. He was a journalist writing about memory championships. He participated in one of these championships to be able to write a better story. He ended up winning the contest. (TED, 2012)

Healthy Nutrition

Healthy eating provides the brain with the necessary nutrition it needs to function well. A balanced diet will keep the brain in an optimum state (Ansari, 2015). A diet high in sugar hinders learning and memory by literally slowing down the brain (Schmidt, 2012) What's more, students will often drink plenty of energy drinks and eat heaps of sugar to keep well awake. However, what goes up must come down. Sooner or later the sugar rush will peak and the caffeine will lose its effect, the crash will be hard and the brain, and consequently memory, will stop functioning properly (Swenson, 2005).

Stress

Depression and other mental illnesses have disastrous effects on memory. These mental illnesses should be dealt with before trying to improve memory. Stress also has a terrible effect on the brain's performance and should thus be minimised (Klemm, 2016). Considering the width of this topic and since the focus of this bachelor thesis is not on creating a memory improving environment, but rather on bettering memory itself, it is advised to consider alternate sources to learn more about depression and stress.

Physical Exercise

Exercising helps blood flow through the body and is hence a necessity as well. The hippocampus even grows as people grow fitter. Walking and cycling during learning a foreign language helps vocabulary stick, at least if not pushed too hard (Martynoga, 2016).

Art of Memory

Memory competitions are getting more fame these days. Using the art of memory, like mnemonics techniques, could vastly improve one's memory (Kaufman, 2012) (Sanders, 2017). There are a plethora of books, (TED) talks, courses and more about mnemonics and the art of memory. Joshua Foer's Moonwalking with Einstein is recommended.

To conclude: it is advised to stay intellectually active and physically active, to socialise, reduce stress, keep a healthy sleeping habit and to eat healthily in order to provide the best possible environment for one's memory.

3   Learning techniques

The next step towards improving memory is to examine study techniques. After all, one cannot ameliorate pupil's memory without dealing with the way they study.

All pupils use their own learning techniques, some are effective, others not so much. Thousands of pages have been written about learning strategies but this page is kept brief. What follows are five learning strategies that have been proved to be effective, and five learning techniques that have not been proved to be effective, at least not in isolation.

The techniques that work, in order from most to least effective and efficient:

1 spaced repetition: Instead of learning large amounts of information in a short period of time, one should study in short sessions during a longer period of time. Large breaks between practice sessions result in better memory;
2 practice testing: testing oneself, asking questions and answering them anytime, anywhere, and with anything. It need not be an actual written test, one can use his own mind to do so;
3 interleaved practice: While studying, the pupil blends several courses at the same time. Making transfers between e.g. Maths and Economics. These transfers will help one's memory to retrieve information easier;
4 elaborative interrogation: A student challenges himself by asking why. This technique integrates new information with existing schemas. Piaget called this assimilation in his Cognitive Theory, which was briefly discussed earlier;
5 self-explanation: This one is similar to 'elaborative interrogation'. This method involves the pupil explaining and recording how he reaches an answer or conclusion.

Techniques that do not work:

▪ imagining: A pupil is asked to imagine what ought to be read or learned. Though there is evidence of benefit when imagery is used for just one sentence, a study of this method using long texts found imagery use in text learning had no noticeable effect on high school pupils;
▪ keyword Mnemonics: The idea of a mnemonic device is to develop mental images and associations with a word or term. Although the best memory masters use this technique (Joshua Foer – moonwalking with Einstein) the author proved it was low in utility. There is a tremendous amount of evidence that illustrates mental imagery is a powerful form of learning, but it is only great for things such as: learning new foreign vocabulary, medical terminology, definitions of words, scientific definitions, etc. However, the method was not effective for learning less concrete ideas or words. The limited applicability of the method is the main reason for its low utility as a learning technique;
▪ summarisation: summarising a section of a chapter one wants or needs to learn. It was found to be effective for those who are skilled in summarising. But that is often not the case with pupils;
▪ highlighting and underlining information: Although an immensely popular study technique, it did not score well. Highlighting and underlining bits of information has proved to be no more effective than simply reading the material, however, in combination with other methods it would be a different story. e.g. combining highlighting with self-testing can prove to be effective in internalising the material;
▪ rereading: Probably the most popular technique amongst students proved to be very ineffective. It almost solely has a positive effect on memorising of what is written in the text, but not on understanding, let alone being able to apply the information in new situations. A personal tip: if you have to reread a text, it is probably because you are tired or less focused. Try using a short break to clear your head before continuing.

It is worth repeating that these study methods were only analysed in isolated use, not when they are combined with other methods. The best way to study is thus to combine several methods. With this in mind, it is perfectly fine to summarise, use mnemonics etc. as long as it is in combination with other learning techniques.

The KISS principle is used for this chapter. This principle states that unnecessary complexity should be avoided and simplicity should be the key goal.

Source: Kirschner, P. (2003, april 5). Top en Flop Leerstrategieën. Retrieved from onderzoekonderwijs.net: https://onderzoekonderwijs.net/2013/04/05/top-en-flop-leerstrategieen/
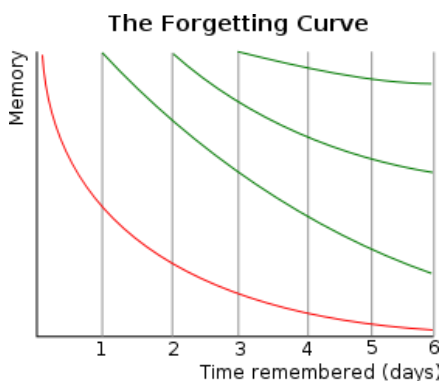
4   Flashcards

It's true hard work never killed anybody, but I figure, why take the chance?
– Ronald Reagan

Now we have a basic understanding of how our brains and memories work and how to create a memory friendly environment. We also know which learning methods are useful and which ones are less effective. Hence, all there is left to do is to put the pieces of the puzzle together and to try and find a way to create an effective memorising technique. Without too much effort, if possible.

Forgetting is a notorious enemy. What we know about it, we largely know because of a German psychologist named Hermann Ebbinghaus. He spent most of his life learning gibberish to calculate the time in which we forget. Him making the forgetting curve is quite impressive. One could call him a pioneer in experimental psychology and memory research.

The forgetting curve illustrates how fast we generally forget and how much of the memory is left. The right-hand side of the curve looks promising, the left-hand side, on the other hand, is quite discouraging. Only one day after learning new information we forget about 70 percent. One way to tackle this problem is by using spaced repetition, our number one learning technique. Spaced repetition is learning in increasing intervals of time. Each repetition increases the optimum interval before the next repetition is needed. This means one will have to repeat information after several hours, days, weeks, months or even years until it has manifested itself permanently in one's memory.

It is important to keep in mind that this curve is about gibberish in general. When emotions and other factors are involved, the curve would, most likely, look differently. Remembering something one is highly interested in will be a lot easier than trying to remember random words or numbers.

A simple way to do spaced repetition is to use flashcards organised into a box. Set up a schedule for when you will revise the cards in each of the sections in your box. If you answer a card correctly, you put it into a section that you will revisit less frequently in the future, whereas if you get the answer wrong, you move the card into a section scheduled for frequent visits.
(Gupta, 2016)

Figure 7: Forgetting Curve

These so-called flashcards are in fact incredibly useful. These flashcards combine the two top learning techniques: spaced repetition and practice testing (active recall) and optionally the third best learning technique 'interleaved practice'. All one then have to do is mix flashcards on different topics together. Flashcards have been used since at least the 19th century. The best-known flashcard system is the so-called Leitner system. It was introduced by Sebastian Leitner, an Austrian scientific journalist.

The learner creates different decks, e.g. three decks. In the beginning, all the flashcards are in the first deck. When answered correctly the flashcard moves to deck 2, when answered incorrectly the flashcard is moved back into the first deck. Deck one is to be revised daily, the other decks should be spaced in time. E.g. the second deck is revised twice a week, on Tuesday and Thursday and the third deck only Friday. Difficult flashcards are thus revised more frequently than easy ones. This is more time efficient because it eliminates the superfluous time spent on the revision of already known flashcards.
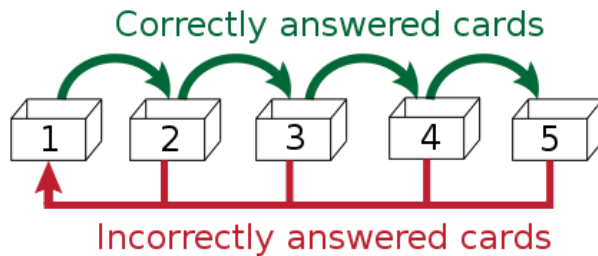

Figure 8: Leitner System

These paper flashcards are incredibly useful but can be a drag to work with. Again we like to keep things as simple and efficient as possible. Therefore, alternative options have to be found. A proper solution is to work with a digital flashcard system: Less time consuming and just as, or even more, effective.

5   Spaced Repetition Software

So far we have encountered a major issue in our current educational system: forgetfulness in pupils. We have briefly examined the brain and its capability to remember. We compared learning techniques and have started our journey towards finding an efficient way to ameliorate pupils' memory. One possible outcome were paper flashcards, which combined two, or even three of the best learning techniques and offered a solution to our forgetfulness. The downside was the elaborate work that came with it, writing hundreds of flashcards is time-consuming, cumbersome, eco-unfriendly, etc.

A logical and proper solution was choosing a digital version: Spaced Repetition Software or 'SRS'. The only thing left to do is to compare the available SRS' and choose the best option. Notable implementations include Anki, StudyDroid, Vocabulary Trainer Flashcards, StudyBlue Flashcards, Dictionary.com Flashcards, BH Inc. Flashcards, Brainscape, Course Hero, Duolingo (only languages), Lingvist (only languages), Memrise, Cerego, SpacedRepetition.com (paid), SuperMemo (only languages) and Synap (only quizzes).

5.1   Important Concepts

Most SRS apps are based on two simple but important concepts: active recall testing and spaced repetition. (0)

> *"Don't confuse recognizing information with being able to recall it."*
> *Adam Robinson, author of 'What Smart Students Know'*

Something probably all students can relate to, reading a text and thinking: "I already know this". Then a question about that text arises on the exam and the student cannot answer the question. The student was able to recognise the information but was not able to recall the information. Most pupils prefer studying passively, like reading and watching, since it is the easiest and less tiresome technique (de Mildt, 15). Active recall demands more energy but is way more efficient. One can, for example, read a text about the Great Depression, without further action this is passive. Asking and answering questions like "why did the Great Depression happen?", is active recall. Active recall is very efficient in consolidating long-term memory but takes more effort.

Cramming, a learning technique pupils so frequently use, is trying to learn lots of information in a short period of time. Knowing that our brain can only store about five to seven new pieces at a time makes that learning the evening for an exam, something we all have done at least once in our lives, is not an efficient way to remember information for a long time. It is, therefore, best to start studying early in advance. Similarly our brain stores memories it encounters regularly and frequently. Spaced repetition, or revising information regularly, is therefore highly effective. (Gupta, 2016) Mr Carey compares it to watering a lawn.

> *You can water a lawn once a week for 90 minutes or three times a week for*
> *30 minutes. Spacing out the watering during the week will keep the lawn*
> *greener over time.*
> *Benedict Carey, author of 'How We Learn: The Surprising Truth About*
> *When, Where, and Why It Happens'*

Spaced repetition and active recalling are generally the most efficient learning techniques (Kirschner, 2003) and we all know how increasingly indispensable smartphones are, not to mention how much pupils like to use their smartphones. With this knowledge, It is reasonable to believe that these apps can claim their place in, and outside, the classroom.

5.2 Motivating Pupils With SRS

The hardest part is predominantly to get pupils motivated. It would be foolish to think that just because they are allowed to use their smartphones, iPhones, iPads, tablets, or laptops to study, that it would guarantee a high level of motivation. However, the time we live in is the computer age, the age of technology and small electric devices. There are not many pupils left that do not use their electric devices on a daily basis. It is a missed chance for teachers to not anticipate on this more. The ways pupils study has not changed much. Giving pupils the chance to study on their laptops, or other electronic devices could boost their motivation.

Adding imagery, sounds, extra examples, etc. can help to provide a meaningful context, which is also motivating and makes for more profound study sessions.

Another major advantage with studying on a smartphone is that one is not bound to study at home, at school or in the library. A pupil can easily study in the bus, while walking the dog, while waiting at the doctor's, etc. This is beneficial for the pupil because it can fill empty hours with useful studying. What's more, studies have revealed that regularly changing location is beneficial for one's memory, changing location improves retention (CAREY, 2010).
It does take some willpower to actually do so. It is easier to check Facebook when waiting at the doctor's than to start studying. But a keen, and accomplished, pupil will make a habit out of it.

5.3 SRS in the Classroom

This part is entirely up to the teacher. Some levers will be provided on multiple approaches. First of all the teacher should try not to oblige pupils to use an SRS, unless be it in the initial phase to give the pupils a little push. If pupils do not want to use SRS apps, they will not benefit much from it. It is, therefore, better to offer them autonomy.

> *Being aware of autonomy has a powerful effect on individual performances and attitudes. According to a number of recent behavioural science researches, is autonomic motivation conducive for better conceptual insight, better grades, higher perseverance at school and during sports, higher productivity, less burn-out and a higher degree of psychological well-being. (Pink, 29-12-2009)*

That does not mean that the teacher cannot promote an SRS app. He does, however, have to believe in it himself, in order to be able to convince his pupils. A good way to start would be to change the traditional evaluation method with a teacher-centred SRS. The teacher provides the learning material and deadlines while the pupils adapt to this new learning method. A new behaviour would be instilled in the pupils and they would reap the benefits of the SRS.
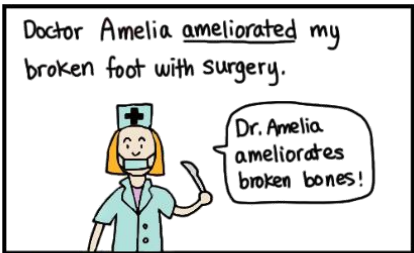
The first step would be to explain how it works elaborately. The instructions should be clear and accessible. A printed version of the instructions or a digital version on whatever platform the school or classroom uses should be readily available. The teacher could start several lessons with a set of time for pupils to use the SRS, to get them familiar with the concept. In time the SRS should mainly be used outside of the classroom, as to facilitate homework.

As mentioned before, the teacher can provide study material himself. This can be useful if the teacher wants full control over the pupils' content of learning. The teacher should take into account that learning should be meaningful and in context. Plain translations of words are therefore not attractive and not advised. If the teacher wants to provide the pupils with a vocabulary list he should include an English explanation of the word, a meaningful sentence

and, depending on the age of the pupils, a Dutch translation. Adding media, like fun images that linger or the pronunciation of a word, is highly advisable. It can be beneficial to add only a picture instead of the translation so the pupil learns to think in the target language rather than translate first. To give some examples:

(to) ameliorate
Make (something bad or unsatisfactory) better: the teacher did much to ameliorate pupils' memories. "verbeteren"   *Figure 9: Ameliorate Flashcard*

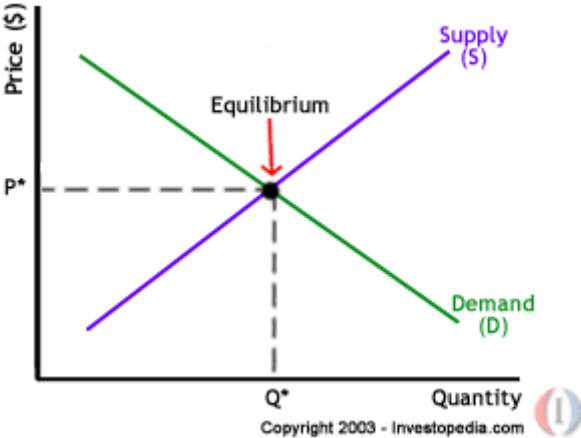| What is the law of supply and demand? |
|---|
| If all other factors remain equal, the higher the price of a good, the less people will demand that good. = **the higher the price, the lower the quantity demanded.** (People will naturally avoid buying a product that will force them to give up something else they value more.)

 Figure 10: Supply and Demand Graph Investopedia |

Another possibility is to, gradually, leave full control in the hands of the pupils when they are familiar with the app's functions. This comes with certain risks but helps pupils grow in responsibility and in the concept of lifelong learning. Possible risks include:
▪ the different interpretations pupils can make from what was initially intended and thus studying incorrect content;
▪ the sharing of faulty, or personalised, flashcards made by one eager pupil, and studying these;
▪ the giving up risk, because the pupil's delayed gratification is not yet developed. Outside the Classroom.

Once the pupils are familiarised with a desired SRS, they can start using it to prepare for tests and exams. If the pupils push through, they will enjoy a rather relaxing exam period, since they already revised everything plenty of times before taking the exams.

The pupils can then discover the possibilities of the app, which stretch much further than the school environment. Children are born with a certain amount of curiosity and by using the app they can specialise in the themes they like best. A pupil interested in strategy video games could use the app to learn more strategies, a pupil interested in playing the piano can use the app to learn the music notes, a pupil interested in dancing can use the SRS to learn the dance moves, etc.

I, for one, use Anki (an SRS) for almost everything I like to remember.
Below some examples of my Anki list:
- famous and influential economists (e.g. Adam Smith, John Maynard Keynes,…),
- Hugo Boss University,
- English slang words (e.g. minger, barmy, chuffed,…),
- the Belgian and Flemish government,
- coffee,
- literature,
- quotes and arduous words from books that I have read,
- all the school's subjects (English, Dutch and Spanish vocabulary and grammar, economics, pedagogy,…),
- Peru preparation (useful information about Peru to be well-prepared e.g. Peruvian dishes, history, climate, …),
- tie knots,
- abbreviations.

SRS can be used to remember information. Even for more abstract subjects like Mathematics, SRS can be of great help. Think of theorems, definitions, formulas, axioms, etc.

5.4   SRS Apps

5.4.1 Comparison

To not be biased, all SRS apps had to be tested. What follows are summaries of my personal findings. With in the end, a summarising grid in which the best contenders are graded on:

1. Price:

If it is to be used in the classroom then it should be free of charge. A paid version or upgrade for extra professional functions would be understandable.

2. Compatibility with other devices:

Some students prefer using their laptop or tablet instead of using their smartphone. This should be an option.

3. Available features:

Features add value. Think of: adding images to improve processing, videos to show how to articulate correctly or an instructional video on how to tie a certain knot, …

4. Lay-out:

We love design, it creates a certain atmosphere, a certain feeling. It is the reason why people willingly buy an inferior or more expensive smartphone or car.

5. User-friendliness,

Students, and all people for that matter, don't like reading instructions on how to use something. If they do not understand it right away, or if someone does not explain it to them, they will most likely give it up altogether.

6. Effectiveness:

Games are fun, but we want to improve memory. Obviously decisive.

7. Feeling of fun,

Students generally do not like studying. Being able to use a smartphone, to be able to add images, videos and more, adds some amusement. Besides, it is rewarding answering flashcards correctly. Sometimes those features are sufficient. For others, amusement is a must. Games are entertaining but not commonly educational so a combination would be lovely.

8. Annoying ads.

We do not like to be bothered by ads, but sometimes if that is what it takes for an app to be free, we can compromise.

Cerego

Cerego launched in 2013, applying the art and science of memory to its learning app. It times your learning and testing to boost the ability to recall. Cerego's preliminary tests on school students suggest that classes perform between 20-50% better using the app, and they are actively working with teachers and educational institutions to develop courses together (Robson, 2014).

One can create content or use existing content via the Cerego website. It is also possible to create a classroom and share content with the rest of the class. When created content, it can be learned through the website or a mobile phone, available on all devices, after which the app will advise you when to revise again by planning it into your schedule.

It is possible to add images and sounds. To create content one can choose between:
- instructional items: make rich content that your learners can review at any time;
- application questions: present a problem, scenario or case that requires prior knowledge to solve;
- item template:
  - associations: make simple flashcards, or create items with several memories;
  - vocabulary: learn vocabulary and word meanings, with sample sentences;
  - passages: highlight key words or phrases in a passage, and use context clues to learn;
  - regions: upload a complex image and map target areas to concepts;
  - sequences: learn procedures, timelines or series of steps in an order;
  - patterns: learn rules to help identify multiple forms through examples.

To conclude: It schedules the revision time for you, it makes good use of an algorithm on when to revise, media can be uploaded, content can be shared and it is available on all devices.

Memrise

Memrise is a spaced repetition software app, but unlike the others it does not use flashcards. It was made by Ed Cooke, a World Memory Championships contender. He wanted to make a tool to help other learn like him and allow them to relax into learning. Memrise already has more than 1.4 million users to learn foreign languages, but it can also be used for other subjects.

The app uses elaborative learning via "mems" (mnemonics) and has its own algorithm to help the student study at the right intervals.

To keep it fun they created a attractive design to compete for attention and set up a community of learners to encourage a friendly competition. Pupils love this tool because now they can compare their scores with each other.

Memrise shows great results in classrooms (Robson, 2014) especially in being fun to use. However, due to its many games and fun factor, there is no active recall. Being able to put letters in the right order is not the same as remembering the word in a real-life situation.

In conclusion, it is a, more than, decent app and can be used as an extra tool. But, it will not be graded because of its lack of active recall.

Anki

This is the app I have been using for a long time now and for good reasons. I have made comparisons before and I found this one to be my favourite.

The compatibility is impressive. It is possible to sync between all devices. It is possible to make flashcards on a laptop, study on a smartphone and then switch to a tablet. However, an internet connection is needed for syncing. Anki's features are endless:
▪ importing existing files;
▪ exporting files;
▪ syncing between devices;
▪ adding audio, imagery, videos;
▪ multiple decks;
▪ useful for all subjects;
▪ add-ons;
▪ customisation: card lay-out, review timing, …;
▪ add notes or draw pictures;
▪ …

The layout can be adjusted according to one's taste if one wishes to do so. It is easy to use but it takes some getting used to at first. Furthermore, there are plenty of instructional videos available. To create flashcards is also remarkably easy.

The most important aspect of an SRS app is its effectiveness. Anki's interval system works like a charm. It takes into account the cards one knows well, and the ones that are harder and adjust the intervals accordingly. It can be manipulated and it is possible to create a 'customised study session' for cramming a night before an exam. Sadly, neither games nor quizzes are integrated into Anki. Although games are less effective, they do keep things lightly and make it feel less like studying. Luckily the customisation options and the possibility to create personal cards can help to improve the fun factor. Ankidroid can be combined with other apps, which would allow one to use Ankidroid decks to play quizzes via another app.

Also worth mentioning is that there are no annoying ads. One can study without being distracted.

The Ankidroid app is free to use for all devices except for iOS. The app for these devices is called AnkiMobile Flashcards and costs 24,99 USD. This is a major issue since we would like to involve all pupils, without excluding those with iPhones.

To conclude: this is a superb and useful app. Too bad it is not available for iPhone since so many pupils nowadays have one. The lack of games or quizzes is also arguably a disadvantage. Arguably, because these games are not effective in improving memory. Nevertheless, games are fun and it would be fun to have it as an extra option in terms of motivating pupils.

StudyDroid

This app is extremely simple to use, its layout reflects this. However, it is possible to change font colour, size, and background colour, but that's about all the customizability there is. The app is free but unavailable for platforms other than Android. There is also a paid version of the app which costs 1,99 USD. The paid version allows people to sync with Quizlet and StudyStack. It also enables quiz mode and custom fonts. And more importantly, it removes all the annoying ads. StudyDroid is compatible with other devices and the paid version is also compatible with other apps. Yet, StudyDroid does not provide many features besides being able to download public decks.

Its best feature is its user-friendliness. Sadly, the effectiveness is rather disappointing, and not the most practical way to study. The full extent of its SRS capabilities is marking a card as "known" which moves them back to the end of the stack. For this very reason StudyDroid is already written off as a contender to be used in the classroom.

StudyBlue

StudyBlue is free on all devices, which is a major advantage. There is a possibility to upgrade for, respectively, 7,00 USD, 10,00 USD and 19,00 USD a month. The price depends on whether one chooses a monthly-, semesterly- or annual subscription. The paid version is ad-free, sadly the free version is not. Within StudyBlue it is possible to sync with all one's devices. StudyBlue's features are also impressive. These include:
- sharing files with friends or classmates;
- syncing between devices;
- adding audio, imagery, videos;
- multiple decks;
- Useful for all subjects;
- customisation of the card layout;
- add notes via Evernote;
- play games: multiple choice, true or false and fill in the gaps;
- …

StudyBlue looks professional and somewhat complicated, yet, It actually is quite easy to use and there are plenty of instructional videos available. The games are fun which makes the app more appealing to pupils. But, they also make a good excuse for not studying via the flashcard mode. If one falls into this trap, the app will be far less effective in improving memory. The flashcard mode itself is also rather basic. The only option one has is 'good' or 'bad'. After the session, one can repeat all the hard ones in a new session or repeat them all. It does not take the forgetting curve into account. To end on a positive note, one can change the settings so that the app sends the pupil text messages on when to revise.

To conclude: It is a magnificent app with lots of tools and features. It is a contender to be used in the classroom, and in fact, it is already used in a variety of areas in the US. Nonetheless, when I used it for a week to try it out, I found out that uploading images was more of a hassle than with Anki. It also bothers me that it does not use the same intervals as Anki. The games are also a poisoned gift, since it is alluring to do the games instead of the actual learning. This results in a less profound learning of the learning material.

Brainscape

In Brainscape it is free to use existing flashcards and to create your own. However, to add media, like pictures or sound, you have to upgrade. Which will cost you respectively 9,99 USD, 4,99 USD or 2,99 USD per month, for either a monthly, a semester or a year contract. It is also possible to pay 79,99 USD once, then you can use Brainscape for a lifetime. It is usable on all devices.

Brainscape was a potential winner. It is available on all devices and it looks exquisite, it has no annoying adds and is effective. The problem is that you cannot add imagery or sounds if you do not upgrade. This makes it far less appealing, and consequently, no contender to ultimately being used in the classroom.

Quizlet

Once again you have to upgrade to add media. More information is therefore superfluous.

Vocabulary Trainer Flashcards

This app looks mediocre and sadly not customizable. It applies the system of the Leitner box (0). But, syncing with other devices is not possible. The main advantage of this app is its ability to read out what is written on a card.

5.4.2   Grading

These gradings are done by the writer of this thesis and are thus personal findings

Free:
- paid
+ free version
++ free on all devices (or free version covers all necessities e.g. adding media etc.)

Compatibility:
- not available on other devices
+ available on Android (+ syncable)
++ available on all devices

Features:
- no added value
+ extra features
++ plenty of extra features

Aesthetics:
- not appealing/professional
+ exquisite layout
++ professional

User-friendly:
- not easy to use (or takes long to make flashcards)
+ easy to use
++ easy to use, available instruction videos and fast making of flashcards

Effectiveness:
- not effective
+ effective
++ highly effective (forgetting curve, separated hard from easy, …)

Fun:
- not fun to use
+ fun to use
++ games and other features to make it more fun

Ads:
- ads
+ no ads

SRS	Free	Compa-tibility	Features	Aesthetics	User-friendly	Effec-tiveness	Fun	Ads
Anki	+	++	++	++	++	++	+	+
StudyDroid	+	+	+	+	++	-	+	-
StudyBlue	++	++	++	++	+	+	++	-
Brainscape	+	++	-	++	+	+	+	+
Quizlet	+	++	-	++	+	+	+	+
Vocabulary Trainer Flashcards	++	++	+	-	+	+	-	-
Cerego	++	++	+	++	+	++	+	+

Conclusion

The winners are Anki, Cerego and StudyBlue. In these apps, we can encounter the two best learning techniques: active recall and spaced repetition. StudyBlue and Cerego are free on every platform, Anki is not for iOS. Anki and Cerego make good use of the forgetting curve and make adding photos from google easy (as in copy-paste), some things which Studyblue does not. In Anki, one can create new content without an internet connection. An internet connection is required for Studyblue, and in Cerego it is only possible to create new content via the web version.

These apps will be further discussed, in detail, in the following pages. Some of the themes discussed in previous pages will sporadically reoccur.

5.4.3 Anki

Figure 11: Anki Logo

Introduction

The first spaced repetition system that will be discussed is Anki. It is content-agnostic (a design that does not impose itself on future content) and supports images, audio, videos and scientific markup via LaTeX, this is used to make math formulas, non-latin scripts, Arabic, Chinese, etc. The possibilities, therefore, are endless. As an SRS it is usable in the classroom, but also outside of the classroom. E.g. for learning a language, memorising people's names and faces, mastering poems or practising guitar chords.

Before Anki, there was SuperMemo, a commercial flashcard program that implemented spaced repetition. SuperMemo pioneered the concept of a system that keeps track of the ideal time to review material and optimises itself based on the performance of the user.

In SuperMemo's SRS, every time you answer a question, you tell the program how well you were able to remember it – whether you forgot completely, made a small mistake, remembered with trouble, remembered easily, etc. The program used this feedback to decide the optimal time to show you the question again. Since a memory grows stronger each time you successfully recall it, the time between reviews grows bigger and bigger So, you may see a question for the first time, then 3 days later, 15 days later, 45 days later, and so on.

This was a revolution in learning, as it meant material could be learnt and retained with the absolute minimum amount of effort necessary. SuperMemo's slogan sums it up: *with spaced repetition, you can forget about forgetting*.

The concept was great, but several extras were missing. So, Anki kept the same concept but ameliorated it.

Anki is the Japanese word for memorization. Its developer's name is Damien Elmes. At some point a few years ago, he had to make a decision: quit his job or stop developing Anki. He chose to quit his job and make a paid iOS app to provide himself with an income. That's his sole source of income according to another developer.

Interesting fact: In 2010, Roger Craig obtained the all-time record for single-day winnings on the quiz show "Jeopardy!" after using Anki to memorise a vast number of facts (Baker, 2011).

Features

Flashcards can be created extremely fast
Teachers and students know how important this feature is. When one has to study hundreds of pages every minute, even second, counts.

Anki supports audio, images and videos

Audio can be useful for languages e.g. practising pronunciation and hearing and videos can be used for giving instructions. Multimedia enriches the learning experience and the student's engagement, it is therefore highly recommended to add as much media as possible.

Easy to copy-paste images from Google to flashcards
At first, this may seem like a detail, but it is not. When making flashcards you want to add images for earlier mentioned purposes. The place to be to find images for almost everything one can think of is "Google Images". It is a real drag to search for an image, save the image on your desktop and then finally upload the image onto your flashcard. In Anki you find an image, you copy the image and paste it into your flashcard. This is quick and efficient and a major advantage.

Sync between devices

Everyone has a preference and they are all met in Anki – except for a paper version preference.

Multiple decks possible

One sizable flash card deck can be interesting, though not very practical if one has to study a wide range of subjects that are not related to each other. A useful feature indeed.

Customisable

What's on the inside is more important than looks. The same is true for the app, nonetheless, appearance is still very important. It is also very personal, so being able to customise is an advantage.

Add notes

Adding a page number or adding the topic your flashcards relates to can be useful. After doing this it is easy to organise and find flashcards well.

Draw your own pictures, like original paper flashcards

Some people are artistic and some images are hard to find, even in Google. The solution? Draw your own images.

Download from a huge database with existing files

What you do yourself, you, usually, do better. This is a loose translation of a Dutch saying. Whether true or not, sometimes it is easier to just use someone else's work. This time it is even legal and free of charge. This database is huge thanks to the many loyal users.

Share files with others

Especially useful in classroom settings. Sharing is caring.

How Anki Works

An Anki collection can consist of multiple decks. A deck is simply a group of cards. It is possible to have decks about all kinds of topics. To study new material one can download existing material or create his own material. It is possible to mix different decks so the learner learns to make connections between different subjects. In the classroom, this would mean that the teacher could create the material and share it with the rest of the class. This is the safer bet in case of young pupils. Better is, for older students or adults, if they create their own personalised study material. That way they will study more profoundly and meaningfully.

Decks can be interpreted differently than intended by the creator. To reduce the chances of studying wrong interpretations the teacher can evaluate on a regular basis. Pupils could create a quiz for each other and keep scores.

Each card has a question and an answer, just like a normal paper flashcards, with a question on one side and the answer on the other. In Anki however, one does not have to flip its card to reveal the answer, one simply has to click on 'show answer' and the answer appears along with the question that, unlike in normal flashcards, does not disappear.

A pupil should first try to answer the question before revealing the answer. When the pupil then opens the answer he will have to choose how well he answered the question. Was he wrong? Did it take too long to answer? Was his answer good? Or was it an easy question? He then selects the most accurate evaluation choosing between again, hard, good and easy. The choice the pupil now makes will determine how long it will take before the card pops up again. In time cards may appear no earlier than several months, from there it is about to be permanently consolidated.

A more detailed instruction on how to install and sync Anki can be found in the attachment. The user manual can be found via this link: https://apps.ankiweb.net/docs/manual.html. Here you will find all the answers to your questions.

5.4.4   StudyBlue

Figure 12: StudyBlue Logo

Introduction

StudyBlue is another good-looking spaced repetition system. It is a collaborative learning system with more than 13 million members. StudyBlue is already used in classrooms in the US.

StudyBlue was founded in 2006 by two students: Chris Klundt and Dave Sargeant. Becky Splitt took over from 2009 because the founders found her better suited since they were both very young and without experience. In the meantime, Klundt graduated and took back his title as CEO of StudyBlue whilst Splitt is now executive chairman in charge of strategic initiatives.

StudyBlue raised approximately 14.8 million USD in funding and is now serving more than 26.000 institutions in over 100 countries.

Features

StudyBlue is a spaced repetition device which enables pupils to use their mobile device to create flashcards in seconds, but unlike Anki, an internet connection is needed to create these flashcards. Students can choose to make their own cards or use the material available in StudyBlue's content library. The library contains hundreds of subjects, especially for high school and college students. There is a variety of study options, but the forgetting curve is not implemented, which makes Anki's spaced repetition system better. the flashcards can also be turned into quizzes, review sheets and flip cards. These games can definitely help in

motivating pupils. However, bear in mind that these games are less effective and can easily give the false impression of having learned much, while the pupils really have not.

The app tracks the student's progress with self-assessment scores. Chances are that the pupils will use these scores to compare them with classmates. One can easily create an account or log in by using a Facebook account, Google Gmail or email which helps one get started even faster. The clear step by step process should take about 30 seconds to complete. Probably the main reason for using StudyBlue is that it can be used on all devices, including Apple. The classroom option, in which the teacher can add all his pupils, is also a precious tool.

The free StudyBlue app is easy to use, but it only offers basic flashcards. An upgraded membership, SB Pro, is available for $8.99/month or $35.99/year. The upgrade allows customisation of flashcards such as adding audio, font, italics and the ability to underline words or add equations. Note that these options are all free in Anki. Even if one upgrades, these extra options, while useful, are not available through the mobile app. This may be a disappointment for some users. The free app includes advertisements each time the "study now icon" is tapped. Pupils can choose to remove the ads by upgrading to SB Pro or they can simply tap the skip and study icon to go right to the flash cards.

StudyBlue is a convenient flashcard study app. The app is free and is especially useful for students with iPhones, or those who need the extra games. StudyBlue is best suited for high school and college students, and not really suited for younger children.

5.4.5   Cerego

Figure 13: Cerego Logo

Introduction

Cerego is a new player in the world of SRS, but a decent contender. Cerego even partnered with Elsevier to provide nursing and healthcare students with an adaptive learning solution for their educational content. Cerego was awarded a grant in 2014 by the Bill & Melinda Gates Foundation for providing "next-generation digital courseware" to reach more than 1 million low-income students and disadvantaged learners in undergraduate courses by 2018. Cerego was founded in 2000 and raised 3.4 million USD in funding.

Features

Both Anki and StudyBlue come short in important aspects. Anki comes short in providing free software for iOS, while StudyBlue does not have an algorithm to provide the best time possible to revise and it makes adding media a hassle.

In Cerego one can create a learning path. First instructions are presented, then items are created that should be practised through distributed learning and finally critical thinking is provoked. The instructions appear only once, while the items are to be practised daily. Cerego replaces the familiar flashcard by giving plenty of other specific options. These options include: associations, vocabulary, passages, regions, sequences, patterns and

question & answer. Cerego's instructions are directed to the teacher, in contrast to e.g. Anki, where the instructions are directed to the user himself.

The following is an enumeration of the possible flashcards that can be made in Cerego
- Associations are flashcards which should be used to combine multiple connections. E.g. a picture of an ear, the word "ear" and the translation of the word ear in Dutch "oor".
- Question and answer flashcards are used to create a quizlike flashcard. One can author "true or false", "select all that apply" and "classic quiz items".
- Application questions are used for deeper analyses. Prior knowledge is needed to solve this kind of flashcards. Think of: a case study, example problem or if one wants to pose a scenario.
- Vocabulary flashcards are ideal for learning new words.
- Passages are used to help students learn from context. It's possible to highlight keywords or phrases and add notes, pictures, videos and more.
- Regions are flashcards for anatomy images or maps. E.g. the anatomy of the human body, a world map, a mind map, etc.
- Sequences are ideal for timelines, procedures or a series of steps in a particular order.
- Patterns are best chosen if the students move beyond basic recognition into identification and classification.

Cerego fills in the gaps of other SRS apps. It is free on all devices, and it provides the learner with a schedule on when to revise what. Adding media is also very easy. Sadly, Cerego does not offer the possibility to add content via a mobile phone but then again they rely more on the teacher to create content than on the student and so this becomes rather obsolete.

It is up to the learner to decide for himself what he finds most important in an SRS app and to choose an SRS app accordingly.

6   Statistics

We are reaching the final stage of the bachelor thesis. A conclusion is to be made through existing research and statistics. Trying out the SRS apps in the classroom would have delivered priceless information for a conclusion, however, due to a teaching practice in Peru, this was not feasible. What follows are interpretations of statistics from other research projects which should provide us with a good idea about the possible effects, if any, of SRS apps in the classroom.

The Effects of Spaced Practice and Spaced Review on Recall and Retention Using Computer Assisted Instruction – Caple Carlous

In this doctoral dissertation the effects of spaced repetition on recall and retention by using computers was examined. The research dates back to 1996! Spaced practice and spaced review studies had already proved to be beneficial (McKitrick LA, 1992) but now they wanted to determine the effectiveness of spaced practice and spaced review within computer-assisted instruction programs.

They tested two groups, one received the structured CAI (computer aided instruction) program and the other received the unstructured program, meaning they did not use spaced review. Thirty-six subjects participated, divided into two groups of eighteen. It was a mixed group of mixed disciplines: graphic communications, technology education and industrial engineering.

The study's findings justify the following conclusions:
- the spacing effects of spaced practice and spaced review could enhance recall and retention when implemented structurally within a computer-assisted instruction program;
- the instructional treatment with the implications for spaced practice (structured CAI), did enhance learning and memory for immediate recall;
- spacing effects can improve educational endeavours, specifically related to computers in education, and interactive environments as a whole.

Finally, the study offers some recommendations. They recommend that educators seek educational software that provides spacing effects for the benefit of enhanced, or a higher degree of learning (we now have this in the form of SRS). The practice of implementing well-developed educational software, allows educators the advantage of teaching effectiveness, which has a direct influence on students and their performance in school. This practice would also increase self-esteem in students. School administrators would also benefit from the implementation of educational software using spacing effects because they are a direct result of effective teachers that have students performing at optimum levels. In the same way, parents should implement similar software at home.
(Caple, 1996)

The effects of Brainscape's confidence-based repetition on two adults' performance on knowledge-based quizzes by Sarabeth Waterman.

This is a master's project for the degree of master of science in education. The purpose of this project was to examine the effects of the Brainscape program, an SRS app, on the acquisition and retention of new knowledge by two male adult volunteers. Both individuals expressed a desire to expand their knowledge in two distinct domains, SAT-related vocabulary and United States trivia. The effects of Brainscape were then compared to a more traditional didactic teaching approach.

Obviously, much more research must be done to reach a strong conclusion and so caution should be used in interpreting the finding. But, at least the results of this limited project were positive. Both participants scored much better on the post-test than on the pre-test. Both participants said to be satisfied with the outcomes from using Brainscape. They felt that it had improved their understanding of selected topics and that it was relatively easy and fun to use. Both participants agreed that Brainscape could not be harmful to others.

Domain	Pre-test	Post-test (after using Brainscape)	Difference
Mastery scores for SAT vocabulary by means of SRS app "Brainscape"	56%	94%	+ 38%
United State landmarks by means of SRS app "Brainscape"	38%	91%	+ 53%

(Waterman, 2013)

Effects of Intensive, Short-Term Study on Language Growth: A Case Study by Malcolm Ross Swanson and Andrew Joseph Zitzmann

In the first semester of 2014, they began a project to test the effectiveness of short-term, regular, intensive study on students' skill levels and performance. In this project, a group of volunteer students were given 20-minute activities to complete every day for a period of 15 weeks. After the project was completed, they compared students' TOEIC scores, reading speed, and vocabulary levels. They found that students who participated fully in the project achieved a measurable improvement compared to those that did not. Therefore proving that spaced learning can lead to improvement.

Visualised in the following grid is the improvement of vocabulary by using Word Engine, a service which uses spaced repetition. Group A clearly scores better than B and C.

	Goal attained	Correct responses	Time (minutes)	Vocabulary gain
Group A	11,89	3.404,33	519,89	511,56
Group B	4,00	1.345,20	216,40	268,40
Group C	1,14	584,43	92,57	149,86

Group A (10 students): Those students who had completed most of the activities and who were still actively participating at the end of the project.
Group B (5 students): Those students who had completed roughly half the activities but weren't active at the end of the project.
Group C (6 students): Those students who never got started, or who had already given up by the midpoint of the project.
(Malcolm Ross Swanson, 2015)

Translating Learning Science into Learning Strategy by Iain M. Harlow, Paul T. Mumma & Andrew Smith Lewis

Cerego conducted an internal research. They examined Cerego users who took part in courses between autumn 2015 and spring 2016. They provide direct evidence that:
▪ their adaptive learning engine reflects the actual review difficulty so the review schedules can be optimised for desirable difficulty;

- reviewing each memory close to the time suggested by Cerego leads to better learning , supporting both the principle of distributed learning as well as the effectiveness of Cerego's specific schedule;
- longer time spent on trying to answer the question before revealing the answer leads to a higher accuracy on later trials, supporting the long-term retention advantage of more profound metacognitive engagement and effortful retrieval when learning.
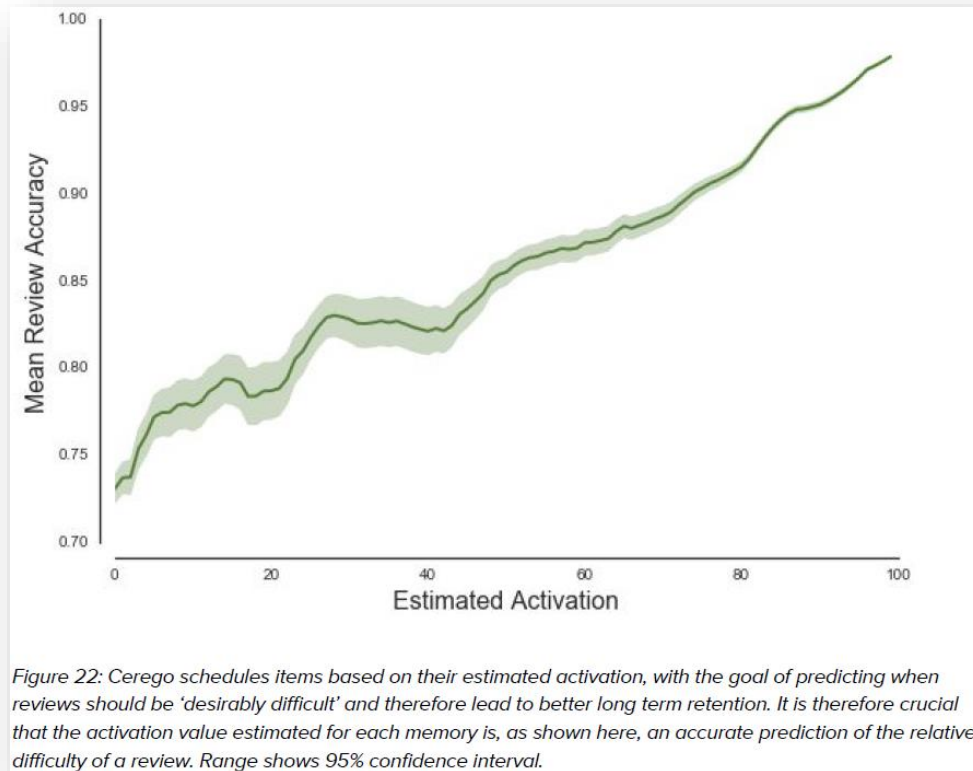

Figure 22: Cerego schedules items based on their estimated activation, with the goal of predicting when reviews should be 'desirably difficult' and therefore lead to better long term retention. It is therefore crucial that the activation value estimated for each memory is, as shown here, an accurate prediction of the relative difficulty of a review. Range shows 95% confidence interval.

Figure 14: Tracking Memory Accurately
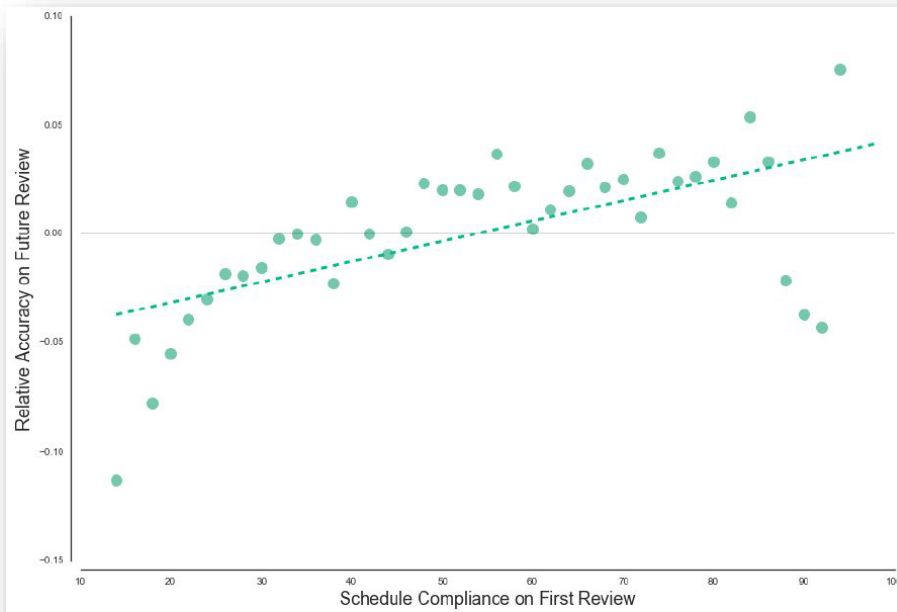
Figure 23: Closer compliance with Cerego's suggested schedule leads to better accuracy on later trials. Relative accuracy is corrected for activation at the moment of review; it reflects the % accuracy on trials relative to the average (so higher numbers mean the material has been better learned). Higher compliance values mean the user reviewed closer to the suggested time for their items. Users are binned according to their compliance on the first review.
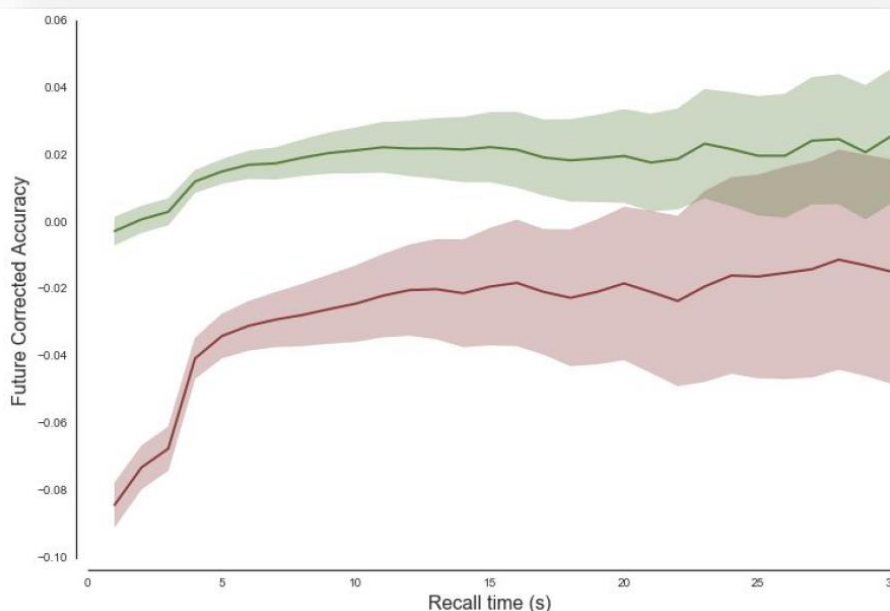
Figure 15: Reviewing at Desirable Difficulties

Figure 25: Future review accuracy (corrected for activation) as a function of recall time on the first review. Shown separately for items answered correctly (green; upper line) or incorrectly (red; lower line) on the first review following the recall screen. Whether the response was correct or incorrect, spending longer on the recall screen before answering improved review accuracy on later reviews for the same item.

Figure 16: Future Review Accuracy

Cerego also made use of external research and case studies.

Homer & Plass (2015) conducted an effectiveness study of Cerego for five high school subjects (Algebra, Biology, Civics, Geometry and US History). Participants came from 7 schools in a network of charter schools in Greater Miami (In total, 126 classes/sections across 7 schools with 4.111 students). The primary goal was to determine if students who used the Cerego system had better learning outcomes compared to students in a "business as usual" control group (not using Cerego).

Primary data collected included knowledge pre-tests and knowledge post-tests for each subject using regular end-of-term tests. The pre- and post-tests were the tests administered by schools as part of their regular educational assessments rather than tests specifically designed for this study. Within the group using Cerego, the authors found that the amount of time spent learning in Cerego was associated with significant increases in the post-test score (Figure 17). The authors also found that users who spent at least 1 hour per week learning in Cerego showed greater improvement between pre-test and post-test than did users who did not use Cerego or used it for less than the minimum time of 1hr per week. (Figure 18).
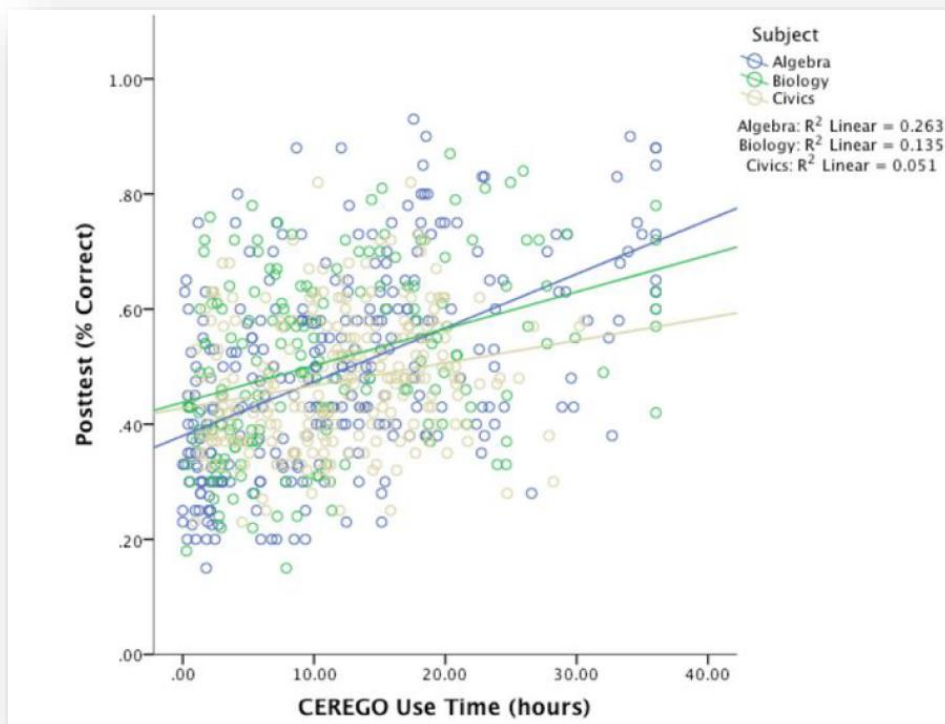

Figure 17: Relationship between time spent using Cerego and Post-test performance for students in the Cerego group.
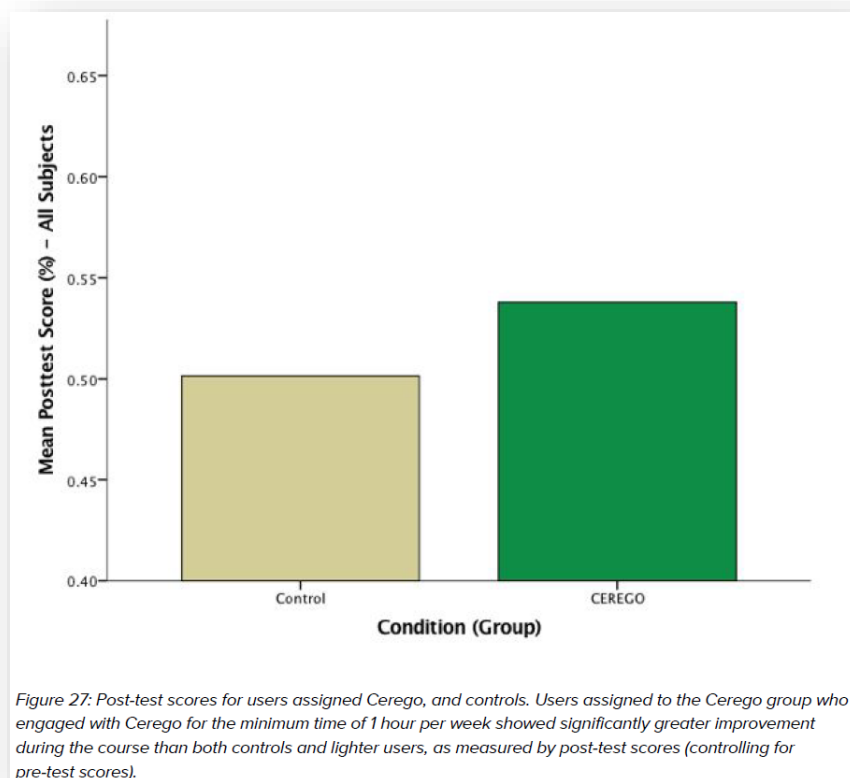
Figure 27: Post-test scores for users assigned Cerego, and controls. Users assigned to the Cerego group who engaged with Cerego for the minimum time of 1 hour per week showed significantly greater improvement during the course than both controls and lighter users, as measured by post-test scores (controlling for pre-test scores).

Figure 18: Post-test scores for users assigned Cerego, and controls.

Cerego is also being used in partnership with EdX and the University of Texas at Austin to provide a 10-week online open course about Jazz music. Using Cerego to increase engagement and retention of the course material:

▪ more than twice the proportion of initial signups completed the course successfully than with a typical MOOC (12% v 5%);
▪ of the completing students, 1408 (59%) scored above 90% , including 773 (32%) who achieved perfect scores;
▪ consistent with the findings from [Homer & Plass, 2015] that greater Cerego use improved learning outcomes, high achieving students spent more time studying in Cerego per week (66 minutes) than the average student who completed the course (51 minutes);
▪ surveyed students reported that using Cerego helped them to learn faster (74%) and retain their knowledge for longer (82%) than traditional study methods.

Finally, Cerego was piloted by New York University College of Dentistry in the summer of 2015. Around 350 students taking review classes for Board exams in the fall were given the opportunity to supplement their reviews with Cerego content created by the professor:

▪ students studied 424 review items in Cerego, replacing 96 hours of class teaching time (reducing the professor's in-class teaching by 50%);
▪ 100% of students in the review class passed the subsequent board exams;
▪ Aggregate Board exam results for the students were exceptionally high; 2.6 standard deviations above the national average;
▪ a majority of surveyed students reported that using Cerego to review was worthwhile, by a margin of 58% versus 16%.
(Iain M. Harlow, May 1st 2016)

Summary of Cerego Academica Pre-pilot Study

This is a pre-pilot study, meaning a larger study is yet to come. It was conducted in 2013, testing 484 high school students in Florida, USA. These were the findings:

- the students reported that learning with Cerego was "easy" or "very easy", and that they were learning "much" or "very much" with Cerego;
- the teachers said that the pupils were either "more engaged" or "much more engaged" with Cerego, and "more on task" or "much more on task". Almost all of the teachers reported that using Cerego had little or no effect on their workload, although they did report an increased workload in the first and last weeks of the pre-pilot study;
- on average, the Cerego classes performed 13% better than the non-Cerego classes on the knowledge tests given at the end.
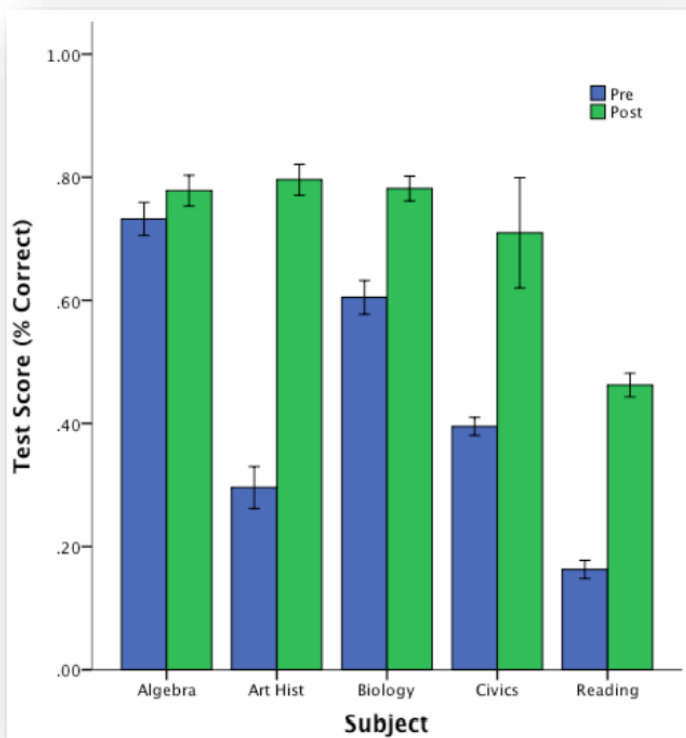
Figure 19: Pretest to Posttest Gains for Classes using Cerego by Subject
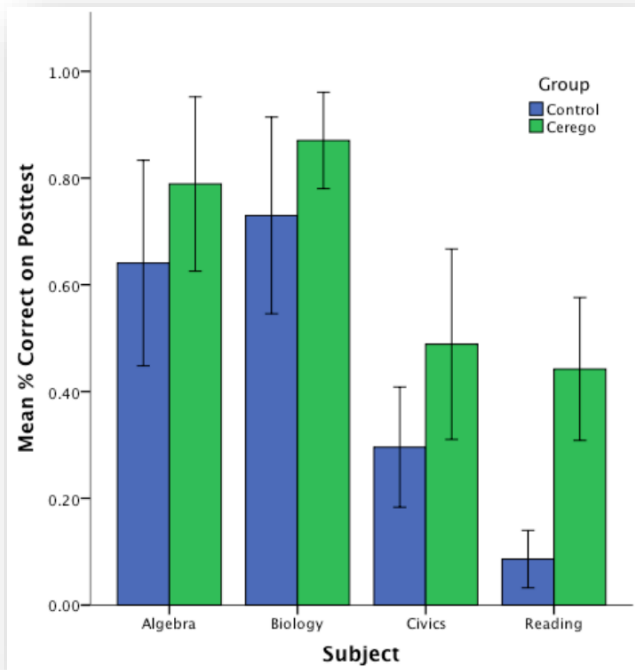
Figure 20: Knowledge Scores for Cerego versus Non-Cerego (control) Classrooms by Subject

(Plass, JULY 11, 2013)

7   Practical Implementation

Example case

Introduction

In this example case, I will provide teachers with a manual on how they can use SRS in a school setting. Feel free to adjust my instructions to better suit your needs for your particular situation. Also, note that SRS is not exclusive for language subjects. You can read about SRS used for mathematics following this link: http://www.ollielovell.com/olliesclassroom/help-students-remember/. Another blog about an English teacher in the USA who tried Anki in the classroom can be read via these two links:
Year 1: http://lesswrong.com/lw/mfm/a_year_of_spaced_repetition_software_in_the/
Year 2: http://lesswrong.com/lw/nkz/a_second_year_of_spaced_repetition_software_in/
Year 3 should be coming out any time now.

Scenario

In this case I will discuss an approach for a second grade TSO class (e.g. commerce-languages), with pupils who are approximately 14/15 years old. The subject will be English.

We discussed three different SRSs, for this case we'll choose Cerego because it's teacher-centred and fitting for a classroom setting. In this example the teacher will be doing the heavy lifting. I believe it's best to start with a teacher-centred approach until the pupils are mature, responsible and motivated enough to create their own content. I wouldn't recommend using it in the classroom itself because every pupils has his own unique learning path in which he will have to walk alone. However, it would be advised to spend some lessons using the app so the pupils know exactly what is expected of them.

Course of Action

Step 1:
Create a Cerego account and use the online manual to get familiar with all its features.
Step 2:
Create a group for each classroom. Although it's not necessary for the pupils to have an account to join the group, it is best if you let them make an account anyway. This way they can start exploring on their own and maybe use it independently for other subjects.
Step 3:
Choose when assignments and new content become available so that students get introduced to the right content at just the right time, while Cerego makes sure to remind them to review on their personalised schedule. When you introduce new content make sure to share this content right after the lesson or at the end of the school day. This way the pupils can revise when the content is still fresh. Try to keep the number of cards to a minimum so the pupils don't get an overload. Don't be afraid to insert easy cards too. Some pupils need these to motivate themselves. Also, don't limit yourself to vocabulary and grammar. In Cerego it is perfectly possible to create flashcards which will make them think critically. Yes, in the beginning, it will take an extra effort but the results should be worth your while.
Step 4:
Set memory goals for each assignment. This gives the pupils something to work towards and makes it easier to grade their progress. Do discuss their progress individually. Just like the regular approach (normal assignments, normal tests, etc.), there will be pupils reluctant to participate. If this happens don't be too quick to throw away the good with the bad, more often than not the pupil will have an underlying reason, e.g. problems at home.

The statistics don't lie. Although a larger study is needed, the research at hand clearly states SRS can improve pupils memory and processing. Therefore, it has its place in schools as well. It is well worth a try because doing nothing is not an option.

To stand still is to fall behind. – Mark Twain

Conclusion

Using spaced practice and spaced review is beneficial in improving one's memory. Modern spaced repetition software is designed to facilitate and ameliorate study habits. This bachelor thesis provides valuable information about available spaced repetition software and helps to determine which one is best suited for specific situations. Carlous Caple's recommendations of 1996 are now more relevant than ever, schools, teachers, parents and, ultimately, students, should embrace this learning revolution. Bill Gates' investment in Cerego can be used as an indicator of SRS' potential.

An inherent limitation of spaced repetition software is that it is exclusively beneficial when used repeatedly. So, how can spaced repetition software improve pupils' memory? By integrating SRS as a substitute for traditional evaluation methods in schools and as an improved learning method at home. Consequently, instilling a new behaviour in pupils. This bachelor thesis is by itself insufficient to conclude that SRS will solve pupils' forgetfulness because it has not been extensively tested in a school environment. It is recommended for future research to use quasi-experimental and experimental designs in classroom situations conducted by independent researchers and data collection systems.

Further Reading

Ansari, A. (2015, May 6). *Healthy diet may improve memory, says study*. Retrieved from CNN: http://edition.cnn.com/2015/05/06/health/healthy-eating-preserves-memory-study/index.html

Asimov, I. (1979). *Life and time. .* New York: Avon Books.

Atkinson, R. C. (1968). *Human memory: A proposed system and its control processes. In The psychology of learning and motivation.* Oxford, England: Academic Press.

Ausubel, D. P. (1978). Preface. In J. D. David Paul Ausubel, *Educational Psychology: A Cognitive View* (p. 733). Holt, Rinehart and Winston.

Baddely, A. (2007). *Working memory, thought, and action. .* Oxford, UK: Oxford University Press.

Baillargeon, R. &. (1991). *Object permanence in young infants: Further evidence. Child development.*

Baker, S. (2011). *Final Jeopardy: The Story of Watson, the Computer That Will Transform Our World.* Houghton Mifflin Harcourt.

BBC Magazine. (2014, juli 14). *20 readers who lost fluency in their language*. Retrieved from BBC: http://www.bbc.com/news/magazine-28022790

Belga. (2016, September 15). *We studeren voor jobs die verdwijnen*. Opgehaald van De Morgen: http://www.demorgen.be/binnenland/we-studeren-voor-jobs-die-verdwijnen-bc5cb651/

Bergland, C. (2017, January 16). *Physical Fitness Keeps Your Brain in Good Shape, Study Finds*. Retrieved from Psychology Today: https://www.psychologytoday.com/blog/the-athletes-way/201701/physical-fitness-keeps-your-brain-in-good-shape-study-finds

C.M., A. (2005). Mechanisms of memory stabilization: are consolidation and reconsolidation similar or distinct processes? . *Trends in Neuroscience.*, 51–56.

Caple, C. (1996). *The Effects of Spaced Practice and Spaced Review on Recall and Retention Using Computer Assisted Instruction .* North Carolina : North Carolina State University.

CAREY, B. (2010, September 6). *Forget What You Know About Good Study Habits*. Retrieved from http://www.nytimes.com/: http://www.nytimes.com/2010/09/07/health/views/07mind.html

Clifford, C. (2016, November 4). *Elon Musk: Robots will take your jobs, government will have to pay your wage*. Retrieved from CNBC: http://www.cnbc.com/2016/11/04/elon-musk-robots-will-take-your-jobs-government-will-have-to-pay-your-wage.html

CNRS. (2016, May 18). *Enhanced hippocampal-cortical coupling improves memory*. Retrieved from Science Daily: https://www.sciencedaily.com/releases/2016/05/160518074211.htm

Cowan, N. (1995). *Attention and Memory: An Integrated Frame Network. .* New York: Oxford university Press.

Cowan, N. (n.d.). *The magical number 4 in short-termmemory: A reconsideration of mental storage capacity.* Retrieved from BEHAVIORAL AND BRAIN SCIENCES (2000): http://docplayer.net/216846-The-magical-number-4-in-short-term-memory-a-reconsideration-of-mental-storage-capacity.html

Danziger, K. (2008). *Marking the mind: A history of memory. .* Cambridge: Cambridge University Press.

de Mildt, E. (15, 05 18). *Je studeert waarschijnlijk verkeerd. Dit zijn 6 studietips die wél werken en tijd besparen*. Retrieved from www.demorgen.be: http://www.demorgen.be/binnenland/je-studeert-waarschijnlijk-verkeerd-dit-zijn-6-studietips-die-wel-werken-en-tijd-besparen-b6217117/

Dr. Aamodt, S. &. (2008). *Welcome to your brain.* New York: Bloomsbury USA.

Dunlosky, J. R. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, 55.

Eadicicco, L. (2015, January 28). *Bill Gates: Elon Musk Is Right, We Should All Be Scared Of Artificial Intelligence Wiping Out Humanity*. Retrieved from Business Insider: http://www.businessinsider.com/bill-gates-artificial-intelligence-2015-1

Edwards, S. (2008). *Sugar and the Brain*. Retrieved from harvard Neurobiology: http://neuro.hms.harvard.edu/harvard-mahoney-neuroscience-institute/brain-newsletter/and-brain-series/sugar-and-brain

Elmes, D. (n.d.). *Anki 2.0 User Manual*. Retrieved from www.ankisrs.net: http://ankisrs.net/docs/manual.html#introduction

English Oxford Living Dictionaries. (n.d.). Retrieved from Oxforddictionaries: https://en.oxforddictionaries.com

Eysenck MW, E. M. (1980). Effects of processing depth, distinctiveness, and word frequency on retention. *British Journal of Psychology*, 263–274.

Eysenck, M. W. (2012). *Fundamentals of cognition.* . New York: Psychology Press.

Foer, J. (2011). *Moonwalking with Einstein: The Art and Science of Remembering Everything.* New York: The Penguin Press.

Foerde, K. &. (2009). *Procedural learning in humans. In L. R. Squire (Ed.): The new encyclopedia of neuroscience, Vol. 7 (pp. 1083-1091).* . Oxford, UK: Academic Press.

Garrett, M. D. (2014, February 25). *Complexity of Our Brain*. Retrieved from Psychology Today: https://www.psychologytoday.com/blog/iage/201402/complexity-our-brain

Godman, H. (2014, April 09). *http://www.health.harvard.edu/blog/regular-exercise-changes-brain-improve-memory-thinking-skills-201404097110*. Retrieved from Regular exercise changes the brain to improve memory, thinking skills: http://www.health.harvard.edu/blog/regular-exercise-changes-brain-improve-memory-thinking-skills-201404097110

Graf P., S. D. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, And Cognition.*, 501–518.

Gregoire, C. (2015, April 06). *This Is What Sugar Does To Your Brain*. Retrieved from The Huffington Post: http://www.huffingtonpost.com/2015/04/06/sugar-brain-mental-health_n_6904778.html

Gupta, J. (2016, Januari 23). *Spaced repetition: a hack to make your brain store information*. Retrieved from www.theguardian.com: https://www.theguardian.com/education/2016/jan/23/spaced-repetition-a-hack-to-make-your-brain-store-information

Hamilton, S. (2017, March 1). *Economists May Be Underestimating How Fast the Robots Are Coming*. Retrieved from Bloomberg: https://www.bloomberg.com/news/articles/2017-03-01/economists-may-be-underestimating-how-fast-the-robots-are-coming

Heshmat, S. (2015, October 8). *Why Do We Remember Certain Things, But Forget Others?* Retrieved from Psychology Today: https://www.psychologytoday.com/blog/science-choice/201510/why-do-we-remember-certain-things-forget-others

How do people lose their native language? (2014, Juni 4). Retrieved from www.bbc.com: http://www.bbc.com/news/blogs-magazine-monitor-27690891

Iain M. Harlow, P. T. (May 1st 2016). *Translating Learning Science into Learning Strategy Cerego White Paper.*

Jarrett, C. (2012, June 27). *Why the Left-Brain Right-Brain Myth Will Probably Never Die*. Retrieved from Psychology Today: https://www.psychologytoday.com/blog/brain-myths/201206/why-the-left-brain-right-brain-myth-will-probably-never-die

JOBAT. (2013, May 18). *Persoonlijkheid en leervermogen belangrijker dan kennis en vaardigheden*. Opgehaald van Nieuwsblad: http://www.nieuwsblad.be/cnt/dmf20130517_039

K., S. K. (2010). Episodic future thought: An emerging concept. . *Perspectives On Psychological Science*, 142–162.

Kaufman, S. B. (2012, July 26). *Interview with World Memory Champion Boris Nikolai Konrad*. Retrieved from Psychology Today:

https://www.psychologytoday.com/blog/beautiful-minds/201207/interview-world-memory-champion-boris-nikolai-konrad

Kirschner, P. (2003, april 5). *Top en Flop Leerstrategieën*. Retrieved from onderzoekonderwijs.net: https://onderzoekonderwijs.net/2013/04/05/top-en-flop-leerstrategieen/#comments

Klemm, W. R. (2016, December 2016). *Thwart Stress Effects of Memory:* . Retrieved from Psychology Today: https://www.psychologytoday.com/blog/memory-medic/201612/thwart-stress-effects-memory

LID. (2015, October 09). *Kwart van jobs met uitsterven bedreigd.* Opgehaald van De Morgen: http://www.demorgen.be/economie/kwart-van-jobs-met-uitsterven-bedreigd-ba4e180e/

Luck, S. J. (2008). *Visual Memory.* New York: Oxford University Press.

Malcolm Ross Swanson, A. J. (2015). *Effects of Intensive, Short-Term Study on Language Growth : A Case Study.* Kitakyushu, Japan: Seinan Jo Gakuin University.

Mandler, G. (1967). *Organization and memory.* New York: Academic Press.

Martynoga, B. (2016, June 18). *How physical exercise makes your brain work better*. Retrieved from The Guardian: https://www.theguardian.com/education/2016/jun/18/how-physical-exercise-makes-your-brain-work-better

McKitrick LA, C. C. (1992). *Prospective memory intervention in Alzheimer's disease.* New Orleans: Department of Psychology, University of New Orleans.

McLeod, S. (2007). *Levels of Processing.* Retrieved from simplypsychology.org: http://www.simplypsychology.org/levelsofprocessing.html

McLeod, S. (2013). *Stages of Memory Encoding Storage and Retrieval.* Retrieved from simplypsychology.org: http://www.simplypsychology.org/memory.html

McLeod, S. A. (2015). *Jean Piaget.* Retrieved from simplypsychology: www.simplypsychology.org/piaget.html

Merrienboer, J. J. (April 2007). *Ten Steps to Complex Learning.* New York: Taylor & Francis.

Neil R. Carlson, H. L. (August 6, 2010). *Psychology: The Science of Behavior, Books a la Carte Edition (7th Edition).* Pearson; 7 edition .

O'Brien, D. (1998). *Learn to remember.* London: Duncan Publishers.

Piaget, J. (1936). *Origins of intelligence in the child.* London: Routledge & Kegan Paul.

Piaget, J. (1957). *Construction of reality in the child.* London : Routledge & Kegan Paul.

Piaget, J. (1958). *The growth of logical thinking from childhood to adolescence.* AMC.

Pink, D. H. (29-12-2009). DRIVE. In D. H. Pink, *DRIVE* (p. 256). US: Riverhead Hardcover.

Plass, B. D. (JULY 11, 2013). *Summary of CEREGO Academica Pre-pilot Study.* Florida: New York University.

R., S. L. (2009). Memory and brain systems: . *The Journal of Neuroscience*, 12711–12716.

Reichelt, A. (2016, October 29). *Exam cramming doesn't help your brain retain crucial knowledge long term*. Retrieved from ABC News: http://www.abc.net.au/news/2016-10-29/why-cramming-for-exams-the-night-before-rarely-works/7974910

Renson, I. (2014, juni 2). *Schaf de klassieke examens af! (Je wordt er alleen maar slimmer van).* Retrieved from www.tijd.be: http://www.tijd.be/politiek_economie/belgie_algemeen/Schaf_de_klassieke_examens_af_Je_wordt_er_alleen_maar_slimmer_van.9508300-4002.art?ckc=1

Richert, K. (2017, APRIL 19). *Why Learn It When You Can Google It?* Retrieved from Cerego: https://www.cerego.com/blog/why-learn-it-when-you-can-google-it

Robson, D. (2014, March 7). *Companies are creating learning aids that tap the science of memories, says David Robson. Do they work in the classroom?* Retrieved from BBC: http://www.bbc.com/future/story/20140307-how-to-learn-like-a-memory-champ

Roediger, H. L. (2012). Inexpensive techniques to improve education: Applying Cognitive Psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*, 242–248.

Russo, A. J. (1990, March). *Implicit and explicit memory and the automatic/effortful distinction*. Retrieved from researchgate.net: https://www.researchgate.net/publication/232519840_Implicit_and_explicit_memory_and_the_automaticeffortful_distinction

Sanders, L. (2017, March 8). *Brain training turns recall rookies into memory masters*. Retrieved from ScienceNews.org: https://www.sciencenews.org/article/brain-training-turns-recall-rookies-memory-masters

Schacter D. L., A. D. (2007). The cognitive neuroscience of constructive memory: Remembering the past and imagining the future. *Philosophical Transactions of the Royal Society B: Biological Sciences.* , 773–786.

Schacter, D. L. (2002). *The seven sins of memory: How the mind forgets and remembers. .* Boston: Houghton Mifflin.

Schmidt, E. (2012, May 15). *This is your brain on sugar: UCLA study shows high-fructose diet sabotages learning, memory*. Retrieved from UCLA: http://newsroom.ucla.edu/releases/this-is-your-brain-on-sugar-ucla-233992

Schoonover, C. (2012, February). *How to look inside the brain*. Retrieved from TED: https://www.ted.com/talks/carl_schoonover_how_to_look_inside_the_brain#t-277613

Small, G. (2002). *The Memory Bible.* New York: Hyperion.

Swenson, A. B. (2005). *Red Bull May Not Give You Wings: A Combination of Caffeine and Taurine Has No Effect on Short Term Memory but Induces Changes in Heart Rate and*. Retrieved from Biotech: https://www.biotech.wisc.edu/docs/default-source/outreach-documents/redbullposterltr2p.pdf?sfvrsn=0

TED (Director). (2012). *Joshua Foer: Feats of memory anyone can do: TED Talk* [Motion Picture].

Thalheimer, W. (2010, December). *How Much Do People Forget?* Retrieved from Work-Learning Research, Inc: http://www.work-learning.com/catalog.html

Thalheimer, W. (2010, December). *How Much Do People Forget?* Retrieved from Work-Learning Research, Inc.: http://www.work-learning.com/catalog.html

Tipper, M. (2007). *Memory Power-up, 101 ways to instant recall.* The UK and Ireland: Duncan Baird Publishers.

Tulving E., S. D. (1990). Priming and human memory systems. *Science*, 301–306.

Ulf Schuetze, D. o. (2015). *Spacing techniques in second language vocabulary acquisition: Short-term gains vs. long-term memory.* Victoria, Canada: SAGE.

Vanweddingen, M. (2008). *SVR-Rapport: Leren een leven lang leren in Vlaanderen?* Studiedienst van de Vlaamse Regering .

Vermeersch, W. (2015, augustus 29). *Laten we de zomervakantie met 2 weken inkorten*. Retrieved from www.knack.be: http://www.knack.be/nieuws/belgie/laten-we-de-zomervakantie-met-2-weken-inkorten/article-opinion-598103.html

Wadsworth, B. J. (2004). *Piaget's theory of cognitive and affective development: Foundations of constructivism.* Longman Publishing.

Waterman, S. (2013). *THE EFFECTS OF BRAINSCAPE'S CONFIDENCE-BASED REPITION ON TWO ADULTS' PERFORMANCE ON KNOWLEDGE-BASED QUIZZES.* Fredonia, New York: the State University of New York at Fredonia.

WHITE, G. (2016, FEBRUARY 2). *Harvard Is Trying To Build An A.I. As Fast As The Human Brain*. Retrieved from Glitch News: http://glitch.news/2016-02-02-harvard-is-trying-to-build-an-ai-as-fast-as-the-human-brain.html

Wyner, G. (2014). *Fluent Forever: How to Learn Any Language Fast and Never Forget It.* Harmony Books.

Yassa, M. A. (2016, March 31). *Hippocampus*. Retrieved from ENCYCLOPÆDIA BRITANNICA: https://global.britannica.com/science/hippocampus

Yina Wei, G. P. (2016, April 14). *How the brain consolidates memory during deep sleep*. Retrieved from Science Daily: https://www.sciencedaily.com/releases/2016/04/160414214830.htm

References

Ansari, A. (2015, May 6). *Healthy diet may improve memory, says study.* Retrieved from CNN: http://edition.cnn.com/2015/05/06/health/healthy-eating-preserves-memory-study/index.html

Atkinson, R. C. (1968). *Human memory: A proposed system and its control processes. In The psychology of learning and motivation.* Oxford, England: Academic Press.

Ausubel, D. P. (1978). Preface. In J. D. David Paul Ausubel, *Educational Psychology: A Cognitive View* (p. 733). Holt, Rinehart and Winston.

Baddely, A. (2007). *Working memory, thought, and action. .* Oxford, UK: Oxford University Press.

Baillargeon, R. &. (1991). *Object permanence in young infants: Further evidence. Child development.*

Baker, S. (2011). *Final Jeopardy: The Story of Watson, the Computer That Will Transform Our World.* Houghton Mifflin Harcourt.

BBC Magazine. (2014, juli 14). *20 readers who lost fluency in their language.* Retrieved from BBC: http://www.bbc.com/news/magazine-28022790

Belga. (2016, September 15). *We studeren voor jobs die verdwijnen.* Opgehaald van De Morgen: http://www.demorgen.be/binnenland/we-studeren-voor-jobs-die-verdwijnen-bc5cb651/

Bergland, C. (2017, January 16). *Physical Fitness Keeps Your Brain in Good Shape, Study Finds.* Retrieved from Psychology Today: https://www.psychologytoday.com/blog/the-athletes-way/201701/physical-fitness-keeps-your-brain-in-good-shape-study-finds

C.M., A. (2005). Mechanisms of memory stabilization: are consolidation and reconsolidation similar or distinct processes? . *Trends in Neuroscience.*, 51–56.

Caple, C. (1996). *The Effects of Spaced Practice and Spaced Review on Recall and Retention Using Computer Assisted Instruction .* North Carolina : North Carolina State University.

CAREY, B. (2010, September 6). *Forget What You Know About Good Study Habits.* Retrieved from http://www.nytimes.com/: http://www.nytimes.com/2010/09/07/health/views/07mind.html

Clifford, C. (2016, November 4). *Elon Musk: Robots will take your jobs, government will have to pay your wage.* Retrieved from CNBC: http://www.cnbc.com/2016/11/04/elon-musk-robots-will-take-your-jobs-government-will-have-to-pay-your-wage.html

CNRS. (2016, May 18). *Enhanced hippocampal-cortical coupling improves memory.* Retrieved from Science Daily: https://www.sciencedaily.com/releases/2016/05/160518074211.htm

Cowan, N. (1995). *Attention and Memory: An Integrated Frame Network. .* New York: Oxford university Press.

Cowan, N. (n.d.). *The magical number 4 in short-termmemory: A reconsideration of mental storage capacity.* Retrieved from BEHAVIORAL AND BRAIN SCIENCES (2000): http://docplayer.net/216846-The-magical-number-4-in-short-term-memory-a-reconsideration-of-mental-storage-capacity.html

Danziger, K. (2008). *Marking the mind: A history of memory. .* Cambridge: Cambridge University Press.

Dr. Aamodt, S. &. (2008). *Welcome to your brain.* New York: Bloomsbury USA.

Dunlosky, J. R. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, 55.

Eadicicco, L. (2015, January 28). *Bill Gates: Elon Musk Is Right, We Should All Be Scared Of Artificial Intelligence Wiping Out Humanity.* Retrieved from Business Insider: http://www.businessinsider.com/bill-gates-artificial-intelligence-2015-1

Edwards, S. (2008). *Sugar and the Brain*. Retrieved from harvard Neurobiology:
        http://neuro.hms.harvard.edu/harvard-mahoney-neuroscience-institute/brain-
        newsletter/and-brain-series/sugar-and-brain

Elmes, D. (n.d.). *Anki 2.0 User Manual*. Retrieved from www.ankisrs.net:
        http://ankisrs.net/docs/manual.html#introduction

Foer, J. (2011). *Moonwalking with Einstein: The Art and Science of Remembering
        Everything.* New York: The Penguin Press.

Garrett, M. D. (2014, February 25). *Complexity of Our Brain*. Retrieved from Psychology
        Today: https://www.psychologytoday.com/blog/iage/201402/complexity-our-brain

Godman, H. (2014, April 09). *http://www.health.harvard.edu/blog/regular-exercise-changes-
        brain-improve-memory-thinking-skills-201404097110*. Retrieved from Regular
        exercise changes the brain to improve memory, thinking skills:
        http://www.health.harvard.edu/blog/regular-exercise-changes-brain-improve-memory-
        thinking-skills-201404097110

Gregoire, C. (2015, April 06). *This Is What Sugar Does To Your Brain*. Retrieved from The
        Huffington Post: http://www.huffingtonpost.com/2015/04/06/sugar-brain-mental-
        health_n_6904778.html

Gupta, J. (2016, Januari 23). *Spaced repetition: a hack to make your brain store information*.
        Retrieved from www.theguardian.com:
        https://www.theguardian.com/education/2016/jan/23/spaced-repetition-a-hack-to-
        make-your-brain-store-information

How do people lose their native language? (2014, Juni 4). Retrieved from www.bbc.com:
        http://www.bbc.com/news/blogs-magazine-monitor-27690891

Iain M. Harlow, P. T. (May 1st 2016). *Translating Learning Science into Learning Strategy
        Cerego White Paper.*

Jarrett, C. (2012, June 27). *Why the Left-Brain Right-Brain Myth Will Probably Never Die*.
        Retrieved from Psychology Today: https://www.psychologytoday.com/blog/brain-
        myths/201206/why-the-left-brain-right-brain-myth-will-probably-never-die

JOBAT. (2013, May 18). *Persoonlijkheid en leervermogen belangrijker dan kennis en
        vaardigheden*. Opgehaald van Nieuwsblad:
        http://www.nieuwsblad.be/cnt/dmf20130517_039

Kaufman, S. B. (2012, July 26). *Interview with World Memory Champion Boris Nikolai
        Konrad*. Retrieved from Psychology Today:
        https://www.psychologytoday.com/blog/beautiful-minds/201207/interview-world-
        memory-champion-boris-nikolai-konrad

Kirschner, P. (2003, april 5). *Top en Flop Leerstrategieën*. Retrieved from
        onderzoekonderwijs.net: https://onderzoekonderwijs.net/2013/04/05/top-en-flop-
        leerstrategieen/#comments

Klemm, W. R. (2016, December 2016). *Thwart Stress Effects of Memory:* . Retrieved from
        Psychology Today: https://www.psychologytoday.com/blog/memory-
        medic/201612/thwart-stress-effects-memory

Luck, S. J. (2008). *Visual Memory.* New York: Oxford University Press.

Malcolm Ross Swanson, A. J. (2015). *Effects of Intensive, Short-Term Study on Language
        Growth : A Case Study.* Kitakyushu, Japan: Seinan Jo Gakuin University.

Martynoga, B. (2016, June 18). *How physical exercise makes your brain work better*.
        Retrieved from The Guardian:
        https://www.theguardian.com/education/2016/jun/18/how-physical-exercise-makes-
        your-brain-work-better

McKitrick LA, C. C. (1992). *Prospective memory intervention in Alzheimer's disease.* New
        Orleans: Department of Psychology, University of New Orleans.

McLeod, S. (2007). *Levels of Processing*. Retrieved from simplypsychology.org:
        http://www.simplypsychology.org/levelsofprocessing.html

McLeod, S. (2013). *Stages of Memory Encoding Storage and Retrieval*. Retrieved from
        simplypsychology.org: http://www.simplypsychology.org/memory.html

McLeod, S. A. (2015). *Jean Piaget.* Retrieved from simplypsychology: www.simplypsychology.org/piaget.html

O'Brien, D. (1998). *Learn to remember.* London: Duncan Publishers.

Pink, D. H. (29-12-2009). DRIVE. In D. H. Pink, *DRIVE* (p. 256). US: Riverhead Hardcover.

Plass, B. D. (JULY 11, 2013). *Summary of CEREGO Academica Pre-pilot Study.* Florida: New York University.

R., S. L. (2009). Memory and brain systems: . *The Journal of Neuroscience*, 12711–12716.

Reichelt, A. (2016, October 29). *Exam cramming doesn't help your brain retain crucial knowledge long term.* Retrieved from ABC News: http://www.abc.net.au/news/2016-10-29/why-cramming-for-exams-the-night-before-rarely-works/7974910

Renson, I. (2014, juni 2). *Schaf de klassieke examens af! (Je wordt er alleen maar slimmer van).* Retrieved from www.tijd.be: http://www.tijd.be/politiek_economie/belgie_algemeen/Schaf_de_klassieke_examens_af_Je_wordt_er_alleen_maar_slimmer_van.9508300-4002.art?ckc=1

Richert, K. (2017, APRIL 19). *Why Learn It When You Can Google It?* Retrieved from Cerego: https://www.cerego.com/blog/why-learn-it-when-you-can-google-it

Robson, D. (2014, March 7). *Companies are creating learning aids that tap the science of memories, says David Robson. Do they work in the classroom?* Retrieved from BBC: http://www.bbc.com/future/story/20140307-how-to-learn-like-a-memory-champ

Russo, A. J. (1990, March). *Implicit and explicit memory and the automatic/effortful distinction.* Retrieved from researchgate.net: https://www.researchgate.net/publication/232519840_Implicit_and_explicit_memory_and_the_automaticeffortful_distinction

Sanders, L. (2017, March 8). *Brain training turns recall rookies into memory masters.* Retrieved from ScienceNews.org: https://www.sciencenews.org/article/brain-training-turns-recall-rookies-memory-masters

Schmidt, E. (2012, May 15). *This is your brain on sugar: UCLA study shows high-fructose diet sabotages learning, memory.* Retrieved from UCLA: http://newsroom.ucla.edu/releases/this-is-your-brain-on-sugar-ucla-233992

Schoonover, C. (2012, February). *How to look inside the brain.* Retrieved from TED: https://www.ted.com/talks/carl_schoonover_how_to_look_inside_the_brain#t-277613

Small, G. (2002). *The Memory Bible.* New York: Hyperion.

Swenson, A. B. (2005). *Red Bull May Not Give You Wings: A Combination of Caffeine and Taurine Has No Effect on Short Term Memory but Induces Changes in Heart Rate and.* Retrieved from Biotech: https://www.biotech.wisc.edu/docs/default-source/outreach-documents/redbullposterltr2p.pdf?sfvrsn=0

TED (Director). (2012). *Joshua Foer: Feats of memory anyone can do: TED Talk* [Motion Picture].

Thalheimer, W. (2010, December). *How Much Do People Forget?* Retrieved from Work-Learning Research, Inc.: http://www.work-learning.com/catalog.html

Tulving E., S. D. (1990). Priming and human memory systems. *Science*, 301–306.

Ulf Schuetze, D. o. (2015). *Spacing techniques in second language vocabulary acquisition: Short-term gains vs. long-term memory.* Victoria, Canada: SAGE.

Vanweddingen, M. (2008). *SVR-Rapport: Leren een leven lang leren in Vlaanderen?* Studiedienst van de Vlaamse Regering .

Vermeersch, W. (2015, augustus 29). *Laten we de zomervakantie met 2 weken inkorten.* Retrieved from www.knack.be: http://www.knack.be/nieuws/belgie/laten-we-de-zomervakantie-met-2-weken-inkorten/article-opinion-598103.html

Wadsworth, B. J. (2004). *Piaget's theory of cognitive and affective development: Foundations of constructivism.* Longman Publishing.

Waterman, S. (2013). *THE EFFECTS OF BRAINSCAPE'S CONFIDENCE-BASED REPITION ON TWO ADULTS' PERFORMANCE ON KNOWLEDGE-BASED QUIZZES.* Fredonia, New York: the State University of New York at Fredonia.

WHITE, G. (2016, FEBRUARY 2). *Harvard Is Trying To Build An A.I. As Fast As The Human Brain*. Retrieved from Glitch News: http://glitch.news/2016-02-02-harvard-is-trying-to-build-an-ai-as-fast-as-the-human-brain.html

Wyner, G. (2014). *Fluent Forever: How to Learn Any Language Fast and Never Forget It*. Harmony Books.

Yassa, M. A. (2016, March 31). *Hippocampus*. Retrieved from ENCYCLOPÆDIA BRITANNICA: https://global.britannica.com/science/hippocampus

Yina Wei, G. P. (2016, April 14). *How the brain consolidates memory during deep sleep*. Retrieved from Science Daily: https://www.sciencedaily.com/releases/2016/04/160414214830.htm