Brain as the Research Tool

Understanding the Human Brain

Your Brain

- Your brain is the most powerful research tool you have; all the other tools are secondary.
- It can understand complex problems, generate creative solutions, and learn from experience.
- It can also be trained and improved over time.

Secrets of the Human Brain

- Maintaining your brain is expensive; you use more than 20% of your energy to run it.
    - Considering that only 2% of your body weight is your brain, it is a costly organ to maintain.
- So, we do our best to use it efficiently; in other words, if we don't use our brain, we kill the functions of it to reduce the cost.
    - Also, we do our best not to use it unnecessarily, that's why we keep lying to ourselves: "I don't need to remember this, or that's enough."

Discussion

- What is your experience of use it or lose it?
- Why do most people not care about their brain health, even though they care about their physical health?
- How about the coding/programming skills? If a student doesn't code by copying LLM answers, what is going to happen to their brains?
- When we train our brain for problem solving (research, pattern recognition, etc.), what is going to happen?

Interesting Stories about Brain

1. We don't use it, we lose it.
2. Some people cannot forget.
3. Brain functions from the connections, not from the cells.
4. We keep lying to ourselves.
5. Spaced Repetition.
6. Red Car effect.

We don't use it, we lose it

Some babies are born with eyes that *can* work, but **no visual input reaches the brain** early on.

Later:

- Eyes fixed ✅
- Brain wiring ❌

Result: **Permanent blindness**

Not because the eyes failed —
because the **brain never learned how to see**.

Discussion

- What does this mean to us as software engineers?
- When we don't use our brain muscles for problem-solving, what is going to happen to us?
- When we keep training our brain muscles through research and pattern recognition, what is going to happen to us?

The man who cannot forget

- Meet Solomon Shereshevsky, a Russian journalist with an extraordinary memory.
- He could remember everything he experienced, from the smallest details to the most complex information.
- However, his memory was so vivid that it became a burden, as he could not forget anything, leading to difficulties in daily life.

- What happened to his brain was that his brain cells were interconnected to sensory inputs.
- As a result, he could connect any input with any other sensory experience, which made his memory so vivid and detailed.

Discussion

- We need to add more input to the topic that we want to remember.
- Emotion is the most powerful input, but we can intentionally add any input, for example, color, sound, smell, etc.
- What is essential is that our brain is designed to forget to avoid too much information, so we should (1) repeat or (2) add more input to remember.
- Research is one of the best ways to add more inputs to the topic: define the problem and search for the solution, instead of listening to the solution in the form of a lecture, video, or book.

Brain functions from the connections, not from the cells.

Meet a Sheffield University math student studied by British neurologist John Lorber.

- He was known to lost 80% of his brain due to hydrocephalus (a brain is occupied by water with almost no detectable brain tissue on scans), yet earned a math degree with an IQ of 126.

Meet a French man diagnosed with extreme hydrocephalus whose brain was mainly replaced by fluid, leaving just a thin outer layer—effectively 90% missing—but he lived normally.

- He was married and had two kids, worked as a civil servant, and had an IQ around 75-80 despite the condition.

Discussion

- Our brain functions best through connections.
- When we think (very hard), our brain cells are **physically** connected.
- It is well known that Einstein's brain had higher neuron/glia ratios and possibly denser connectivity in certain regions.
- Elephants have a much bigger neuron count (250+ Billions vs 85+ Billions), but humans have much denser neuron connections and 16+ Billions in the cerebral cortex (reasoning, language, abstraction, and planning).

- Problem-solving in any form wakes up our brain.
  - We need to use all parts of the brain to solve the problem.
  - We need to connect our previous experience or others' experience to the current issue to solve the problem.
- Research is one of the best ways to connect the brain cells, and it is also one of the best ways to connect the knowledge and experience in our brains.

We keep lying to ourselves.

Self-Deception and the Recognition Trap

Cognitive Burden Management

The brain constantly tries to conserve energy.

- Sustained thinking is metabolically expensive.
- Holding conflicting thoughts creates cognitive tension.
- The mind often resolves tension cheaply rather than accurately.

One shortcut:

> “I already know this.”

This belief reduces mental effort and frees attention — functioning as a form of cognitive offloading.

Recognition vs Recall

Recognition (Cheap)

- Cue is present.
- Feels familiar.
- Example: Rereading notes, slides, textbooks.

This creates the false sense of knowing (familiarity).

Recall (Expensive)

- No cue is present.
- Knowledge must be reconstructed.
- Example: Exams, essays, teaching.

This requires real retrieval pathways (retrievability).

- It takes repetition (expensive and hard to do) to transform the familiarity into retrievability.
- We don't want to do it until it is absolutely necessary or automatically repeated.

The Illusion of Knowing

Students often mistake recognition for mastery:

- “I’ve seen this before.”
- “This looks easy.”
- “I understand this.”

But familiarity ≠ retrievability.

So the brain concludes:

> “I know it — no need to study.”

This is less deliberate lying and more a metacognitive bias.

Discussion

- It is really dangerous to mistake recognition for mastery, especially when we are learning new skills or knowledge, because we lose the opportunity to learn and improve.
- The best way to learn it or not is to teach others (or yourself).
- The next best way to learn is to write about what you're learning.
- The next best way to learn is to solve problems without looking at the solution, and then check your solution against the correct one.

Discussion - What is the indication of the Nobel Prize, Turing Award, or Fields Medal?

- Those who have been awarded these prizes have in common.
- What do you think they have in common?

We are living in a miracle era, as you have the best tutors.

- Who are they?
- How do you use them?

Spaced Repetition

Memory fades quickly after learning.

- The brain removes unused information.
- Cramming builds short-term familiarity, not durable memory.
- Recognition feels strong (lying to us), but recall is weak (harsh reality).

Result:

> Fast learning → Fast forgetting

In other words, we may be wasting our time learning something we will soon forget and will never be able to use when we need it.

Spaced Repetition as the Solution?

Spaced repetition distributes review over time instead of concentrating it in one session.

Example:

- Day 1 → Learn
- Day 2 → Review
- Day 4 → Review
- Day 8 → Review
- Day 16 → Review

Each review happens just before forgetting, strengthening retention.

Discussion

- Many software tools, such as Anki, use spaced repetition to help you remember things.
- However, it is not the only way to remember things, and to some, it is not the best way to remember things.
- Research is one of the best ways to remember things, because it is not only about repetition, but also about adding more input to the topic that we want to remember repeatedly.

Red Car effect (Reframe your brain).

- Our brain is designed to forget; otherwise, we would go crazy. Do you remember the story of the Russian journalist who could not forget?

There are two main ways to teach your brain to remember:

1. (Spaced) Repetition: the more you repeat, the more you remember.
2. Use Red Car Effect: give your brain a goal.

Question: How many red cars did you see today?

You may see many red cars in a day.

But normally:

- You recognize them as an input, but you don't remember them as a valid input.
- You ignore them because they are not important to you, and they are not related to your goal.

Because there is no goal attached, your brain systematically filters them out to save energy.

The moment you ask your brain questions, you give it a goal (or a research question).

> "Normally, how many red cars do I see per day on average?"

Everything changes.

Suddenly:

- You notice them more.
- You remember how many you saw.
- You feel like they increased.

Likewise, when you ask a research question (as a part of ASE 485).

- Why functional programming solves the problem of asynchronous programming?
- I heard that JavaScript is based on functional programming. Is there a relationship that JavaScript is good at asynchronous programming?

Now, your brain wakes up when you hear about "functional programming" or "asynchronous programming", and you start to connect the dots between them, and you start to notice the relationship between them.

- Now, your brain accepts it as interesting and worthy of your energy.
- Your brain tries to find the answer to this question, and it tries to connect the dots between the knowledge and experience in your brain to find the answer.

Rubber Duck Debugging

- When you are debugging your code, you can explain your code to a rubber duck (or any inanimate object).
- This technique forces you to articulate your thought process, which can help you identify gaps in your understanding and find the solution to the problem.
- This is another form of "Red Car Effect" that can help you solve the problem effectively.

Remember

- Your brain cannot understand "negative" things.
  - When I say "Don't think about red cars", you are thinking about red cars, because your brain cannot understand "Don't".
  - So, when you ask a question, you need to ask a positive question, for example, "How many red cars do I see today?" instead of "Don't I see red cars today?"
- Again, we have a miracle tool that can answer any questions for you.

Discussion

- What is your research topic for this semester?
- What is the problem that you promised to solve this semester?
- Do you have a system to organize/catch your thoughts, notes, and research progress to solve the problem effectively?
- Why is discussing with others (or yourself, or LLMs) one of the best ways to solve the problem and to remember things?

Use Your Brain as the Research Tool

Always use your brain as a research tool, both in low-level and high-level problem-solving.

1. Find patterns (low-level problem solving)
2. Find wisdom from patterns (high-level problem solving)
3. Build a second brain (low-level problem solving)
4. Build a system (high-level problem solving)