Spaced Repetition
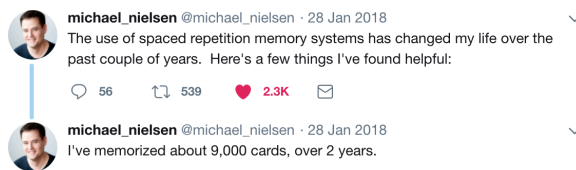
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This document describes how to use spaced repetition to efficiently memorize information. I cover my motivation for exploring this, the science of spaced repetition, tools you can use to implement a spaced repetition memory system, and best practices for card creation and review.

Why?

- Currently trying to quickly ramp/expand knowledge in two fields:
  - Computational genomics because daughter's rare genetic disorder
  - Machine learning for career in general (books, MOOCs)
- Frequently feel like I don't retain enough of what I read
- Then, I saw Michael Nielsen[1] post a tweetstorm[2] about spaced repetition and all the ways he uses it. He goes on for 50 tweets and it gets better and better:

[1] Quantum physicist, author, and computer scientist **https://en.wikipedia.org/wiki/Michael_Nielsen**

[2] Michael A. Nielsen. Tweetstorm on spaced repetition/anki. **https://twitter.com/michael_nielsen/status/957763229454774272**, January 2018b

Figure 1: Wat? 9000 cards wtf?

- Nielsen went on to write an essay[3] about his experience using a spaced repetition memory application called Anki[4].

[3] Michael A. Nielsen. Augmenting long-term memory. **http://augmentingcognition.com/ltm.html**, July 2018a

[4] Anki is the Japanese word for "memorization"

So, like, flash cards?

Yes.

The Promise of Spaced Repetition

- Make the things you remember a conscious *choice* (do not leave to *chance*)
- Exploit memory research to learn with extreme efficiency[5]
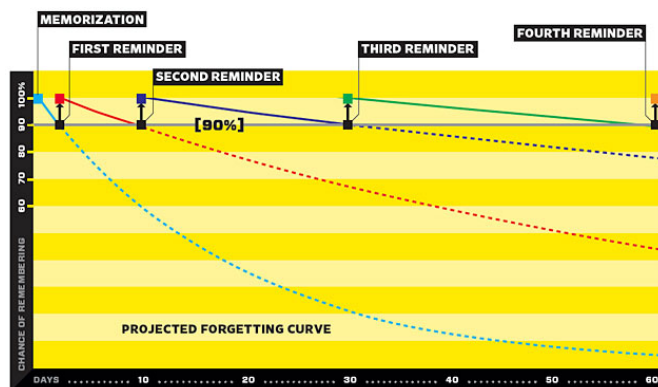- Lifetime effort per fact/card < 5 minutes

[5] Robert Craig set multiple records on the quiz show Jeopardy! 2010-2011 in part thanks to using Anki to memorize chunks of a collection of >200,000 past questions.

Possible Topics to Memorize

- Quotes
- Vocabulary
- Foreign language
- Historical events
- Industry jargon
- Computer commands
- Demographic statistics
- Facts about cities
- Frequent mispellings
- Political figures
- Best dish at restaurant
- Programming language syntax
- Unit conversions
- Trivia about people
- Philosophical concepts
- Logical fallacies
- Study material
- Paintings or artists
- Recipes
- How to exit **vim** :)
- Anything you look up repeatedly
- Anything you're embarrassed you don't know
- ?

Science of Spaced Repetition

Gwern Branwen has compiled probably the definitive online resource[6] on the science of memory[7]. Here is a brief summary:

Figure 2: Forgetting Curve with Retest (Slopes are exaggerated to illustrate the concept. The initial decay is actually much steeper per Figure 3)

- The "Forgetting Curve": Memory decays exponentially (like radioactive half-life). Ebbinghause (1885) memorized a series of nonsense syllables and retested at periods ranging from 20 minutes to 31 days. See Figure 3.
- Initial rate of decay varies based on complexity of information, similarity to other things you know, and other unknown factors
- Review resets probability of recall (you go back to 1.0)
- Rate of decay decreases after retest
- Change in rate of decay seems to be function of elapsed time between retest (how much decay occurs before retest)
- Decay following cramming is roughly equivalent to or slightly better than learning once with no review. See Figure 4.
- Spaced repetition systems exploit these properties of memory to efficiently retest at the most optimal time for reinforcement and slowing of recall decay.

Figure 3: Ebbinghaus (1885) Forgetting Curve (Steep!)
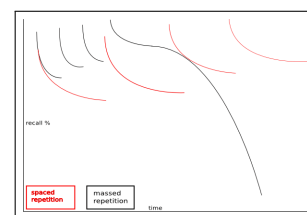
Figure 4: Cramming (black) vs. Spaced Repetition (red)

Available Tools that use Spaced Repetition

- Anki[8]
  - Very popular, extensible, open source
  - Available and syncs across web, desktop (Mac/Windows), mobile (iOS/Android) clients
  - Types of cards available:
    * Basic question and answer (front and back)
    * Basic with reversed (front-back and back-front)
    * Basic but type in the answer first
    * Cloze deletion (fill-in-the-blank)
  - Can use text, graphics, audio, and LaTeX equations as question or answer
- Others: Mnemosyne, SuperMemo, Brainscape

Process

- Start-up and Mindset
  - Install Anki on desktop and mobile and get sync working.
  - Train yourself that you now have a bucket where information goes that you want to remember.
  - Treat Anki as a tool that sits alongside your reading/learning process.
- Create cards
  - Create your own cards instead of downloading pre-made decks
  - Start small. Don't overwhelm yourself by creating 200 cards at first.
  - Either create cards as you read, or develop a system for adding them later (i.e. write a boxed A in the margin as you read a book, email links to yourself with the data you want to Ankify, etc.)
  - Consensus: Create in desktop app, review in mobile app
  - See best practices below for card creation
- Review/Study
  - Does not require huge chunks of time[9]
  - Exploit small windows of downtime (standing in line, on hold, waiting for kettle to boil, other indisposed moments)
  - Stages of Learning in Anki:
    * New: Card just created. You haven't seen it yet in an Anki session.
    * Learning: Again (<1 minute), Good (<10 minutes), and Easy (4d). Once you hit Easy, the ard moves into the Review stage.
    * Review: Rating recall as Good will increase the review duration by 2.5x[10]. Rating as Hard or Easy will shorten or lengthen the review duration. Anki will detect cards that are Lapsing (forget a card you already learned and it moves back into Learning) and Leeches (cards that you repeatedly Lapse on). Leeches are too hard or poorly designed.
  - Configure the number of new and review cards per day[11]
  - The iOS Review Mode is shown in Figure 5.

Best Practices

Anki Essentials, by Alex Vermeer

Alex Vermeer wrote a short e-book called Anki Essentials[12] which is an excellent introduction to the mechanics of Anki. It walks you through setup of a sample deck, your first review of that deck, and then deep dives into power user tooling. I highly recommend this resource and think it will save you a lot of time getting up to speed. It's only $5.

[9] Nielsen learned 9000 cards in < 20 min per day.

Pro tip: Replace mindless social media scrolling with Anki

[10] At rate of growth of 2.5x per successful recall, cards rapidly reach a review frequency of many months.

[11] Defaults are 20 new and 100 review.

[12] Alex Vermeer. *Anki Essentials: The Complete Guide to Remembering Anything with Anki*. Foggy Mountain Pass, 1.1 edition, 2017. URL **https://alexvermeer.com/anki-essentials/**
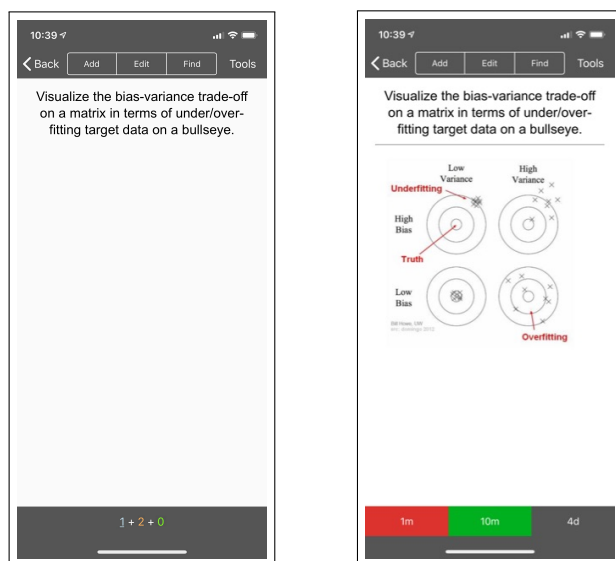
Figure 5: Anki Review Mode

Augmenting Longterm Memory, by Michael Nielsen

To really get into the mind of a master on this topic, Michael Nielsen[13] also published an essay on this topic after his Twitter thread generated so much response. This paper is a fun look into a brilliant scientist's process.

In this article, he does a deep dive on his process for using Anki. He describes how to use Anki to thoroughly read a research paper in an unfamiliar field[14], using Anki to do shallow reads of papers, how he uses Anki to memorize the meaning of technical graphs, and syntopic reading of unfamiliar fields (grokking the overall view of an entire field).

A few patterns of advice or topics from Nielsen that overlap slightly with Wozniak's advice below:

- Make most Anki questions and answers as atomic as possible
- Anki use is best thought of as a virtuoso skill, to be developed
- Anki isn't just a tool for memorizing simple facts. It's a tool for understanding almost anything.
- Use one big deck
- Avoid orphan questions (they are probably irrelevant)
- Don't share decks / Construct your own decks
- Cultivate strategies for elaborative encoding / forming rich associations (represent the same information multiple ways)
- Challenges of using Anki to store facts about friends and family (Most appreciate the effort although it may come across as strange if they know you do it)
- 95% of Anki's value comes from 5% of the features (I.e. no need to go crazy)
- Procedural versus declarative memory (use what you learn)
- Get past "names don't matter" and don't take Feynman[15] too far. Learning

[13] Michael A. Nielsen. Augmenting long-term memory. **http: //augmentingcognition.com/ltm.html**, July 2018a

[14] Which is how he wrote this article: **https://www.quantamagazine.org/ is-alphago-really-such-a-big-deal-20160329/**

[15] "I learned very early the difference between knowing the name of something and knowing something." Richard Feynman

art is a great use-case.

- What do you do when you get behind? Catching up is not as bad as you think it will be.
- Using Anki for APIs, books, videos, seminars, conversations, the web, events, and places
- Avoid the yes/no pattern
- And more!

Wozniak's Rules of Formulating Knowledge[16]

[16] Piotr Wozniak. Effective learning: Twenty rules of formulating knowledge. **https://www.supermemo.com/en/articles/20rules**, February 1999

1. Do not learn if you do not understand

   Richard Feynman, in the essay *O Americano, Outra Vez!*, relates the analogy of a Greek scholar who comes to a new country to find everyone studying Greek, even small kids in elementary schools[17]:

[17] In the book: Richard P. Feynman. *Surely You're Joking Mr. Feynman!*, 1985.

   > The Greek scholar goes to the examination of a student who is coming to get his degree in Greek, and asks him, "What were Socrates' ideas on the relationship bewteen Truth and Beauty?"–and the student can't answer. Then he asks the student, "What did Socrates say to Plato in the Third Symposium?" the student lights up and goes "Brrrrrrrrr-up"–he tells you everything, word for word, that Socrates said, in beautiful Greek.
   > But what Socrates was talking about in the Third Symposium was the relationship bewteen Truth and Beauty!

2. Learn before you memorize

   To drastically reduce learning time, start by obtaining an understanding of the big picture or overall structure of the topic you are trying to learn. Then, you have a container in which to place narrower facts. Go for breadth, then depth. Do not start memorizing loosely-relatd facts about a topic.

3. Build upon the basics

   Start with the most simple and seemingly obvious things and gradually build complexity off of them.

4. Stick to the minimum information principle

   Formulate material into the simplest form possible to make it (a) easier to remember and (b) spaced review easier to schedule. Answers should be as short as possible.

   Bad (1 question): What are the characteristics of the Dead Sea?

   Good (9 questions): Where is the Dead Sea located? What is the lowest point on the Earth's surface? What is the average level on which the Dead Sea is located? How long is the Dead Sea? How much saltier is the Dead Sea than the oceans? What is the volume content of salt in the Dead Sea? Why can the Dead Sea keep swimmers afloat? Why is the Dead Sea called Dead? Why only simple organisms can live in the Dead Sea?

5. Cloze deletion is easy and effective

   Omitting words or phrases (fill-in-the-blank) helps greatly in sticking to the minimum information principle.
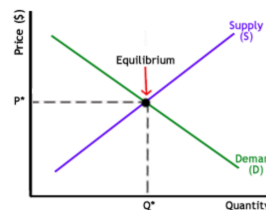
   Example: _____ deletion is easy and effective.

6. Use imagery

Instead of "What is the law of supply and demand in words?", ask "Explain the law of supply and demand visually" and see if you can draw the figure (set the figure as the card's answer).

Think of creative ways to use photographs, figures, maps, diagrams, or art to reinforce concepts you are trying to learn.

7. Use mnemonic techniques

A mnemonic is a general term for a tool or trick that aids information retention. Apparently Tony Buzan is resource for mnemonic techniques.

8. Graphic deletion is as good as cloze deletion

Graphic deletion is exactly the same as cloze deletion except it omits portions of images rather than sentences. Graphic deletion is great for learning things like anatomy, geography, or labels on other types of diagrams.
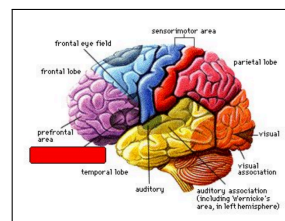
9. Avoid sets

Sets are collections of objects and are very hard to remember. They are also inefficient to memorize because they are prone to all-or-nothing evaluation.

Avoid questions like "What are all the countries in the EU?" and instead ask questions around associating facts between the EU and specific countries or a small subset of related countries.

10. Avoid enumeration

Avoid enumeration (ordered sets). If you do need to memorize something that is meaningfully ordered, use overlapping Cloze deletion to avoid all-or-nothing efficiency losses. This also works with memorizing poems.

Bad: What is the sequence of letters in the alphabet?

Good: What three letters does the alphabet begin with? Fill out the missing letters of the alphabet A _ _ _ E. What letter follows L M N _?

11. Combat interference

Interference is when knowledge of one item makes it hard to remember another item, or you confuse similar things[18].

If you find yourself tripping over and mixing up similar concepts, simplify cards according to the minimum information principle in a way that disambiguates the two concepts and reduces confusion.

12. Optimize wording

Formulate questions in such a way as to minimize the chance that different meanings of words or interpretations will make the core concept ambiguous or vague. Optimized wording will reduce the chance of error and increase specificity.

Bad: "Aldus invented desktop publishing in 1985 with PageMaker. Aldus had little competition for years, and so failed to improve. Then Denver-based _____ blew past. PageMaker, now owned by Adobe, remains No. 2."

Good: "PageMaker lost ground to _____."[19]

If you need the additional information about these companies, create more cards.

[18] *historic* vs. *historical*

[19] Quark

13. Refer to other memories[20]

    Reference other concepts in your memory system that you have learned previously or are learning if they provide better context, simplify wording, and reinforce the other memories. Factor these out if they cause memory interference.

14. Personalize and provide examples

    Link to something from your personal life, especially memories with strong situational or sensory associations.

    Okay: What is the most expensive sandwich within a 1-mile radius of Georgia Tech?

    Better: What is the most expensive sandwich within a 1-mile radius of Georgia Tech (that **Eric** still owes me money for)?[21]

15. Rely on emotional states

    Associating cards with vivid, shocking, bizarre, or fantastical examples makes them easier to remember.

16. Context cues simplify wording

    Use context cues like "title:", "author:", "year:", "define:", "math:" to simplify wording.

    The phrase "author: Getting Things Done" may be better than "Who wrote the book Getting Things Done?"

17. Redundancy does not contradict minimum information principle

    This means representing the same information in multiple ways in your system. Perhaps add items with swapped questions and answers such as: "What is the Spanish word for brother?" and "What is the English word for hermano¿'

18. Provide sources

    Except for well-tested and proven knowledge, try to include sources of information in your system. Providing sources will help you distinguish conflicting information, assess the bias in a fact, judge an idea's reliability or importance, and also help you respond when challenged. Especially valuable for statistics which depend on methodological factors and differ depending on the reporting source.

    You might preface a question with: "According to *source*, ..."

    Also feel free to add "reliability labels", such as: "Suspect!", "Seems high/low", etc.

    You might want to add a statistic to your system that you know is wrong, simply because you need to be able to quote the source of the wrong figure. In this case, you are not trying to memorize that "apples are purple" but that "That idiot so-and-so claims apples are purple."

19. Provide date stamping

    Many pieces of information are subject to change over time[22]. When appropriate, include the date that information was created, accessed, published, or first encountered in order to anchor it in a time-based context.

[20] Not memories in the normal sense, but data in Anki.

[21] Beef-n-cheddar

[22] E.g. Economic indicators, technical specifications, software functionality, almost any statistic, etc.

20. Prioritize

    You have finite time, so prioritize the information that will matter the most for your goals. Exercise your intuition about what is relevant and should be added to your memory system. Schedule very high priority information for higher frequency review.

    What hierarchy of sources drives your field[23]? Prioritze the more reliable.

    Extract just the meaningful information and sufficient amount to provide context and reinforcement. Do not try to memorize everything in a book or article just because you read it.

[23] journal articles > books > blogs > Twitter > Facebook?

References

Anki. `https://ankiweb.net`.

Gwern Branwen.   Spaced repetition.   `https://www.gwern.net/ Spaced-repetition`, March 2009.

Michael A. Nielsen.   Augmenting long-term memory.   `http:// augmentingcognition.com/ltm.html`, July 2018a.

Michael A. Nielsen.   Tweetstorm on spaced repetition/anki.   `https: //twitter.com/michael_nielsen/status/957763229454774272`, January 2018b.

Alex Vermeer.   *Anki Essentials: The Complete Guide to Remembering Anything with Anki*.   Foggy Mountain Pass, 1.1 edition, 2017.   URL `https://alexvermeer.com/anki-essentials/`.

Piotr Wozniak. Effective learning: Twenty rules of formulating knowledge. `https://www.supermemo.com/en/articles/20rules`, February 1999.