Neuroscience and learning – repeat after me.

I was intrigued by a comment I read recently in Lucy Crehan's excellent book 'Cleverlands' where she is appraising educational achievement in key countries worldwide. Lucy observes that Chinese culture is influenced by the teaching of Confucius, a 6th century BC philosopher, who felt that the path to virtue included self-improvement through knowledge and that 'learning is a goal to be achieved by personal striving to perfect oneself'.

Hard work to improve one's knowledge is thereby viewed as a virtuous and moral activity and is celebrated. Many of the stories that Chinese children listen to are of characters who work hard, overcome challenges and achieve great things. In Western culture we are more likely to believe that intelligence is fixed; for example, you're either good at maths or you're not. In China the response is invariably that this can be dealt with through hard work (4)

One of the ways in which Chinese students work hard is through repeating learning. They experience a lot of practice, both in school and through homework. This consistent and expected repetition of learning steps leads to an intuitive feel for the subject and a deeper understanding of the subject content (4). Dragan Trninic suggests that practice does indeed make perfect as patterns then become evident and relevant to the student (13). Both authors are quick to point out that practice by itself is insufficient; having a guide to highlight inaccuracies and celebrate success is essential.

Knowing that China does rather well on the educational world stage – the 4 Chinese regions (Hong Kong, Taipei, Macao, BSJG) all sit in the top 10 in the PISA results (10) – I did wonder if this success in maths, science and reading was attributed to hard work and repetition or what the brain is doing in the meantime.

Is it down to brain power?

> "Learning is defined as the process by which new information is acquired. Memory is the process by which that info is retained and retrieved." (5)

I am becoming increasingly fond of my hippocampus. It plays an integral role in the consolidation of declarative memory and is one of two areas in my brain where neurogenesis or new synapse connections occur throughout my adult years (5).

So, what is going on in my head if I choose to repeat? I have to say, that whilst not a neuroscientist or even remotely near in my understanding of the complexity of brain chemistry, I got quite excited when I read Joana Gil-Mohapel's work on the hippocampus and learning. Ok, so the study was on rodents, but she explained things in a way that I felt I could grasp!

She highlighted that repeated activation of a neural synapse in the hippocampus releases various chemicals in the brain which, ultimately, if the repetition is maintained, results in genetic change and subsequent increase in the size of the synapse (6). You are effectively changing the anatomy of the brain as synaptic and axonal buttons grow with each learning episode. More transmitters and receptors are recruited at each synapse, strengthening the synapse and leading to a potential doubling in size (6). This process is called long term potentiation (LTP). You get a bigger cell which offers a stronger neural responses with increasingly limited exposure (5). Effectively this means you need less of a reminder each time to recall previous learning.

De Keyser develops this, describing further the declarative knowledge memories, "knowing that", which are induced in the hippocampus. These memories can be started with a single neural stimulation and each element of declarative knowledge is not blended with others but can be accessed independently. This is important.

> "Elements of declarative memory can be reactivated through many routes, and this flexibility permits the inferential use of memories in new retrieval situations." (2)

However, procedural knowledge, the "knowing how to", occurs in a different area, the basal ganglia, and this requires many days of stimulation before potentiation occurs. And, whilst it too consists of various elements, these blend permanently and cannot be activated independently, thereby rendering rehearsal less flexible.

I could read this on the lines of if I am wanting to learn a dance step, I can watch the moves and 'know that' different combinations will produce different outcomes. It won't take much of a reminder to recall this information either. However, dancing the steps myself, the "Know how to" is a very different ball game - excuse the mixed metaphor!

Skills acquisition theory (SAT) is underpinned by the notion that declarative understanding leads to procedural knowledge and then highly automated procedural knowledge. This is not due to the myth of declarative knowledge changing into a procedural version and moving from one area of the brain to another. I can't think my feet into an accurate rendition of particular moves. What SAT does suggest is that what we know, in theory, prompts us to engage with the 'how to' and to therefore practice.

Consider learning to ride a bike. It's an example of how thinking about riding has prompted us to get on the bicycle. But only physical practice has ensured success.

So, practice then?

How much I practice, and when, is also key in consolidating new learning. Do I practice, practice, practice, cramming the learning into a short as possible period of time? Or do I spread the practice out, providing space between each rehearsal? And how much space is the right amount?

Spreading the practice out, aka distributed learning, is more effective than massed, or cramming, learning approaches (3).

Distributed learning research involves a first learning event where new material is introduced. An interstudy interval or space is allowed between the second and (sometimes) third studies, where the material is revisited. A final space is then given, the retention interval, before the student is tested on the material that was introduced and reviewed.

The length of these spaces is key. Too long in either and learning is lost. Too short and we move into cramming mode where salient knowledge gained appears strong over the short term but weakens over the long. (12)

Work done in the 1960s and 1970s looked into these interval lengths.

> "This work was groundbreaking as it began to clarify the question, "What is the best way to distribute my studying?"
>
> (Answer: "Depends on when your test is.")" (3)

Overall, if your test is a while away then the study interval can be long. If the assessment is immediate then the interval, obviously, needs to be shorter. For example, 6th grade students studying foreign language vocabulary were tested at either a week or a month after the initial input. For those tested after a month, the optimal study interval was 10 days after the input. For those examined after a week, the optimal study interval was 1 day. The conclusion reached is that review units should be planned carefully in the light of when the actual test is. (7)

The second and third studies were considered further with researchers identifying that, when retrieval is effortful at these events, the "difficulty in re-accessing the information improves the likelihood of remembering that item on a final test" (3).

> “Such desirable difficulties...include varying the conditions of learning, rather than keeping them constant and predictable; interleaving instruction on separate topics, rather than grouping instruction by topic (called blocking); spacing, rather than massing, study sessions on a given topic; and using tests, rather than presentations, as study events” (1).

Bjork and Bjork suggest that creating these challenging recall events can lead to greater retention and optimise learning transfer even though it may slow the rate of apparent learning (1).

Correspondingly, how the student is feeling at the time, alongside the environment and mental cues all get encoded into the study event at the same time.

> “Varying conditions of practice—even varying the environmental setting in which study sessions take place—can enhance recall on a later test. For example, studying the same material in two different rooms rather than twice in the same room leads to increased recall of that material.” (3)

Varying too the task, rather than teaching specifically to the test, leads to greater learning gains.

> “A study of children’s learning provides a striking illustration of the benefits of varying conditions of practice. Eight-year-olds and 12-year-olds practiced throwing beanbags at a target on the floor with their vision occluded at the time of each

> throw. For each age group, half of the children did all their practicing throwing to a target at a fixed distance (for example, 3 feet for the 8-year-olds), while the other half threw to targets that were closer or farther away. After the learning sessions and a delay, all children were tested at the distance used in the fixed-practice condition for their age group (8)
>
> Common sense would suggest that the children who practiced at the tested distance would perform better than those who had never practiced at that distance, but the opposite was true for both age groups. The benefits of variation—perhaps learning something about adjusting the parameters of the motor program that corresponded to the throwing motion—outweighed any benefits of being tested at the practiced distance." (1)

This contextual variability theory suggests that spacing helps increase cue variability; the more cues we can draw from at the point of final test that are similar to those at the study sessions, then retrieval of the target learning will be easier. By ensuring an appropriate amount of time between the study sessions, these cues increase and thereby give the brain more to draw from when endeavouring to access the relevant learning. (11)

In summary, appropriately timed and spaced repetition offers the brain the best opportunity for LTP in both the hippocampus and the basal ganglia.

LTP can remodel existing neural connections and is responsible for new synapses and stronger synaptic connections (2). In other words, new and stronger memories.

These are the mechanics that underpin our ability to be reminded of previous memories and that these can then be amended by similar learning experiences.

We can learn things well if we are encouraged to recall existing knowledge in a manner that is deemed desirably difficult (1) and then repeat the learning in order to build on and consolidate it. Even just by visualising it in our heads can continue this consolidation (11). The intention overall is to pass the learning into that place of intuition referred to by the Chinese (4). This "knowingness" is down to repetition which is suggested is the fixative (9)

Theory into practice then?

With all of that in mind I set myself a task – to learn the Shim Sham. This was developed in the 1920s and consists of a particular sequence of individual jazz steps. These are performed as a line dance and can be found, with minor variations, on any jazz dance floor worldwide:

I attended a weekly dance class where the Shim Sham was the current learning focus with the added pressure of a test, i.e. having to perform it at a local festival in a few weeks. I don't find it easy mainly because there are a variety of steps to learn, and they come in a particular order. Brain study and Chinese example in front of me, I decided that I needed to rehearse – a lot!

We initially had 2 sessions at dance class where our teachers, Richard and Helen, demonstrated the moves and we copied. But, as I know from experience and the likely way the brain works, I needed to keep revisiting this otherwise I would forget. After the sessions, I then made the most of the distributed learning approach and practiced the steps for a few minutes each day in my kitchen. It was a tad frustrating at times but, to ensure variation, I added some challenging recall methods and mixed up the learning approach. I:

a) used a variety of YouTube videos where I followed expert dancers. The best ones are when the dancers are being filmed from behind as it is much easier to follow!

b) used the pause and repeat facility to practice and polish each step.

c) written down the order of the moves.

d) visualised each move and the sequence in my head.

e) tested myself - what can I remember before I restart the videos to continue the practice.

I made it to about 80% through and could follow without stumbling before the next class practice when I could get some feedback.

The test came in the form of the public performance a couple of weeks later and I danced error free on the day, which was such a relief! However, was that enough evidence to prove I had learned the dance skills?

> "Performance is what we can observe and measure during instruction or training. Learning—that is, the more or less permanent change in knowledge or

> understanding that is the target of instruction—is something we must try to infer, and current performance can be a highly unreliable index of whether learning has occurred. (1)

As a foot note therefore, pun intended, the idea is that, whilst I managed to perform the Shim Sham 3 years ago, I asked myself if the learning would still exist now? In theory, having practiced in the manner I did, had the learning become permanent as suggested? Having not danced since we went into lockdown in spring 2020, would I still be able to sequence the moves in 2022?

The answer is yes. Just about. I played the Shim Sham video above and managed to achieve about 60% success on a first run through. Which was greatly encouraging. I may have performed it in 2019 but the learning still exists, a little rusty, but the memories are still active and available.

Practice indeed makes perfect then?

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