The final edit of this was lost so this is an earlier draft. Apologies for any typos — I can't bring myself to go back and edit again.

Introduction

In *Faust: The First Part of the Tragedy,* Goethe, the German author esteemed as highly in German literature as Shakespeare is in English literature, portrays a character named Faust who strived to learn everything that can be known:

> *Alas, I have studied philosophy,*
> *the law as well as medicine,*
> *and to my sorrow, theology;*
>
> *I studied them well with ardent zeal,*
> *yet here I am, a wretched fool,*
> *no wiser than I was before."*

Those who identify with this quote, that is those with insatiable, obsessive, and perhaps pointless curiosity are likely to enjoy reading what follows.

The article contains my personal collection of learning techniques I've encountered through a lifelong addiction both to learning and to sitting in libraries and reading "how to learn X" chapters in books from various fields. I've gathered techniques from all sorts of places, including computer programming, calculus, weight-lifting, piano playing, law, electronic music production, writing, German as a foreign language, body posture, online marketing, and other places I'm not shameless enough to mention in an article intended for public consumption. Through reading "how to learn" chapters narrowly focused on particular fields, I hoped to find strategies I could apply generally, or at least to the fields I cared most about.

These learning techniques do not represent hard science, so you're advised not to take this as a gospel and to instead test out the techniques for yourself.

I should also mention that there are two biases within this article. The first bias is towards learning *skill*s as opposed to learning *facts*. Although skills rely on your knowing some foundational facts (e.g. a golfer ought to know the rules of the game), learning a skill contains additional challenges, such as muscle training and muscle memory. Knowledge in this article, then, is treated as knowledge in pursuit of some desired ability. The ability will be of your choosing, and this ability may be something reassuringly mundane or it could equally be deliciously weird. I don't care what you want to be able to do; I only wish to discuss ways you might learn how to do it. The second bias is in my choice of examples, which align with my interests in technical subjects. You'll find examples that might be foreign to you, hailing from mathematics, computer science, signal engineering and music theory; I endeavour to explain these in such a way that you get the gist of what I'm talking about, but in order for that to be

possible without drowning the reader in a sea of nuance, I've sometimes simplified the examples and allowed for minor inaccuracies in my explanations. Please forgive me.

Besides my primary goal of sorting through my own thoughts on learning, I'm also motivated to write this article based on what I regard as a relatively easily repaired failing of the education system: minimal effort devoted to teaching learning *strategies*. Given that technological acceleration is causing an increased proliferation of new fields, I believe the need for teaching autodidactism (!) outweighs the need for the teaching of any specific knowledge beyond the basics of reading, writing, numeracy and logic. Learning *learning strategies* should be treated as equally fundamental in our schools, yet it isn't. My schooling reality starkly differed, in that the powers that were deemed it preferable to dedicate an hour a day during our fifth year at primary school learning the names of all the rivers, lakes and mountains in Ireland, names I have long forgotten. Wouldn't it have been nice if they had taught us the more portable and relevant skill of how to memorise any arbitrary long list of items? Enough complaining, let's get on with it.

Part A: Mental Algorithms (Malgorithms)

Optimising internal dialogue for processing and structuring information attained.

1. Demand a consistent mental model.

Let's start this section with an example far removed from the official school syllabi but close indeed to the school's teenage attendees priorities. Imagine you simultaneously believe that the best way to flirt with someone you fancy is:

1. to show your interest to that person
2. to hide your interest in that person

If you've ever read the dating advice columns in Men's Health magazine or Cosmopolitan while waiting at the hairdressers, then you'll know that these publications will literally publish a column on the left "why you should show interest" next to a column on the right "ten reasons to hide your interest". Assuming you believe both prescriptions equally valid, then owing to their contradictory nature, you have learned exactly nothing, except perhaps that showing interest is a key parameter worth varying. The next time you flirt, your beliefs don't inform any way to behave, and therefore what you had thought you had "learned", was in fact useless. Tolerating unresolved inconsistencies in your world view may be part of our natural human predisposition, but it is the antithesis of learning.

A robot holding inconsistent beliefs about flirting might experiment with alternatively showing or hiding their interest with various fancies over the years, thereby figuring out which approach works better for them. The eventual picture will likely not be black or white, but instead nuanced. Perhaps hiding interest works well with fancies who are confident about their sexual

attractiveness, while showing interest works better with potential partners with less self-confidence. The point, then, is that a rational actor will resolve inconsistencies as best they can by exploring their beliefs' details until each belief occupies an exclusive niche in belief-space, thereby rendering them no longer inconsistent, but instead simply applicable in separate contexts.

Inconsistent beliefs are particularly prevalent in things like "best practices" (e.g. programming best practices) or when considering a world view as a whole instead of narrowing focus to a specific knowledge compartment. For example, a 70kg biologist might be certain that the absolute maximum amount of protein a 70kg person can synthesize within a day is 100g—no matter what the circumstances. Yet the same biologist might consume 200g per day in their body-building efforts, acting under the belief commonly held in exercise circles that more protein means faster muscle growth. Globally, their beliefs are inconsistent with one another, and this warrants investigation. Perhaps the absoluteness of one of these two beliefs is unjustified, or perhaps even one of the beliefs is outright incorrect.

2. Actively cancel out redundant items of knowledge.

Imagine you need to memorise a list of plants that contain seeds. Instead of memorising the entries {apples, oranges, tomatoes and pears}, you can save mental effort by only remembering the rule "fruits contain seeds", and then relying on your existing knowledge of what, technically, counts as a fruit. If you quantify the amount of learned items before and after the cancellation, you've gone from four items to one item.

When I say "actively" cancel out, I mean that while some canceling out will passively form in your mind, you can elicit much more by asking yourself questions like "how are these two concepts similar?" or "is there an underlying rule that explains both items of knowledge".

Here's another example of cancellation from some wasted effort I had in music theory (readers without music theory can safely ignore the music theory details and still see the point): I painstakingly learned the interval quality (i.e. whether an interval was major/minor) of the 6th intervals in all 1st inversion diatonic chords (I: minor 6th, II: major 6th, III: major 6th, IV: minor 6th, V: major 6th, VI: minor 6th, VII: major 6th). Later, I realised that these qualities were the opposite of the qualities of the 3rds in the root position, which I already knew. (I: major 3rd, II: minor 3rd, III:minor 3rd, IV:major 3rd, V: major 3rd, VI:minor 3rd, VII:minor 3rd). Therefore all I needed to remember in the first place was that I could take the interval qualities of the root position chords and replace any appearances of "major" with "minor" and vice versa. I would have saved myself the tedious effort in learning the interval qualities of the 6ths had I actively cancelled out my knowledge earlier.

Programmers reading this article might consider the depicted mental attitude equivalent to the DRY principle (Don't Repeat Yourself), whereby you minimise repetition of information of all kinds.

3. Constantly think of applications

With regards to skill-building, knowledge without application is useless, and therefore a conscientious learner will think up situations where their new knowledge might apply. Should you fail to think up any application, that constitutes evidence that the newly gained knowledge wasn't clear/valuable/consistent with your other knowledge.

For example, many programming textbooks recommend to "use assertions"— that is to loudly and prematurely crash whenever something is wrong in your program's logic,—instead of continuing to run with a hidden error that may cause a tangled mess of difficult-to-detect issues down the line.

That rule sounds fairly straightforward in abstract. But where do you apply it? The textbook I learned the technique from gave only one example: check that a function's arguments match expectations, and that's all I ever used assertions for. Even though I found the assertions I used incredibly useful, it was difficult for me to think of good opportunities to apply this abstract technique when I was in the midst of programming. An abstract rule floating around my head doesn't do me much good when I'm juggling 7+/-2 more immediate concepts.

Had I instead brainstormed applications for assertions in advance, I would notice the opportunities to apply the technique when they crop up. I would see the markers and clues within the code, and I would know that my knowledge could latch onto these components. For example, when I think about applications of assertions now, I realise I could check that the intended *output* is within certain bounds; that the *time taken* to calculate is acceptably low; that *memory usage* is acceptably low, and so on.

Here's a related technique I learned during my time studying law. This technique applies more broadly to rules-based learning. Whenever you read a particular law, such as "a contract cannot be accepted by silence", you ought think of example situations where that rule clearly does apply, clearly does *not* apply, or where it is less certain whether it applies.

Where the rule clearly does apply:

> *You are on vacation for three weeks. I deliver a horse to you, without you asking for it, along with a note stating that you consent to buying the horse if you don't write back rejecting the offer within three days.*

Where the rule clearly does not apply:

> *You are deaf. I give you the keys and deeds to a house, which you sign a contract for and communicate consent for via sign language. As is standard within property conveyance transactions, you bring a property conveyance lawyer to oversee the*

transaction. It is clear that you completely understand the transaction, despite your literal sonic "silence".

Where it is less certain whether the rule applies:

For an entire day, a family sit in rentable deckchairs I've laid out on the beach. I have signposted an hourly price for the rental, albeit not clearly. That evening, I demand the family pay the sum as communicated on the signpost, despite no prior verbal or written agreement. It's not clear that the literal silence here is enough to negate the formation of a contract or whether it was unreasonable for the family to presume the deckchairs conveniently laid out were free without some effort to enquire after their price.

By brainstorming possible situations where the legal rule about contract formation would/would not apply, I became more familiar with its scope, its consequences, and its potential problems.

4. Identify the key parameters

This technique involves asking yourself what are the most important factors in affecting the outcome of some process you wish to learn about and optimise or influence to your desire. It's easiest to identify key parameters in numerical terms, so our first example will be sales tax. This one borders on trivial, but bear with me until the subsequent paragraphs.

Let's say there are three factors in determining how much sales tax you pay: a) the purchase price set by the retailer; b) and the country/state you purchase the goods within; c) the tax status of those goods (e.g. prescriptions drugs are exempt in the U.S.). A business person having identified these key parameters will realise that as soon as their company does something that could switch the values of any of those parameters (e.g. setting up a store in another country) then their sales tax rate will change and accounts require adjustment. When brainstorming new business optimisations, the business person might ask "how can I reduce prices for our customers by minimising their exposure to sales tax?" . Given that they don't want to cut their own profits by varying the first key parameter (purchase price set by retailer) they'd try substituting different prices or goods types until they arrive at a workable solution. For example, at time of writing, binded books are exempt from sales tax in the EU whereas ebooks are not. Were it cheaper to print books than pay sales tax, then the business person might ship a printed copy with each sale of an ebook, which is, in fact, what actually happens. Dear EU: Thanks for looking out for me by considering the consequences of your sales tax laws on price-optimising agents. Your fleetingly, The Environment.

Another example: legal systems could be said to sum up their laws by the use of key parameters. In UK negligence law, the courts have identified key parameters for the existence of a duty of care. To name only a few factors, the courts are more likely to find a duty of care owed when a) there is a high degree of risk and b) when someone suffers serious harm when

the risk materialises. However c) a heightened expense of taking precautions in time or money decreases the likelihood of a court finding that a duty of care was owed.

The court's analysis in terms of these parameters is more transparent and applicable than the overarching, somewhat nebulous, idea that one has to "act as a reasonable man". In identifying the key parameters and specifying at what levels these parameters ought to be set at for a duty to exist, the courts have added *some* clarity to what would otherwise be much vaguer.

What's the takeaway for you, the learner? Approached with something you don't understand or that you wish to influence, you might ask yourself "what imaginary buttons can I press" or "what imaginary volume sliders can I move" and thereby influence the outcome. Even if you don't know how to get the results you want, having identified the key parameters means you know where to start experimenting.

5. Play with it / Put a human inside it

I've read again and again that "playing with a concept helps you learn it" but never knew what on earth the authors meant. Eventually I arrived at a definition I could actually use: ask yourself what you would observe if you had input a human into some process, no matter how abstract that process might be. Starting with a trivial example, inputting a person into a division process will shrink that person in proportion to the the size of the divisor.

Moving on to an example with something unknown to most readers, let's try to understand *sound compressors*, devices typically used to make loud sounds within recordings less loud without affecting the quiet sounds. The overall effect of a compressor is that it decreases dynamic range, that is the difference between the loudest and the quietest sounds in someone's performance. Audio engineers might use compression to repair a recording of a guitar track where the player unintentionally hits sporadic notes so quietly that they can't be heard while the vocals and drums are also playing. Let's start by explaining how to interpret the wave form of a sound, by using an example of a drum track.

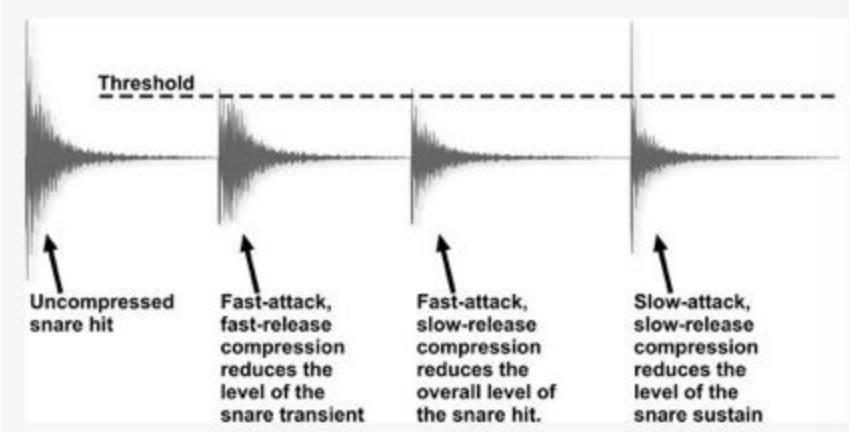


Image from http://bbasound.wikispaces.com/

As you move across this diagram of a drum track from left to right you'll see four blobs: each of these is a drum hit. The height of the very many black lines within each drum hit (lines extend upwards and downwards from a centre point/line) indicates the volume at a given moment *within* each drum hit. You'll notice that each drum hit starts off loud then fizzles out, which corresponds to the relatively instantaneous nature of the sounds created by a drum—or in other words its percussive nature.

I found it easiest to understand the controls of a compressor (e.g threshold, attack, ratio) when instead of just viewing a soundwave like the above, I also imagined a conveyor belt of annoying celebrities and watched the house-of-mirrors-like effect the compressor had upon their good looks.

Image from http://brianorndorf.typepad.com/

(Note that squashing with compression doesn't push the cheeks out. It only squashes sound downwards.)

Compression, roughly, caused the celebrities heads and legs to be squashed downwards while the rest of their bodies remained in normal proportion. Look again to the diagram above and find the horizontal line labelled *threshold*: this represents the compressor setting that determines

what should be affected and what shouldn't. Adjusting the compression threshold is the same as deciding from which point of the celebrities head/neck/shoulders (and lock-step parallels in the lower half of the body) the squashing begins.

Adjusting the *ratio* of the compression decides how squashed those parts lying beyond the threshold should be. A ratio of 2:1 means squash to half their original size and 10:1 means squash to a tenth of their original size. The *attack* setting of the compressor determines how long it takes for the compression to kick in *after* the threshold has been exceeded. Increasing it means that the leftmost part of the celebrities head remains normally proportioned (unaffected by the compression which has yet to start, despite the head being over the threshold point) whereas the right side of the face will be squashed looking (since after X milliseconds of attack the compression takes effect). The proportion of unsquashed to squashed head from the left to the right is thus determined by the attack setting. In audio terms, a higher attack setting means that we'll preserve the really loud bit of the start of each drum hit in the diagram above while we reduce the volume of subsequent sound that exceeds the threshold.

By posing silly questions, I find it easier to understand and remember the underlying mechanisms. The motivation behind this technique is that I noticed my model of mechanisms can often be shallow, despite my having an illusion of understanding. By forcing myself to reapply the mechanism to something fresh, like inputting a human, I think about compression from first principles instead of relying on memorised facts and mantras. In this way, incomplete understanding on my part will be more likely to be exposed.

6. Create your own jargon

I wrote about this in a previous blog post on jargon for typos so I'll only summarise here without full argument: by learning existing jargon for describing a concept or coining your own terms when none exist, I believe you increase your perceptual awareness within that topic and can juggle more abstract ideas within your head. Knowing the names and definitions of all the concepts in contract law helps you identify issues upon reading a new contract. And, as argued in the above link, creating terms for all the classes of typos you commit in your writing helps you notice future instances of that typo, where previously you routinely failed to spot.

7. Remedy partial understanding (...when it matters)

Ever read an explanation filled with terms or concepts you didn't precisely understand and then force yourself to memorise the wording on the page? I've been guilty of stupidities like "learning" English language grammar rules for comma usage with relative clauses, despite not knowing what a relative clause was.

Sometimes partial understanding is an intentionally taken shortcut to some goal besides knowledge acquisition—e.g. learning the right phrases to pass an exam. But even people genuinely aiming to learn may end up with partial understanding because they harbour under

the illusion of complete knowledge after a schooling in the cosy finite world of their textbooks' explanation and examples.

When I first encountered the comma usage rule, I probably thought "yes, I see the 'relative clause' in that single example they give—I know what these 'relative clause' things are— I got this—onwards". Imagine instead that I asked myself, "*why* is that clause in the example called 'a relative clause'?", or "*what other forms* do relative clauses take?"; then I would have realised my understanding was only partial. The lesson then, at least for me, was to pay attention to any hints that I might not fully understand some foundations, and probe or rectify accordingly.

Rectifying means reading definitions for unfamiliar words, consulting Wikipedia pages for unfamiliar concepts, or revisiting previous material whenever the current section confuses you. It means stopping and asking whether the new bit of knowledge fits harmoniously into your current model of the world. As mentioned elsewhere in this article, a strong indicator of understanding is your ability to manufacture fresh examples.

Knowledge filled with partial understandings, that is, knowledge where the original concepts are replaced by X's and question marks, is cumbersome and stressful to remember. Substituting those X's and question marks with understanding dramatically simplifies the effort of retention, justifying the upfront effort in understanding foundations.

I hesitate to suggest this as a fully general instruction because rigid adherence may sometimes create problems. Researching every unfamiliar concept will quickly lead you down an infinitely deep web of Wikipedia links that may not be relevant given your end goals. For example, your typical restaurant chef doesn't need to understand the heat equations of physics in order to bake a good lasagne, whereas that same information might be invaluable to a mass-manufacturer of microwave lasagnes seeking to cut energy costs.

8. Hang new facts onto at least one branch of your knowledge tree

Say you already know programming and you want to learn mathematics. As you read the introductory chapter in your Algebra textbook you encounter the unfamiliar concepts of *domains* and *ranges*, two properties of mathematical functions. You can speed up your learning by viewing domain in terms of programming, that is viewing domain as the "valid range of possible inputs for an argument to a function" and viewing ranges as the "possible outputs generated by the function when fed the allowable inputs"

Once you get to linear algebra, when you encounter matrices, you can take an intuitive shortcut by associating matrices with the multi-dimensional arrays you've already worked with in your programs. Your past experiences with programming can be recycled, in that your knowledge of function inputs/outputs or multidimensional arrays has parallels in mathematics. Furthermore,

you also reinforce your old programming knowledge by forging these associations: let's say that a piece of knowledge dies in your conscious memory if not accessed in a year— in that case the action of linking the old computer science knowledge to a new idea in algebra might reactivate the link and sustain your memory.

A significant proportion of the features in programming languages are meant to ease mathematical computational, and therefore it shouldn't surprise us that concepts are shared between these two cousins. The almost trivial lesson we can extract from this observation is that we are likely to find the most promising branches within similar disciplines.

I find the trick musicians use to learn to play by ear remarkably clever. Knowing that a good melody is more-or-less impossible to forget, musicians memorise and name the intervals (distances between notes) within well-known songs whose melodies they have already internalised. A *minor third (descending)* is the melodic distance dropped between "Hey" and "Jude" in the Beatles classic of the same name; a *perfect fifth ascending* is the first two notes in the *Star Wars* theme, whereas a *perfect fifth descending* is the melodic drop between *Flint* and *Stones* within the theme song to, um, *The Flintstones*.

Sometimes the analogies and knowledge-links flood to mind automatically, but more often no link offers itself to our awareness. During these moments, the practical question becomes "what mental algorithm ought I follow when I want to push myself into forming a connection". I don't have a good answer for you (or for myself), other than the suggestion that actively spending 30 seconds searching for a concept will be more effective than not doing so. You might ask yourself "What does this concept remind me of?", "Is this a more specific/general version of some other concept?", "Is this like X but for Y?"

I'll finish by pointing out that forging connections between ideas in analogous disciplines might speed up learning and ease memory, whereas forging connections between ideas in distant disciplines, although less likely to be fruitful, may lead to innovation when you discover a valid underlying link that no-one ever noticed before. You might be the first person in history to hold those two ideas in the same thought.

9. Encode in easily memorised forms.

I admit personal inexperience in not having yet explored this area as deeply as I'd like, so for now I offer only a distant overview. The theory goes like this: certain mechanisms of memory are more effective than others; in particular our memory for a) the sexual, violent or novel/bizarre and for b) physical locations, such as the way around our grandmother's house or the drive there, outperform our memory for facts like mobile phone pin codes, genders of foreign language vocabulary, or dates of mother's birthdays. Someone wishing to optimise their remembering would translate their knowledge into one of these superior encodings.

My only experience with this technique was through Memrise, a website mainly used for learning foreign language vocabulary. Each word in my target language was associated with a *meme*, that is an easily remembered thought, be it a funny photo, delightful metaphor or sound-a-like pun. The meme for *schwarz*, German for *black* is a picture of Arnold Schwarzenegger photoshopped to have black skin, an image I will never forget. (The original contributor was of African descent so no accusation of offensively intended "blacking up" should be levied.)

Subjectively, I felt that these memes were significantly easier to remember than normal vocabulary lists with English on one side and German on the other, so I judge this to be a triumph of the encoding technique.

For a more in depth look at this technique check out Moonwalking with Einstein, a book about the founder of Memrise, Ed Cooke, and his experiences training journalist Joshua Foer to win the U.S.A. Memory Championship.

Part B: Note-taking

1. Employ spaced repetition systems (SRS)

Spaced Repetition Systems ask their users to formulate "items" of knowledge in a question and answer format, input these pairs into a computer program, then answer mini-tests based on these pairs at increasingly long time intervals, intervals determined by memory research to minimise the lifelong time cost of goading knowledge into memory.

I'm a big fan of this technique and possess thousands of cards spread across various topics. But, don't take my word about SRS—consult the science, where you'll find that SRS has a brilliant track record.

I started using SRS in its typical intended manner, which was foreign language vocabulary. Upon seeing how well I retained vocabulary, I asked myself whether I could use SRS to speed up learning programming, a topic I was struggling with. It worked just as well (read my experiences here), and now I use SRS to memorise all sorts of topics, such as algebraic formulae, German grammar rules, (native) English grammar and style, music theory, and rationality ideas. All of these topics contain large sets of facts or rules that I'd like to have on rapid access. For example, the music theory deck contains cards to train for sight-reading or chord spelling (naming the notes that constitute a chord), knowledge that I don't want to spend more than a millisecond recalling when improvising on a piano. While these decks do not remotely equate to the full skill in question, they *are* a useful supplement for the knowledge component.

Having regularly reviewed cards in SRS decks for about four years, I've noticed advantages beyond memory, advantages that other authors do not emphasise half enough:

1. Like prose writing or software unit-testing, SRS forces you to restructure your thoughts through its simple question and answer format. Even if you never reviewed the card you created, this restructuring and simplification of your thoughts promotes honest understanding and beats underlining your text ten times out of ten.

2. The unpredictable order of flashcard reviews promotes creative connections within and between your chosen disciplines. For example, I might see an English grammar card, followed by a Natural Language Processing card (using computers to understand human language), followed by an algebra card. Sometimes seeing these cards consecutively forges a welcomed connection between the three in my head. Juxtaposition is, for me at least, the first step to creativity.

3. My flashcard decks form notebooks where I store ideas worth remembering, albeit with a superlative advantage over conventional notebooks: the SRS algorithm causes you to revisit old notes instead of leaving them forgotten in some drawer. Through reviewing your old thoughts, you combine, question or build upon them, forming richer and more nuanced ideas that grow to proportions not possible through conventional note-taking alone. In my prior Evernote/pen-paper notebooks, I found that I'd sometimes note the same ideas two years later, showing that my thinking had run around in circles all that time, never really progressing.

I love SRS and find it amongst the most effective learning strategies in my toolkit, but as an SRS power-user I know it ain't perfect. The following list of drawbacks presumes you are already familiar with SRS; if you aren't, you may want to come back to this later.

1. SRS mostly delivers on its promise of not forgetting, albeit somewhat literally in that remembering a flash-carded question/answer pair is not necessarily equivalent to learning the underlying idea. With SRS, you sometimes train yourself to only have answers to the specific questions you input, so your learning becomes overfitted to the data; you remember the specific example instead of the general rule; you remember that answer instead of building the ability to calculate answers on the fly. For example, I'll remember the application of a German grammar rule to the particular sentence in the example, but not necessarily to unseen sentences.

   This danger can be partially overcome through the mental discipline of challenging yourself afresh whenever you review. In terms of the example given, this means inventing new sentences that exhibit the rule whenever you review that grammar card.

   I wish there were dynamic SRS decks for language learning (or other disciplines). Such decks would count the number of times you have reviewed an *instance* of an underlying grammatical rule or an *instance* of a particular piece of vocabulary, for example its singular/plural/third person conjugation/dative form. These sophisticated decks would

present users with fresh example sentences on every review, thereby preventing users from remembering specific answers and compelling them to learn the *process* of applying the grammatical rule afresh. Moreover, these decks would keep users entertained through novelty and would present users with tacit learning opportunities through rotating vocabulary used in non-essential parts of the example sentence. Such a system, with multiple-level review rotation, would not only prevent against overfitted learning, but also increase the total amount of knowledge learned per minute, an efficiency I'd gladly invest in.

2. SRS has become conflated with flashcards for the overwhelming majority of users. This isn't ideal because some types of knowledge are process-oriented or require physical skills, therefore reduction to your typical flashcard is insufficient for sustained learning. I know that I have until recently never even considered SRS outside of a flashcard context, and for the convenience of avoiding too many abstractions in my explanations, I also equated the two in my preceding paragraphs.

   The format of a spaced repetition could be anything: "solve an equation using this trigonometric technique", "draw a venn diagram demonstrating the differences between these six medical diseases", or "sing a perfect 5th interval". The key to SRS is repetition at scheduled intervals, but that which you repeat can and should vary with the type of material you are studying. Khan Academy, an online learning platform with a special focus on math, has taken a step in this direction with their dynamically generated exercises that drill previously learned topics.

3. SRS reviews take time out of your schedule every day. Personally, it takes me about half an hour every day. I'm willing to live with this, justifying the time expenditure as a long-term capital investment in my knowledge that will lead to increased opportunities and efficiencies in the future. Nevertheless, I would welcome more intelligent review systems that pack in more learning per minute, systems such as the multi-level review rotation I espouse above.

As I mentioned above, I've written extensively about my experiences with SRS in 2011 and in 2013. Read those articles then add these further refinements from the past year, refinements based on the deeper principles of learning I explain in the earlier Malgorithms piece.

1. **Have a fresh thought every time your review the same card.** When reviewing my deck on cognitive biases/logical fallacies/rationality, I challenge myself to think of an example of that specific flaw in thinking that either I or someone else committed in recent memory. Failing this, I construct a fictional example. The point here is to use the knowledge in a manner parallel to its real world usage, rather than mindlessly press a button within my Anki application. In other words, I'm increasing the activeness of an active review.

2. **Challenge yourself with possible confusions.** In my German grammar deck, I noticed that the verb conjugation rules for present tense are similar to those of the present subjunctive tense. When I was next reviewing subjunctive tense I paused and asked myself to verbalize the differences between these two tenses, thereby confronting early a confusion I was sure to encounter naturally later when speaking or comprehending German in the wild. This practice of confronting potential confusions is another form of the classic learning technique “making connections”, and the technique can partially alleviate the problem that flashcarded knowledge is too removed from real-world complexities.

3. **Resolve suspected inconsistencies.** As soon as you realise that two flashcards have (or suggest) different answers to the same question, you need to examine the area and figure out whether one card is wrong or whether there is a subtlety that has escaped you.

   For example, in grammar flashcards one card might describe a general rule, whereas another shows an example of a class of exceptions you hadn’t realised existed. Primary school teachers in English-speaking countries belaboured the incorrectness of sentences such as “My mom and me went to the supermarket”. Here, the objective case first person pronoun (“me”) was used instead of the correct subjective case pronoun (“I”). You add a flashcard and learn that rule. Months later, your teacher might correct your sentence “Between you and I, I have a secret identity” to “Between you and me, I have a secret identity” and you spin up another flashcard. Only after reviewing both might you realise that the two cards seem inconsistent at first sight; you rectify their differences through realising that “between” is a preposition and therefore must use the subjective case.

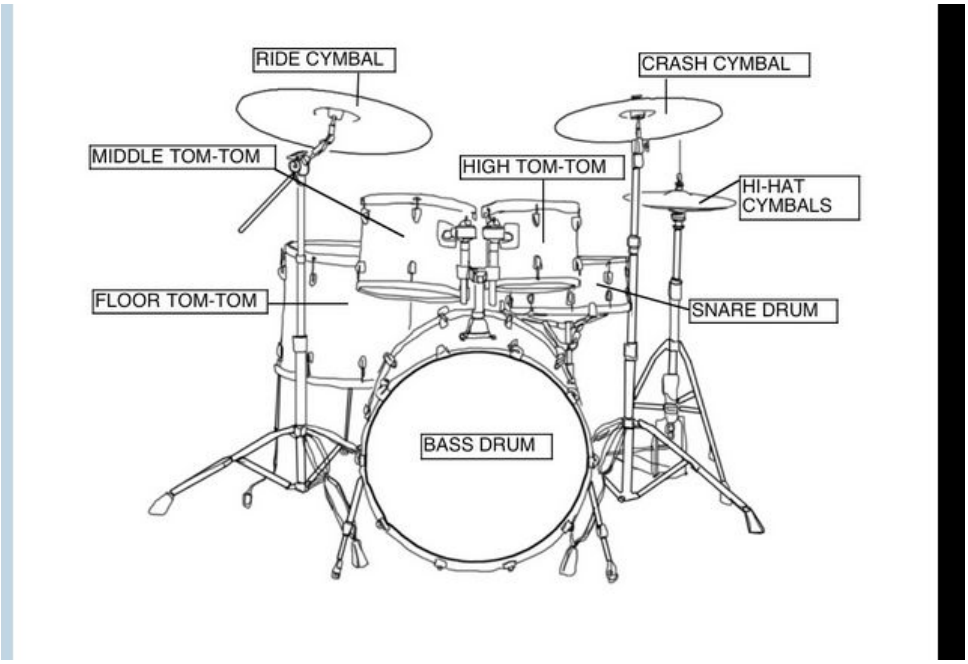
   I’ve had many eureka moments of understanding through confronting and resolving inconsistent knowledge in this way. Similarly, with conflicting “best practice” advice, no matter what the field: figure out what advice applies in which situations by performing experiments, and then delete the rest. Evict knowledge that does not pay rent.

4. **Avoid ambiguous questions.** This might be specific uniquely to me, but I include it for the benefit of my spiritual clones. In computer science, I like to create flashcards with the format “What’s wrong with the following?” then display a picture of a deeply flawed piece of code. Reviews of this card become problematic when there is an additional problem with the code: despite my only intending to quiz the specific major problem, I might answer with the secondary problem during my reviews, thereby usurping my intended question. To relieve this issue, I reworded the question part of the card to direct my attention. For example, the above card would become “what’s wrong with the **function names** in the pictured code?”, and now I know I can safely ignore issues with something like variable naming.

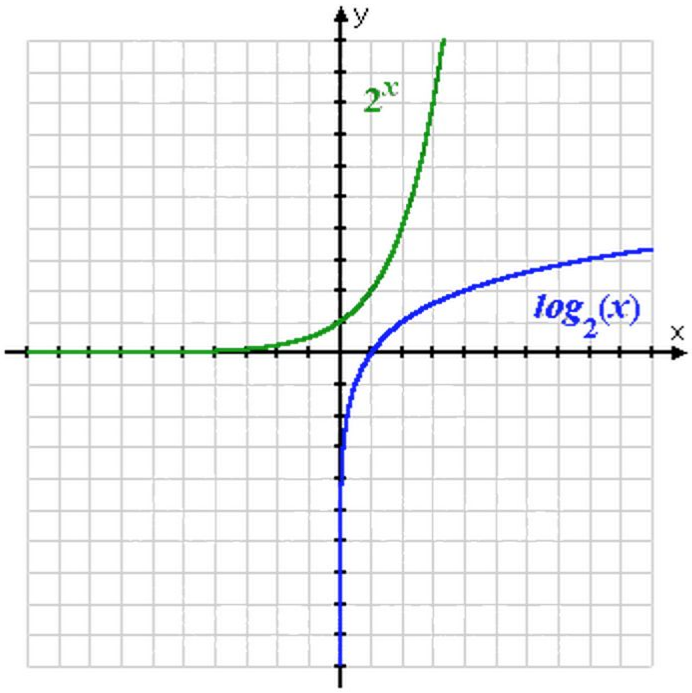
5. **Give names to techniques,** associating them with a person, adjective, and/or place. For example, I describe a piano-playing techniques that my musical mentor showed me as the “Fred’s Calypso Technique” and note that he taught me it in Portugal. In naming the previously unnamed, I believe you grant your memory a convenience in later recalling. I’ve written elsewhere about the value of naming concepts.

2 Include visual notes

Not only can an image sum up a thousand words, but—critically, for our purposes—images are much easier to remember than even a handful of those words. Given the massive availability of images online and available through Google Image Search, the ease of taking a screenshot of all or part of your screen, and the convenience of using your phone to take a photo of something you scribbled, we now have unparalleled ease in making rich, colourful, visual notes.



This image from Drum Nuts helps you remember the parts of the drum kit easily because you map your memories of playing your friends’ kits as a teenager onto it, or you remember a concert where a favourite band played a certain part of the kit and associate the sound you remember in your mind’s inner ear with that part of the drum-kit.



The above graph from Purple Math shows two common mathematical functions—one exponentiation (multiplying something by itself X times: 2^3 = 2 x 2 x 2 = 8) and the other a log (the number of times the base of the log must be multiplied by itself to get X—e.g. log base 2 of 8 is 3) . The diagram shows how these functions behave at various values of X or Y in a far more vivid and information rich way than a solely verbal description. You can see how exponentiation output quickly approaches 0 as the X value decreases below 0, and how it quickly tends towards infinity as the X number increases above 0. Likewise, you can see how the log function behaves and even notice how the two functions have similar contours.

3. Document internal realisations

When you were in math class at school, I bet you noticed convenient simplifications that either sped up or expanded the scope of arithmetic. For example:

- to multiply a number by 10 add a zero to the end (=> 2x10= 20)
- to multiply by a multiple of 10, such as 20, 30, or 40, just multiply by the initial digit (2,3, or 4), then add a zero at the end (=> 2 x 30 = (2 x 3)0 = 60)
- to multiply a number by 9, multiply by 10 (add a zero to the end) then subtract the original number (=> 6 * 9 = (60 - 6) = 54)
- to multiply by 8, do the same, except subtracting two times the original number (=> 6 * 8 = (60 - 6 - 6) = 48)

I used these simplifications haphazardly because they only presented themselves to my awareness in a haphazard manner. Adult Jack, existing in a hypothetical world where calculators weren't built into phones, would document these simplifications in a deck of

flashcards for spaced review. The point of documenting is not just to remember, but also to stimulate myself into thinking of more advanced simplifications. When reviewing the rules above, the happenstance and chaotic (both meant in a positive sense) placement of the cards might trigger fresh insight or a connection between two previous rules. Indeed, while I was writing the above list of examples I realised:

- to multiply by a number ending in 9, such as 29, 39, or 49, just multiply by a digit one higher (29 becomes 30, 39 becomes 40 , and 49 becomes 50), then subtract the original number. (=> 2 * 29 = (2 * 30) -2 = 58)"

Given a place in your memory, these insights accumulate and mature into richer connections. Sparks of insight and momentary flashes of understanding can be so rare and valuable that I find it appallingly wasteful to effectively throw them out through failing to document them; you may never arrive at that spark again. These insights have fantastic pedagogical power, and Kalid Azad at BetterExplained.com has harvested his personal realisations when studying computer science to create perhaps the most fun and memorable math resource ever compiled.

4. Extract, document, and improve the process.

Let's start with a definition. By "process" I mean the workflow you use to actuate your skill; I mean your criteria for choosing your online advertising photos; I mean the checklist of potential issues you check before submitting an essay for grading or an article for publishing; I mean the order in which you compose sections of your song (and your reasons for doing this); I mean the time of the day you choose to deploy important code changes; I mean the little things, like how you tile your programs on your Macbook screen to see as much text as possible at once, or the keyboard shortcuts you press to speed you up.

We already have processes for everything we do—we just may not be aware of it. Indeed, process may be too strong a word for what might start out as inconsistent and rough intuition. Process matters in skill-based learning because it enables you to attain higher quality results, more consistently, and in less time.

I learn process best by watching experts at work. I watch videos of expert programmers at work and paid attention to the keyboard shortcuts they use, the way they name variables, and the various other factors that the textbooks leave out as "trivial" but real world workers consider indispensable.

I say that you might need to "extract" a process because the process isn't always spelled out for you in an apparent manner. When you read a solution to a mathematical problem, it's not enough to see how the author solved that *particular* question; a solution so closely fitted to the previously seen problem does not help you with unseen future problems. Instead, you need to identify an abstract reusable technique, a tool available to you when faced with a future problem. Ask yourself "what general rule would I need to have formulated in order for me to

solve that class of problem?" and "what tell-tale sign in the problem should have prompted me to consider this particular technique as a candidate solution?". For example, you might formulate the rule that seeing three sides of a triangle should prompt you to consider the Law of Cosines.

Extracting a process is particularly valuable when you have mentors or teachers. These experts are likely to have rich internal processes, albeit processes that might exist only as intuition that these experts never verbalised before. Your job is to ask probing questions about what thoughts fired through their head when performing certain tasks, and thereby reverse engineer their expertise. I have found that experts' descriptions of their workflows only form the tip of their proverbial knowledge iceberg, so do not settle with these explanations alone. Search for the points so obvious to them that they would never think to mention unless pressed.

I say "document" your process because human memory isn't reliable. A 12 month break from applying your processes may result in you forgetting the subtle skill in how you once made magic happen. Process is accumulative, but our minds can only juggle a limited set of factors at once. Therefore, to arrive at sophisticated processes, some work on pen-and-paper pays dividends. For the same reasons that an architect builds on paper before plot, you'll arrive at better results by planning your process on paper, where edits are cheap and the full picture becomes apparent at the scroll of a page.

In anticipation of potential criticism, I do not argue that those in possession of process ought to close themselves off to potential changes and only adhere strictly to their existing workflow. The process is always a work-in-progress, and improvements are ever welcome. Improvement necessarily requires that you try something different, so I advocate some element of locally inefficient exploration in expectation of long-term efficiency gains. Think of process as a way to spare the expenditure of mental energy in areas where it doesn't matter or on matters where you've already reached a *good enough* decision; by doing so, you save energy to invest in creativity where it has the chance to impact most spectacularly.

Part C: Sources

1 Throw away most learning sources

Notwithstanding that the following point may demolish the authority of this piece, the democratisation of publishing ability through the web has meant that online learning sources, while typically free and conveniently accessible, sometimes lack the accuracy, depth, and careful attention to pedagogy contained in textbooks (or their rich-media equivalents). Typically, book publishers require better-than-average credentials of their textbook authors, and prior to publishing the author's script must pass through an editorial or peer-review process. Along with these hurdles, the long form of a book imposes an additional intellectual rigour upon its authors (assuming these authors are conscientious enough to care about avoiding rambling). Overwhelmed with the size of the text, they adapt by organising their bulk of information into its underlying logical structure; aware of the subtle inconsistencies that become apparent to them as their text grows, they revise their thesis to iron them out; knowing that the reader cannot be expected to click on a Wikipedia link, they include the relevant background information. It is for these reasons that university students observe that a 10,000 word essay requires much more than four times as much of their time as four separate 2,500 essays.

I've found that textbooks beat online sources nine times out of ten, and you'll save yourself a great deal of misinformation and unsatisfactory explanation by researching and purchasing the best textbook in the field you'd like to study instead of reaching into the blogosphere. Oxbridge Notes, my current business, lies in the middle, providing learning materials far more in-depth than blog articles, but shorter than full textbooks.

A less wrong article provides another reason to choose textbooks, arguing that they contain settled knowledge as opposed to the latest fads or controversial knowledge. Yudkowsky writes, "If you only care about scientific issues that are controversial, you will end up with a head stuffed full of garbage." (source) Like newspapers, the blogosphere drools over fresh information, but is prone to omitting the more stable and important fundamentals.

When I recommend textbooks I do so on the basis that their *factual content* tends to be superior. I am not arguing that the book form is in absolute terms a better choice for learning. Other media found online, such as video, communicates information vastly more vividly, and I prefer these sources whenever their quality and length is on-par with similar textbooks. A textbook describing musical production techniques will fail to elucidate without audio examples; a five minute long video of a pencil drawing technique beats a handful of photos of this technique "in action" along with accompanying text. I've found that videos of programming techniques, such as Pluralsight, lodge more readily into my memory than similar textbook descriptions. Furthermore, videos offer simultaneous example and commentary, whereas textbooks require laborious flicking between the textual description and the photos which they describe. Finally, videos communicate additional contextual information that might not be mentioned in a typical text. So, besides the programming technique in question, a Pluralsight programming tutorial video will also demonstrate how an expert navigates through their code-base with their text-editor.

In my ideal world, the great textbooks would be recreated for rich media online consumption.

2 Recognise learning porn

Have you heard of *productivity porn*? As a former daily productivity blogger, I've been a victim of this disease and given that this article is essentially "productive learning", I know that I've not fully recovered. I digress. Productivity porn's mechanism of infection works because instead of *being* productive, it's easier to *read about* being productive. You fall into a trap of spending half your "productive" time reading about productivity. It feels good; you're learning and improving every day. But the reality behind these feelings is that you're procrastinating and you've done nothing for your goals since April last year. Knowledge of productivity techniques is valuable, but the division of your time between learning about and applying these techniques should probably rest at 1:1000 instead of 1:1.

The internet is filled with a closely related vice: *learning* porn. Amongst its ranks lie blog articles about AI that gloss over the fully necessary details, popular science books that skip the pesky bit about physics, or lecture series on mathematics that omit any exercises. These education

sources are enjoyable to consume as entertainment, and useful to the extent that they excite you about a field, provide helpful “broad before deep” introductions, and deliver the key jargon for Googling should you wish to investigate further. But we must recognise learning porn for what it is, complete with all its shortcomings, and be aware of the opportunity cost of its consumption when learning time budget is limited. Despite the subjective feeling of ease and the sense of speedy learning you’ll experience when watching Khan Academy videos on Linear Algebra, you probably won’t be capable of applying this knowledge to any real world problems without doing supplementary exercises,

3 Observation and analysis

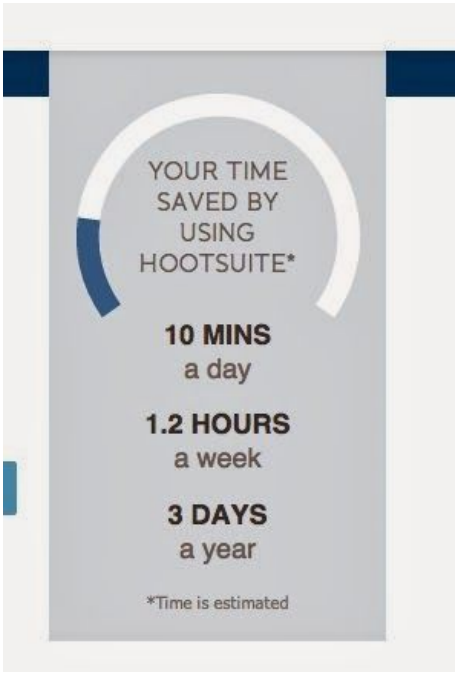
Frustratingly, life doesn't always provide textbooks for the topics you find most important. Nobody told you what specific e-commerce market to enter into for high margins and low competition. Likewise, nobody taught you how to be well-liked socially, despite its emotional, romantic, and financial benefits. These desired learning sources might be unavailable because despite their interest, nobody ever found the time to write one; or perhaps because the topic is so unique to your circumstances that no-one else has thought about it before; or maybe because the knowledge is valuable to competitors who wish to guard their secrets; or it could be because the information is too taboo for anyone to willingly attach their name to.

Nevertheless, these reasons for unavailability don't mean that knowledge about this topic is not of immense value to you, and luckily you need not be stopped by the lack of existing information. Where prepackaged knowledge runs out, observation and analysis begins.

Even if the world has provided scores of textbooks for your topic of choice, it may still be worthwhile to observe first-hand and cut up reality into slices that make sense to you. Academics call this working with primary sources, as distinguished from relying on secondary sources (sources which cite, comment on, or build upon primary sources). By working with primary sources you reduce the risk of inheriting the mistakes of others and open the possibility of seeing something everyone else missed; for these benefits you pay a cost in needing to analyse and structure the information yourself.

For initial context before the details, I'll share some areas where I've applied this technique:

1. I took screen-shots of impressive marketing strategies used online (attention grabbing Facebook photos, curiosity arousing Buzzfeed headlines, great email subject lines) so as to inform my own marketing at Oxbridge Notes



Hootsuite demonstrate the benefit of using their products through calculating and spelling out the time you save over very long intervals.

2. I analysed my favourite songs and figured out, bar-by-bar, how each song developed. Reading the table pictured below from top to bottom and left to right, you'll see that each cell represents a bar of music (i.e. four beats). Within these cells, I show the time at which each musical element plays/is introduced (e.g. "++kick" means the kick drum was introduced; "4.5 calypso synth" means that half way through the 4th beat this calypso synth plays).

Song Structure

++kick/snare/bass/hats			4—single note of vibratoed synth
++djenge			
4.5 calypso-under-the-sea-synth chord (plays until 2 in next M, but reverb lasts nearly until the 4)		**4.5** calypso-under-the-sea-synth Hrepeat chord (plays until 2 in next box, but reverb lasts nearly until the 4)	
			1: bass- synthy note that spends the beat pitch-bending downwards; no synth for rest of bar although kick on 1, none in rest of bar; no djenge; 2: high toms play for 1.5B panned left 3.4: low toms respond panned right
(verse)<1.5 vocals++ (40 seconds) 1R-O; no djenge; 4.5 vibrato synth that echos a		**4.5** vibrato synth again	

Analysis of Heartbeats by The Knife (*contains JackJargon, sorry)*

3. I identified the specific behaviours of people whose company I thoroughly enjoyed and those whose company I couldn't stand, the point being to build awareness of the components of social skill and likeable character.

selfExample: When someone always takes what you say and gives you an example from *their* life, even though you weren't talking about them.
Example of bad: (name removed) always **self-exampled** about his experiences running his company. (Sidenote: he is widely known and disliked for his arrogance)
Example of good: (name removed), by contrast, always spoke of points generally or tried to apply the knowledge to *my* situation.

One my social observations. I've removed identifying information to preserve the observed's privacy.

By no means was I fully successful in my efforts with these three areas; otherwise you'd be reading the musings of a rock star turned popular head of state. But I did, nevertheless, find my observations useful in figuring out a little bit more about how these small slices of the world worked.

On to the mechanics of the observation and analysis technique.

First, designate somewhere as a collecting place for your observations: a folder on your computer, a Google Doc spreadsheet, a custom piece of software, or maybe an Evernote notebook. I strongly recommend software over paper. I don't buy the existence of any supposed benefit to handwriting your ideas that does not equally apply to typing. I am, however, thoroughly convinced of the advantages of digital text, text easily searched, organised, edited, synchronised, backed up, shared, and published.

Second, gather the questions you'd like to answer with your observations. It might be a question as specific as "what harmonies did the bass-line play through?" or as general as "what makes this song unique and interesting?".

Third, observe. You might timetable a proportion of your day for purposefully observing—say looking at famous marketing campaigns or listening to classic tracks. Or perhaps, instead of regular timetabling you continue your daily activities but grab your phone and make a quick notes as soon as you notice something worth recording.

Finally, once you've recorded sufficient numbers of observations, it's time for analysis. I like to "code" my observations, which is the qualitative research jargon for what every blogger knows as tagging. I tag my observations with one or more, em, tags. In music, that might mean tagging the lament bass as "sombre", owing to the sad impression it creates, and also as "pure music" since it was created through the composer's choice of notes instead of a sound engineer's post-recording efforts. Other musical techniques, such as the chorus effect, would be tagged as "effect" since the song's sound engineer created that sound using hardware/software. Arguably, the chorus effect sounds sombre, so you might add this as second tag. With my social observation project, I categorised behaviours with tags such as "compliment", "transparent", "likeable", or "insufferable". The goal in both music and social observation was to draw circles around related ideas.

Seeing as the goal in my knowledge seeking is the eventual attainment of applicable skills, I ask myself not only "what did I see?", but "how can I do that?" and "what mantra would I need to have circulating within my brain to instruct me to act/avoid acting in that way?". To clarify what I mean by these questions, I offer an example.

At a Couchsurfing meetup in Berlin, a place where strangers mingle, I began an uncomfortable conversation with a person I'll refer to as M. The conversation went as follows:

Jack: *"Hey. I'm Jack. Where are you from?"*
M: *“Germany. I come from Dresden originally.”*
Jack: *“What brings you to Couchsurfing events?*
M: *“I come to these things because I need a fresh start. I fell into a deep depression 18 months ago I and don’t have any friends. I’m in a really dark place and my health started failing before I’ve hit 25. You?”*

The general behavioural rule here is easy to discern: "you will alienate people by dumping your problems on them as soon as you meet them." Clothed in this compressed form, you might think that observation has become actionable knowledge. This isn't fully true. Imagine you knew no alternative conversation topics so your next best course of action was to respond with silence. To transform our proposed general rule into actionable knowledge, you must suggest a positive alternative course of action, for example "ask other people lots of questions about themselves when you don't have anything to say".

As explained elsewhere, I like to name techniques I've identified. Once named, the techniques are easy to remember, and I more readily perceive their recurrences in future observations.

Observation and correct identification of reusable truths through analysis does not equate to the ability to perform that which you have observed. I assume most people would rather their road trip led by a driver with one year’s experience on the road over someone with no road experience but perfect test scores on the rules of the road. Why, then, does a discrepancy between analysis and doing exist, and is there anything we can do to help close that gap in our own efforts?

- Incomplete description of the rule. You might have observed the specific words that an exceptionally charming public speaker used, but not have recorded how the speaker warmed their voice in speaking those words, thereby missing a key component of their performance.
    - Proposed solutions: Observation in richer, more-detailed formats such as video or audio; gathering of more observations enabling comparison of common factors; brainstorming alternative explanations for what was the causative element (instead of only focusing on the specific words, you might have considered tonality/dress/body language/relationship to the audience as causative factors).
- Lack of foundational underlying skill, upon which correct application is necessary. You won’t have much luck selling high-ticket items over email if your written grammar is weak.
    - Proposed solution: identification of foundational skills; dedicated practice to attain them

- Slowness of applying the rule: You know the rules and have the foundational skills, but that which should be intuitive and instantaneous takes you ten minutes and a pen-and-paper calculation. Using a foreign language grammatically falls into this category.
    - Proposed solution: Practice sessions and copious repetition
- Incorrect identification of the rules: You've observed and seen what you thought were patterns. The issue is that you mistook random variation for the truth. Human minds rush into finding patterns on too little evidence, a predisposition leading to conspiracy theories and Malcolm Gladwell best-sellers. In the 21st century, society's guardians of truth are the statisticians, and they name these false positives Type 1 errors.
    - Proposed solution: Using statistics to set a required significance level before concluding there is a truth.

I'll finish with another advantage of observation and analysis: by partaking in this practice you build a body of knowledge in possession of no-one else, knowledge that offers you advantages over competitors who are limited to publicly available information. Should you wish to share your first-hand observations, then you'll rightly establish yourself as an original thinker.

4 Dip into closely related fields for alternative views

If our small minds, for some convenience, divide this glass of wine, this universe, into parts — physics, biology, geology, astronomy, psychology, and so on — remember that Nature does not know it!

—Richard Feynman in The Feynman Lectures on Physics

As eloquently put by Feynman, we bottle our knowledge into artificially constructed compartments, yet reality does not conform to these divisions.

Let's consider a student learning to write better essays. Their search for information should not end at essay-writing guides written by university academic departments; instead they could also refer to style guides for newspaper journalists, to books on writing non-fiction, even to books on writing fiction, film scripts, or speeches. These resources from more distant fields may only warrant a skim-reading, since many areas, such as character development in fiction writing, are unlikely to be helpful in the next essay. However, the advice often given to fiction writers to "show, not tell" will certainly spice up the student's next essay. The information you need may not be available in the compartment you first search; rather it lies a few shelves away.

Another example: say you already understand the math of descriptive statistics sufficiently for a programming project, but know nothing about how to efficiently model these statistical techniques within a computer program so that the program spits out a result in a few seconds instead of in a few hours. Your primary programing language is Javascript, so you search for textbooks, forums and blogs dealing with "statistics in Javascript". You read all these resources

and then believe you've exhausted all existing knowledge on programming statistics. Your belief here would be premature: the core of what you wish to learn, how to efficiently model statistics in computer programs, could also be dealt with in articles intended for programmers of *other languages* such as Python, C or R. Yes, the examples in these languages will require a little mental translation back to Javascript, but it is possible that the clearest and most accurate resource ever written for the efficient computer-modelling of statistics was penned for programmers in one of these other languages. This kernel of knowledge remains the same regardless of programming language; indeed language is only incidental. Therefore, you would be wise to seek out answers to your questions in closely related fields.

5 Dip Into foundational fields

Someone in search of a truth in biology may find their bullet of inspiration in chemistry or physics, fields that often underpin biology. Perhaps, as has often been the case in physics, the physical process studied was already described by a set of mathematical theorems. Knowledge of these "foundational" fields can help you solve problems in the field of your focus.

Some fields are more likely to provide reusable views than others. Given my interests in technical subjects, it's probably not surprising that I find mathematical ideas, even simple ones like negation, inversion or the concept of zero, to be frequently reusable. As Paul Graham puts it, "Mathematics is a sort of Zen garden from which to draw inspiration."

Let me offer an example of how math can inspire useful models for understanding other fields.

During my law degree, I looked to logical fallacies to provide solid ground and self-confidence in combating bad arguments. I found myself struggling to understand some of the formal logical fallacies, such as Affirming the Consequent. I eventually realised that I could visualise some fallacies as Venn diagrams, those overlapping circles you learned about in primary school. An example of an argument where one "Affirms the Consequent" is:

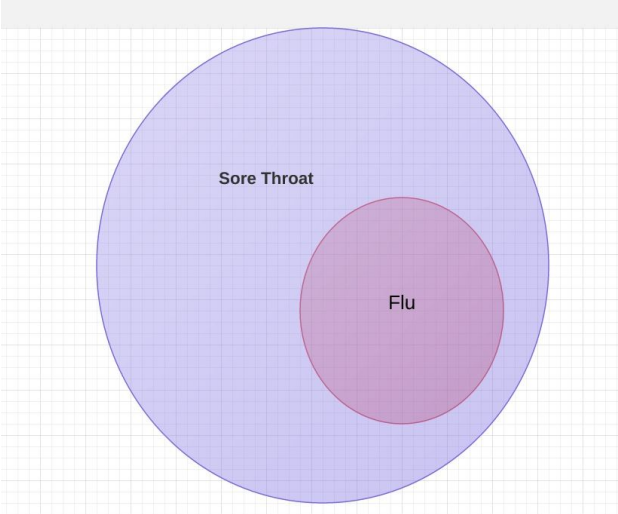
> *If I have the flu, then I have a sore throat.*
> *I have a sore throat.*
> *Therefore, I have the flu*

Formally, the logic goes:

> *If P, then Q.*
> *Q.*
> *Therefore, P.*

This is a fallacy because P was never asserted as the only sufficient condition for Q; other factors could also account for Q. You might have a sore throat because you smoked forty cigarettes last night, so you'd be wrong to conclude that you had the flu on the basis of your

inflamed throat. I realised, as I'm sure many have before me, that the logic can be represented with the following circles:



According to the logic of this diagram, someone with the flu will always have a sore throat (as you can see by the flu circle being fully contained within the sore throat circle), but someone with a sore throat may—or may not—have the flu. Omitted from this picture are the infinitely many other sore-throat causing circles, such as "having smoked forty cigarettes", and "swallowing cheesy pizza before it was cool". You can also envisage that if a flu *sometimes* caused a sore throat but sometimes didn't, then a proportion of the flu circle would not overlap with the sore throat circle.

Mathematically inspired techniques spur you to analyse your income in terms of variables and constants, or to understand your subjective feelings of happiness not as a level of good fate you currently possess, but rather the comparative increase or decrease between what you have today and what you had yesterday (the "calculus of happiness"). Math will inspire you to visualise the slog of daily effort towards a goal as the area under the curve of expertise, thereby making integrals integral to your motivation, or to approach problem-solving with analogues of mathematical proof-systems, such as the inductive technique whereby you solve for case of one then two items, then extrapolate to three and derive a general rule.

Part D: Practice

1 Do work that fully reflects the final work you wish to produce.

If you wish to pass law exams your *primary* activity at law school, from day one, ought to be answering past exam questions under time constraints and without a textbook. Most students

don’t get this—I certainly didn’t when I was at university. For about 98% of my university time I read textbooks, typed up notes, and learned these notes off by heart. Only during the months before finals did I begin to look at past questions and attempt answering these questions under exam-like conditions; only then did I realise that I couldn’t write essays quickly, tersely summarise my knowledge, recall relevant information absent my computer’s search, or even spell without a squiggly red line appearing under the culprit word.

By doing work that mirrors your final output, you identify where your shortcomings lie, prompting corrective measures and training in foundational skill. You practise applying knowledge in realistic circumstances, and you thereby build speed during future applications.

Taking more examples, music producers learn to produce six-minute long electronic tracks by—surprise—writing lots of crappy six-minute-long practice tracks, not by writing lots of perfected ten-second loops. Sure all ten seconds of the loop sound great, but aside from advertisers, no-one really cares for ten-second songs. By focusing on the ten-second format as “practice” you’ll never learn how to arrange and develop a full track *from* an initial ten-second idea, thus leaving out the majority of the necessary skill set.

In a similar vein, programmers won’t learn how to program complex websites by writing 100 mini-projects covering in aggregate a similar features-set, with each project containing only 200 lines of code. A single integrated program with 20,000 lines of code is a completely different mechanical beast, requiring unrelated skills compared to a small program. In the case of the large program, you’ll need tools to manage its code complexity and sheer size, such as object orientation, testing methodology, refactoring, design patterns, project searching, editor navigation tools, and reversion control branch management.

TLDR: you won’t learn to play piano by practising soccer.

2 Practice involves experimentation

Somehow, somewhere, a distorted idea entered people's minds: the idea that practice equated to mindless repetition; that the way you learn to play Für Elise on piano is to repeat it hundreds of times in a row until you finally get it right.

This kind of repetition has some limited worth. For one, repetition, even if mindless, is nevertheless practice, and bad practice beats no practice at all. Secondly, especially for highly physical skills, repetition is necessary for the comparatively slow-learning muscle memory to internalise and perfect a movement. But repetition, even in the realm of the physical, is weak when unaccompanied by some experimentation. By experimentation, I mean no more and no less than “trying something different”.

The experimenting piano-practicer might realise that the section tripping them up cannot be mastered their current technique, and therefore they ought to attempt a different fingering, an

alternative way of applying pressure to the keys, or a contraction of a long note during a fast passage. During their practice sessions, they devote twenty minutes to each alternative hypothesis and judge whether the change holds promise. Compare this to the mindless brute who repeats their original flawed technique thousands of times, doing the wrong thing over and over. Sure, the mindless brute will improve their speed somewhat through the force of repetition alone, but they will accumulate bad habits and eventually reach unsurmountable plateaus. It's the tale of The Tortoise and the Hare all over again.

Spending practice time in experimentation feels wasteful. Just as scientists run into many dead-ends during their experimentation, so will you in your practice sessions. After a few hours of fruitless experimenting, you'll feel guilty, a guilt arising from your mental comparison with improvements you might have won through channelling those hours into brute-force practice. Resist these thoughts by reminding yourself that whereas mindless practice can lift you to a local maximum, only experimentation can take you to a global maximum.

3 Apply new techniques, even when you don't need to

Given that you already know how to perform a certain task, instead of completing it the way you already know best, employ a novel technique. Programmers might solve problems using recursive approaches instead of standard iteration; chefs might chop using an alternative directionality; guitarists might hit chords with untried new hand positions; writers might experiment with unfamiliar literary techniques. With practice, these new techniques join your repertoire, growing the total surface area of your skill. In exchange, you sacrifice efficiency in completing the task at hand. This loss in efficiency may prove costly to you or your employer, meaning that this technique isn't always appropriate. Nevertheless, it's worth bearing in mind when the costs of variance are bearable.

4 Press every button

During a time before Youtube video tutorials were a thing and under the pressure of a looming deadline, I watched a co-worker with no Photoshop experience learn the basics of this complex image-editing program in a single evening evening through a chaotic yet brilliant method: they systematically pressed every button in the program. Photoshop crashed repeatedly and the undo button took a memorable beating, but the end result was a completed project and my coworker's newfound working familiarity with the program.

I find this technique admirable for its confidence and its efficiency. Typically, before attempting something new, I am restrained by an over-egoed identity of myself as "someone good at things", thereby postponing my inevitable and necessary jump into experience, experience that will drive real learning. All this for the sake of some egotistical delusion.

Underlying principles for why pressing a button works are connected with other techniques in this guide: it maximises mistakes per minute; it is grounded in real world observation; and it practices the work you wish to finally do.

Having stolen this technique from my co-worker, I've modified it for use with other novel computer programs. Print out a "cheat sheet" of keyboard shortcuts (Google “X cheat sheet” to find vast numbers) then press each one of these shortcuts. Keyboard shortcuts typically reflect the most commonly used functionality within a program, and by beginning with these you lay a productive foundation. The reasoning is similar to that language learners implicitly use when focusing initial efforts on the most frequently used words— the language of I, you, me, of going and coming, and of eating and drinking.

From here on please substitute "pressing buttons" with "pressing buttons, twiddling knobs or otherwise setting parameters"—otherwise these repetitive additions would inject clunkiness into the text.

Computer programs, BMWs, lightswitch boards, DVD players all have buttons begging for pressing. Rocket launchers and helicopters have buttons too, but you’re advised to read the manual here first. Other human-made constructs without *physical* buttons could be said to have *abstract* buttons, in that you can identify controllable inputs and expect that manipulating these will lead to varied observable outputs. Many mathematical functions have conceptual knobs, the value of these knobs set by the presence or sizes of input arguments. Place -100, -1, -0.1, 0, 0.1, 1, and 100 into a square root function for an exquisite tour.

X (input)	**Square Root of X = Y (Output)**	**Observations**
-100	10i	Same as positive equivalent, except now we put an i (for imaginary number) at the end
-1	¡	“
-0.1	0.3162i	“
0	0	Same output as input
0.1	0.3162	When you take the square root of a number between 0 and 1 the output is *bigger* than the input, which is the opposite of what happens when you take the square root of a number larger than 1

1	1	Same output as input
100	10	Contrast with square root of 0.1

Pressing some of the buttons in a square root function

Imagine you're using that image-editing program, Photoshop, and that it's completely unfamiliar to you. Some buttons you press will have no effect because they require some photographic content to be selected on screen but you haven't imported any photos yet. The systematic experimenter ought to not only try the buttons from the initial blank screen, but also from various program *states*, such as "photo on screen", or "section of photo selected with flashing broken line". In other words, the state of the system is a hidden slider that will profoundly affect the effects of buttons.

Is observation gained from button pressing applicable or worthwhile with respect to learning about objects not architected by humans, that is, those that exist within nature? A person curious about the physical rules of downward acceleration would improve their understanding by considering "weight of object dropped" and "height from which the object was dropped" as appropriate potential knobs and inputting different values, e.g. first dropping a car then a feather, or first dropping from 10 cm then 10m. (Foreseeing a physicist berating me for misinformation: the weight of an object dropped matters for downwards acceleration on *Earth* due to air resistance.)

Our experience with Nature diverges decidedly from our earlier examples of pressing buttons in computer programs since Nature will not cleanly label her key parameters as buttons, nor will she make them so easy for us to press; observation, conjecture and laborious experimentation will be necessary to identify and slide these parameters into the desired positions.

5 Experiment with doing it clearly wrong

You're in singing classes and your teacher says you hit notes a quarter tone flat, but you never noticed or heard this fault before they pointed it out. In subsequent solo practice sessions, you will still be unable to correct this issue because you lack the skill to recognise these small pitch errors. The solution here is to experiment with purposefully committing the error you wish to eradicate. Sit at the piano, play a note and sing that note so obviously flat against the piano tone that the fault becomes painfully obvious. From this starting point, sing incrementally *less* flat notes so as to train your ears to perceive slight differences in tuning. By having a means of knowing *how* wrong sounds, you give yourself the yardstick necessary for consistent future self-evaluation, an important stepping-stone towards skill acquisition.

6 Focus on one technique at a time.

Bad teachers tell you the 50 things you are doing wrong and expect you to correct them all at once. Imagine it's your first time bench pressing in the gym and I'm your physical trainer. I can't expect you to perfectly place your feet on the ground, align your elbows orthogonally to your chest, address balancing issues, and breathe in and out in perfect sync with the barbell movement. Our brains can't juggle that many factors at once. A more realistic teacher would focus on your feet placement until you've got that right, then move onto the elbows, and so on. Only after the previous factor has been internalised and solidified into an automatic habit would they teach you something new.

In cases where you are teaching *yourself* a skill—e.g. programming, you'd be wise to focus on some small aspect each week. Write it down on a sheet of paper and keep it on your desk."I will explore *VIM operator movements* this week" or "I will use *git bisect* at least three times this week", thereby focusing your learning efforts and avoiding potentially overwhelming yourself. A learner of a foreign language might instead focus on using three particular prepositions every day that week.

7 Feedback loops

Feedback, i.e. a way of knowing whether you're on the right track, is essential to learning. If you don't know when you're wrong and when you're right then you'll repeat the same thing regardless of its correctness. Feedback from other people arrives by hiring a teacher; by releasing your work to a critical public and providing means for them to contact you; by forming study groups; by entering competitions; by asking a trusted and appropriately qualified friend for straight-up feedback; by driving traffic to your supposedly "killer" startup and counting whether your vocal fanbase actually pull out their credit cards.

You might devise other means of feedback that don't depend on the input of others. For example, by solving problem exercises in your physics textbooks and checking the answers in the back of the book; by recording yourself play guitar then listening back and comparing your timing to a metronome beat; by rereading your essays a month later, a sufficient passage to time for you to judge with a more critical eye.

Immediate feedback is preferable to delayed feedback. Can you imagine writing an email without that red line underneath a misspelled word? Can you imagine programming where it takes four hours for the compiler to evaluate your statement? Bret Victor has dedicated his entire life to feedback loops, and I encourage you to watch his hour long talk on this topic, Inventing on Principle. From a learner's point of view, if you can reduce the time it takes for you to receive trustworthy feedback, you'll improve faster.

8 Maximise mistakes committed per minute

Here we've arrived at the turbo-pedal for efficient learning. If you can find an activity where you make many mistakes per minute, and through this system you can identify *what* those mistakes

were and what the right answers would have been, then you've found your educational silver bullet.

One-on-one foreign language conversation classes fit this criteria since your teacher will correct your grammar and vocabulary errors instantly. Once you have a low number of mistakes per minute your teacher can increase the difficulty by choosing to focus on more challenging topics: instead of conversations in the past tense they'll switch to speaking in the conditional tense.

What are the downsides? For the less self-confident, there'll be the embarrassment and mild humiliation that accompanies a constant pointing out of your imperfections by other people, for example when speaking a foreign language. Sensitive private teachers or interactive activities not mediating by other people (e.g. reading a foreign language book as opposed to talking to someone in that language) can lessen these feelings, as can toughening up for the sake of faster learning.

Maximising mistakes committed per minute isn't a full solution for all skills you wish to learn: just because you know what the "right" looks/sounds/feels like, doesn't mean you have the skills to arrive at it yourself. For example, an iPhone app that indicates when you are singing flat can't teach you the physiological skills you need to sing notes consistently in tune. All the app provides is feedback to recognize mistakes you otherwise might miss, thereby making those mistakes productive. You'll still need to supplement this knowledge of mistakes with other singing exercises.

Part E: Social

1 Transform parts of your social life into learning projects.

By pulling a proportion of your social life into learning activities, you benefit from your peers' knowledge; expertise that is often superior to your own. Besides this extra knowledge, you'll get your fix of socialisation, something you might otherwise forego in your Faustian quest.

Some examples: programmers attend 48-hour programming competitions called hackathons and build applications in unfamiliar new technologies, usually with other programmers they meet at the competition. Music producers collaborate with like-minded friends. Students form study groups to help them through late study nights before exam periods. Writers form writer's circles. Well-capitalised friendship circles jointly evaluate financial investments and pool their knowledge about their options.

It's not just a matter of learning X topic faster; groups beget confidence, the strength to jointly tackle more challenging topics that individually they might avoid. In my friendship circles, we run laptop-ridden "nerd nights" where we recreate graph shapes with algebra, write programs to turn Google Trends data into sound so we can "hear" them, or do back-of-the-envelope calculations about the costs of social policies like the Basic Income.

Organising meetup groups is another great way to combine social with education. I help organise an online marketing group where local marketing experts meet for beers every two months to discuss recent discoveries they've made about marketing. Some members have expertise in Google Adwords, others know SEO, and others again are expert email marketers. Through this forum we combine our knowledge.

2 Teach others

I'd frequently read that teaching is a fantastic form of learning not for just for the recipient, but for the *teacher* themselves. My initial reaction to this counterintuitive idea was skepticism; at best teaching others would be grossly inefficient. Owing to the many proponents of this technique, I nevertheless examined it and ended up surprised by its utility.

I'll start my argument with a belief: mastery of fundamentals is more important than a merely OK knowledge of the fundamentals along with some (otherwise unheld) advanced knowledge. In other words, knowing how to mix a great gravy and the perfect side-salad doesn't matter if you can't cook the main course.

Through teaching beginners a topic, the teacher revisits the fundamentals and must explain these or demonstrate them without their usual aids—be that advanced software packages or black-box techniques, techniques which they understood deeply at college but have long since forgotten, or simply jargon which they take for granted and haven't had to define to a novice in years. Sometimes a teacher will find themselves unable to explain something to their pupil; this inability often indicates that the teacher was operating on illusory knowledge, having swept their prior misunderstanding away. As a result of teaching others, gaps in the teacher's knowledge become apparent, and the diligent teacher will rectify before their subsequent pupil session.

This mechanism of "revisiting fundamentals" implies that teaching others is useful at first, but loses value as the teacher repeatedly drills the same topic. By then, the teacher will already be comfortable with the basics and have little more to gain.

Should a teacher have the good fortune of teaching a skeptical student, they will have additional help hammering out inconsistencies in their mental model of the chosen domain. The teacher explains some supposedly general rule then later breaks this rule, and the student cries foul and demands an explanation for their inconsistency. At this point the teacher has two choices: a. They admit to the student—and themselves—that they erred in breaking the *genuinely* general rule. b. Alternatively, the teacher admits that they were wrong in calling it a *general* rule, since the rule is excepted in certain cases such as this. The outcome of this confrontation: once the lesson is over the teacher can verbalise their model of the domain with increased granularity. Some small part of their intuition has hardened into more reliable and reproducible knowledge, i.e. words and rules. Furthermore, in explaining to the student the reasons why an exception was granted, the teacher may become conscious of other analogous situations where the exception also applies. Absent the skeptical student, the teacher might never have thought these thoughts, and their world-view would remain unenriched.

Teaching others doesn't need to be formal lessons: you could bring up the points you recently read at a dinner party and see if you can explain it in a sufficiently clear manner. You could teach through writing blog articles, earning yourself reputation as a domain expert, or teach through internal company training documents, adding value to your company.

3 Rephrase for understanding

This short tip applies when you have a teacher or mentor. After your teacher explains something ask them to listen to you rephrase what they've just taught you in your own words. Your teacher then listens to your rewording and checks whether or not you have a correct understanding. Not only does this technique turn your teacher-mediated learning into a more "active" exercise as compared to "passive" —and quickly forgotten—intake, but it also helps your teacher determine whether you've understood the concepts. Without it, they are limited to relying on your poorly hidden facial expressions of confusion and on any later blunders they notice you committing.

Part F: Ancillary Ideas

1 Learning takes *way* longer than you expect, but its scope is often further reaching

Much to my dismay, nearly everything I've ever begun learning required an investment of three-up-to-infinity times longer than I'd initially anticipated. I say "infinity" because, despite months of toil in some topics, I still haven't remotely conquered the basics.

I blame my unreasonable expectations about fast learning on the unbelievable amount of suspect advice touted in self-improvement blogs/products. Read at double your speed while retaining similar comprehension after only six weeks with our shiny new app? I don't think so.

Any speed reader I've met in real life gained the skill through reading four to twelve hours per day for a decade. (I'm envious enough of the skill to always inquire when I meet a fast reader.) This goes to show that the community reviewing and recommending these self-improvement products can't always be trusted, and I suspect they perpetuate misinformation like this not just to sell products but also because they wish to appear smart. When some jackass claims something like "I learned programming in 4 weeks" the hidden assumption they want to goad you into believing is "because I'm *sooo much smarter* than normal folk".

Negativity aside, the long term benefits of learning have astounded me—both in material benefit and in the general applicability of insights I've gained. Regarding material benefit, reading an e-book introduction to the Ruby programming language while my flight was delayed culminated in years of passive income through a website I later programmed. Taking Spanish classes during my gap year resulted in my helping set up a newspaper in Bolivia. As for general applicability of insights, let me explain through showing that knowledge of grammar makes you funnier. In an episode of the 90s sitcom *Friends*, Monica sees a photo in a newspaper of her friend Rachel's ex-boyfriend's attractive new partner.
"*Monica: Wow! She is pretty… *(realising that her friend Rachel will be offended by her ex having an attractive new partner)* ...lucky."*

What does someone with grammatical training notice? That "pretty" was initially used as an adjective of the subject "she" but then Monica saved face by detaching "pretty" from "she" and transforming it into an adverb for "lucky". In short, an adjective transformed into an adverb can provide effective raw material for a wordplay. A joke-writer with this kind of awareness could then be on the lookout for any other adjectives that also function as adverb. My turn: "*God is just……. *(then turning on my consoled religious friends)*... stupid.".* I don't think I'll be performing comedy on stage any time soon, but you get the point.

Learning may take a long time, but the subtle long-term benefits could be worth the Herculean effort.

Expect the time taken to learn a new topic to be reduced in proportion to how well you know a similar topic. A language learner fluent in French, Italian, and Portuguese will pick up Spanish in a fraction of the time that it would take someone with no experience of learning a second language. The shallow reason a third language is easier to learn than a second is because "foreign" languages share similar underlying concepts and skills, such as the ability to label parts of speech correctly (e.g. as direct objects or indirect objects), the ability to figure out unfamiliar vocabulary words from context, or familiarity with grammatical concepts shared between languages (e.g. pluralisation, case, or conjugation rules). The deep reason a third language is simpler is because, in some sense, you are learning less.

This entire series of articles represents my personal opinions, but the following represents a more personal—or controversial if you will—take: you gain a lot less by studying topics similar to ones you already know. Your second language teaches you about languages generally,

enabling you to think of other entities as analogous to languages (such as music, math, or fashion); it brings you an awareness of grammar in your mother tongue that will improve your writing there; it enables you to sympathise with learners of your mother tongue and therefore simplify your speech when next communicating with one such learner. Your third, fourth and fifth language only offer incremental insights over the paradigm shift you gained with your first foray into languages. Were you to diversify, and instead of learning your *third* natural language you learned your *first* programming language, you'd maximise for deep, broadly applicable knowledge.

2 All techniques can be improved with basic productivity methods.

I don't want this article to turn into one about broader productivity (see productivity porn above), so I'll summarise tightly. In order to learn quickly you'll need to be productive with your time.

The most heinous distractor you'll ever battle is your own mind. Thus, the foundation of all productivity comes from reliable and focused internal attention. I mean attention in the meditation sense—or in less wishy-washy terms—the awareness and ability to refocus mental energy away from distracting thoughts. Distracting thoughts could take the form of: circling the same idea/dream forever without conclusion or action; admiration/attention needs that culminate in pointless like-collecting on social media platforms; jealous or hateful thoughts that upset you and drain your energy; new ideas that sound exciting and easy at first (but only because you don't know the complexities that lurk within); and, banally, those hundreds of daily mind wanderings that can result in opened tabs and lost hours.

Whether you believe it or not, you control what you choose to focus your mind's eye on. Yes, your subconscious will constantly and always interrupt you by bubbling up thoughts you'd rather not have, but you *can* respond by the simple act of looking away and refocusing on what you'd prefer to be thinking about. You might have refocus thirty times per hour, but at least you *can* refocus.

Aside from distraction from within, you ought to protect yourself from distractions originating outside. The ultimate productivity hack in today's age is switching your phone into airplane mode and turning your laptop's internet off. I don't trust my willpower to stay offline, so I use software (Self Control) that irreversibly disables distracting websites for X number of hours.

Only once you're already getting the most impact out of your scheduled learning hours, consider scheduling more learning time. Real people don't have two spare hours in a day, so I won't offer such condescending advice. Instead I'll look at ways to find time in an already packed day.

For one, you can harvest otherwise unused minutes, for example by installing learning apps like Anki on your phone for use while queuing, waiting for late friends in a restaurant, on a bus, while walking to the supermarket, or even sitting on the loo. Second, you can squash learning into other activities: watch foreign language TV while on the exercise bike; attend discussions

groups with your friends during social time; after a long day of work, substitute entertainment time with undemanding learning, such as watching Youtube tutorial videos instead of doing hard exercises. Yes, watching videos is less effective than doing exercises, but a little bit of learning is better than none.

Finally, prioritise and commit yourself to a learning schedule before other calls on your time have a chance to affect you. I use precommitment, which means I mark off learning time in my calendar in advance and treat that time as I would treat any other appointment. If a social invitation pops up, I'm already busy; I have "plans". There will always be a social appointment waiting to gobble up your learning schedule, so if you accept all of them don't be surprised when you're in exactly the same place in your learning as three months later.

3 Appreciate packaging

This point is somewhat of a digression, but it's an important message I wish had been emphasised more to me during my early life. Your knowledge must often be communicated to others in order for it to accrue societal value. It's existence confined within your brain or on handwritten scrawls that only you and you alone understand may not be enough for your purposes.

A law student seeking good grades must convince their examining professor that their legal arguments are solid; a lawyer must convince the judge of the same. These arguments are packaged in prose, and the student or lawyer with more grammatical, presentable and intelligent-seeming prose will accrue a bonus in their judge's eyes—be that the examiner or the court. Thus, the wise would invest some of their learning time-budget into improving grammar, writing style, computer skills (for prettifying text), or handwriting speed/typing speed (so they can portray more points in limited time). Similar arguments apply elsewhere. A salesman should invest in their physical appearance and a language-learner should ensure their speech isn't misunderstood on account of mumbling.

Knowledge, even if sound, can become degraded through transmission; it's your responsibility to ensure the signal reaches its destination intact.