Expertise and Fluency

In chapter seven I introduced the idea that procedures are important in learning (a) because when we learn something really well it becomes an automatic response (which is to say a procedural memory); (b) because much of what we actually want to learn in life involves physical procedural memories whether that is writing using a pen and paper or manipulating glassware in a lab; and (c) because - as the Cognitive Reflection Test shows - much of the time we do not actively choose how we are going to learn and solve problems (using System 2), but instead we allow ourselves to follow our instincts (System 1 - driven by procedural memories).

Despite the importance of procedural memories I spent the last two chapters outlining how we learn by forming long term semantic memories. In this chapter I will turn my attention back to the question of forming procedural memories.

Features of Expert Knowledge

One way of thinking about the goals of learning is to ask ourselves what it looks like when someone has really learned something very well. This question can be reframed as follows: how does expert knowledge differ from novice knowledge?

In looking at this question it is important to remember that 'experts' are not special types of people: we are all experts in some domains - the vast majority of us, for example, are experts in walking and speaking our native language. Because these skills are widespread, we tend not to question them and so it is hard to see what is distinctive to such expertise. It is only by looking at expertise which is rarer (expert chess playing, expert teaching, expert firefighting, expert physicists etc.) that a clearer image of what constitutes such expertise emerges. At the same time, we should not forget that, even if these studies refer to uncommon expertise, expertise is not in itself all that uncommon.

Early attempts to answer the "how does expert knowledge differ from novice knowledge?" question were made with studies of expert and novice chess players. The original hypothesis of these studies was that experts were more reflective and thorough than novices in that they thought more about moves and considered more options. Although it was clear that experts did reflect a lot and did consider a lot of possibilities, de Groot's early studies on the subject found that this was not all that different to what novices did.

Through a range of studies over the next decade, a number of features of expert knowledge began to emerge:

- Experts see patterns of information where novices see individual pieces of information. In one early study with chess pieces, Chase and Simon (1973) found that good chess players could remember the placement of more chess pieces on a board than could novices. Good players could do this best, however, only when the board showed a game in play. When the pieces were placed at random on the board, the good players' performance was not particularly better than that of novices. It appears that where novices see individual pieces on squares, good players see how pieces relate to each other ("the knight is attacking the bishop, which is protected by both the queen and the rook"). This allows them to remember more pieces since they remember a chunk of interacting pieces together rather than remembering each piece individually. Similar findings have been found in many other domains: electronic technicians see wiring diagrams in terms of chunks which perform functions, whereas novices see only a mass of wires, for example.

- Experts know a great deal and have the information organized meaningfully. It is probably obvious enough to say that experts know more than novices. At the same time, this is worth repeating since sometimes people interpret "deep approaches to learning" as meaning a focus on understanding *instead* of on retaining a lot of information. In the case of experts, it appears they do both: (a) they retain a lot of information, which (b) they organize in meaningful patterns. This can be seen in a number of ways: when asked to organize problems in physics, for example, experts tend to organize problems in terms of the principles which can be used to solve the problems, while novices tend to organize problems in terms of whether or not they look similar (Chi et al, 1982). When experts recall a piece of information, this tends to lead to a number of related pieces of information to be remembered at the same time - suggesting that different pieces of information are stored together as a chunk. Novices on the other hand tend to remember pieces of information one at a time, suggesting that the information is not stored together as a chunk. In the last chapter, I identified that elaboration and organization were key aspects of deep processing of information which was important for long-term storage of information in ways that allowed it to be recalled. The evidence from experts is that they have learned through such deep processing of information.

- Experts perceive relevant information and recall knowledge appropriate to the context. De Groot's early studies on chess expertise identified that it is not that experts think more thoroughly through moves than novices, it is simply that good moves come to mind quicker for experts (1965). Studies with firefighters have found similar patterns: when they arrive at a fire they make judgements as to how to act and usually their first judgement is a good one (Kahneman, 2011, 236) (as we will see below, this quality of expert judgements depends in part on the type of problem they are facing). Novices on the other hand tend to spend time working through a range of different options without a good solution presenting itself as more obvious than others. It is thought that part of what drives this ability in experts is that they have learned and applied their knowledge in a wider range of contexts and so their recall of memories is aided by contextual factors. That is, they perceive key features in a context quicker, and these in turn spark the relevant memory which is fluently recalled without having to be searched for.

As a result of these features, experts tend to be fluent in their retrieval of relevant information - that is, it tends to come to them quickly and automatically (system 1), without requiring much input from working memory and conscious control (system 2). This is not to suggest that experts never think about what they are doing. Indeed, in some cases, they think longer than novices. When faced with physics problems, for example, experts will often spend longer than novices examining the problem and its components in order to see what principles underpin the problem. Novices, on the other hand are more likely to look at the appearance of a problem and to intuitively try a solution they have previously used with problem that looks similar. So, it is not as simple as saying that experts use system 1 and novices use system 2. Experts and novices both use system 1 and system 2, but they use them in different contexts and for different purposes.

We have seen above (in relation to learning styles) that learning is often considered in terms of binary opposites (conceptual vs. applied; surface vs. deep and so on). What we can see from studies of expertise is that expertise typically means having *all* these types of learning in place (i.e., lots of information, which is organized in terms of meaning and concepts and which is applied in a wide range of contexts - surface and deep, conceptual and applied).

Expertise and Automaticity

If expertise involves the mobilization of system 1 automatic processes, how are these learned? Shell et al. (2010) suggest, firstly, that procedural knowledge does not look all that different in microstructural terms when compared to declarative knowledge. In other words, both are a chain of neurons which have built strong connections. Connections are built, they suggest, through activating different actions at the same time. So, for example, when you first learn to cycle, you focus on a range of different actions (ankle movements, knee movements, left and right leg movements, etc.) but by repeatedly completing these different actions at the same time they become connected in a 'chunk' or a chain which is the learned procedure.

Part of what makes procedures distinct from other types of memory is that they become automatic. Shell et al. suggest that this occurs through repetition. If something is thrown towards us, the reason why your body reacts and moves your hands to catch it without you having to think about it is because, over your life, this has happened a great number of times and the memory has been repeated so often it has become automatic. The reason why you do not have to search your memory to retrieve the information that the lump of glass and metal in front of you is a 'car' is because you have made the connection so many times and so now it comes to you automatically. Likewise, the reason why you probably still have to search your memory to find the names of the elements of the Five Factor Personality model (remember: O-C-E-A-N), is because you have not (yet) repeatedly made the connection often enough for it to become automatic.

Procedural memories are, like declarative memories, somewhat idiosyncratic. This can be seen by taking a simple piece of mental addition. Add the following numbers: 25+26+17+33. When you have done this, describe to yourself how you solved this problem.

When faced with this problem there are multiple solutions:

- One could add all the units (5+6+7+3=11) then add this to the tens (11 is then added to 20+20+10+30)
- One could recognize meaningful numbers that are easily added (25+25+1) + (10+[7+33])
- One could add each number in order (25+26=51), (51+17=68), (68+33=101)
- and so on…

When solving the problem, did you consider multiple solutions and chose the one you thought best or did the solution just 'come to you'? If it 'just came to you' then this selection of how to solve the problem is an automatic procedure which you have developed through repeated exposure to problems such as this. The person next to you could take an entirely different route to come to the solution. It is in this sense that procedures are idiosyncratic. It is likely that something similar happens with other learning activities. When reading a text, for example there are many different reading strategies that could be used:

- using the title and subheadings to predict what it will say before starting
- summarising content after each paragraph
- stopping to clarify meaning of each unfamiliar word
- continuing to read when things are unfamiliar in the expectation that it will become clearer as you continue
- and so on...

Two people may well read the same text and may even gain similar information from it, but their procedure for reading it may well be very different. However, these differences remain hidden because they have become proceduralised, which is to say they have become hard for us to recognize and to describe.

Sub-optimal procedures

In the last section I highlighted that we may have different procedures from each other when it comes to activities like learning from reading or problem- solving. It should also be noted that not all successful procedures are equal: some procedures will be encoded because they are successful most of the time without being successful all of the time (remember this is central to the definition of a heuristic: a problem-solving procedure which has the benefit of being relatively quick and easy but the cost of not working all the time). Other procedures may have a higher chance of being successful, but because our procedure comes to us automatically, we tend not to have the chance to choose the optimal procedure.

We can see this with sporting skill where even very good procedures may be open to being improved. Golf, for example, is full of examples of players who have had to re-learn or re-develop their swing in order to improve performance as they aim to hit the ball harder, or with more accuracy, or with less stress and damage to their joints. Likewise in learning, we may well have developed problem-solving procedures which are good, but are still sub-optimal.

Another way of looking at this question is to consider the intuitive judgements of experts. Kahneman notes that, while many experts make good intuitive judgements, other experts' intuitive judgements are more problematic. His starting point is a series of studies which showed that when experts in a range of domains (clinical psychologists, trained counsellors, doctors, economists, wine experts, football commentators, etc.) studied cases and made predictions, these predictions tended to be less accurate than predictions which were based on simple statistical procedures: "The important conclusion from this research", he concludes, "is that an algorithm that is constructed on the back of an envelope is … certainly good enough to outdo expert judgement" (2011: 226).

Before you start looking for an algorithm to replace the decision making of firefighters, it is worth noting that experts are not universally bad at all judgements, just at particular types of judgements. When faced with judgements which will have immediately evident results, experts typically make good judgements. However, on tasks which require long-term predictions they are typically less successful. The reason for this, he argues, is because some experts typically get little feedback on the validity of their long-term judgements. Firefighters get to see pretty quickly if their prediction for how the fire would develop was accurate. Psychotherapists, get to see the short-term response of patients to particular lines of questioning. However they do not get to see the long-term effects of these questions or discussions on patients. The same is true for many other specialties. He notes:

> Among medical specialties, anesthesiologists benefit from good feedback because the effects of their actions are likely to be quickly evident. In contrast, radiologists obtain little information about the accuracy of the diagnoses they make and about the pathology they fail to detect. Anesthesiologists are therefore in a better position to develop intuitive skills. If an anesthesiologist says, "I have a feeling something is wrong", everyone in the operating room should be prepared for an emergency (Kahneman, 2011: 242)

Deliberate practice

Developing expertise takes repetition - lots of repetition. But how much repetition? In the 1990s the figure of 10,000 hours was proposed by the psychologist K. Anders Ericsson (1993) and this has now entered into popular consciousness and popular debate, through books like Malcom Gladwell's *The Outliers* (2008).

Ericsson's (1993) finding was that in the case of musicians in a musical academy (violinists and pianists):

- Best musicians have accumulated an average of 10,000 hours practice by the age of 20
- Good musicians have accumulated an average of about 7,500 hours practice by the same age
- Average musicians have normally spent about 5,000 hours practicing.

The figure of 10,000 hours is generally accepted as a good "rough estimate" of what is required to develop expertise. It corresponds to about 3 hours practice per day for ten years. However, time spent on task was not enough in itself. Ericsson identified that what was required was a particular type of practice, which he called Deliberate Practice. This means: highly structured activities that are created specifically to improve performance in a domain through immediate feedback, that require a high level of concentration, and that are not inherently enjoyable (Hambrick et al., 2013). Deliberate practice does not include work (performing music for others), nor does it include play (enjoying playing without a clear learning goal).

Ericsson's 10,000 hours finding is often misunderstood. Some have argued that 10,000 hours of practice is necessary in order to become an expert, but this is not what the data says; 10,000 hours is the average for expert performance. In a study by Gobet & Campetelli (2007) on chess players it was found that some chess masters have as little as 2,500 hours of practice (about 12% of them).

Is 10,000 hours enough? Will anyone who spends 10,000 hours practicing become an expert? Ericsson (2007) says that deliberate practice is enough and that - except in areas that require height or body size (like sports) - the only major difference between elite performers and others is that elite performers have extended and intense practice activities. (You should note that this fits with what I said above about expertise in walking and in talking your native language – everyone has had lots of practice in those domains and everyone has become an expert).
Others have tried to answer the same question in a slightly different way. Hambrick et al. (2013) have recently reviewed a number of different studies of expertise in order to see what percentage of the variance in performance is explained by deliberate practice. They found that:

- in chess, the average correlation between deliberate practice and performance was =.57
- in music, the average correlation between deliberate practice and performance was =.52.

In other words, Deliberate Practice accounts for a minority of the variance in performance (about 30%), leaving the remaining 70% of variance unexplained. The findings of Ericsson and Hambrick are not as contradictory as they may seem. We can all become experts in certain performance areas by putting in a great deal of practice, aimed at improving our performance and with the assistance of immediate feedback. At the same time, within the category of experts, some still perform better than others. The same is true in the category of 'good' and 'average' performers. Our 'level' of performance can be affected by things other than the amount we have practiced (how early we start to learn, our intelligence, and perhaps innate 'talent' [Hambrick et al., 2013]).

Deliberate practice and learning

One of the key themes of this chapter is that in addition to learning procedures, we also learn though procedural memories which intuitively guide our judgements when we are seeking to learning something. It is clear that by the time a person has become an adult they have spent many thousands of hours engaged in learning, but does this experience qualify to be regarded as deliberate practice? In particular, we might ask, do we get immediate feedback which tells us how well we have performed the learning task in question?

It may be that under some circumstances we do get feedback. Many textbooks contain questions at the end of each section or chapter which allow the reader to evaluate their own performance and to see if he or she has really understood and begun to learn the chapter's content. Just because we get feedback on how well we have learned does not mean that we will necessarily use it to adjust our learning (in the way in which a violinist who gets feedback on their playing will adjust their playing), but at least the feedback makes this possible. In many learning contexts, however, we do not get any feedback. In most lectures, for example, the students will leave at the end without having had a chance to evaluate if their learning approach worked for them. Lectures, and similar types of learning experience which do not provide immediate feedback, are exactly the type of circumstance which is likely to give rise to problematic procedures and sub-optimal intuitive judgements.

Conclusion

We are all experts in some domains. Our expertise means we know a lot about a topic, we have organized the knowledge and elaborately encoded it so that we remember it easily. We have rehearsed the memories many times so that they come back to us fluently. We have applied the knowledge is a wide variety of contexts so that we remember it appropriately in a diversity of contexts. It is probable that it has taken us sometime like 10,000 hours to develop this expertise.

The 10,000 hours has not simply been spent playing or working, but engaged in challenging activities which are designed to stretch and develop our skills. We have got feedback on our performance which allowed us to develop our performance. Where experts get such immediate feedback their judgements tend to be appropriate. However, where feedback is delayed or not available, experts still develop the ability to make fluid judgements, however the judgements themselves can often be sub/optimal. Because these judgements become automatic, they become very difficult to un-learn and to change.

Learning is an area in which any adult has had more than 10,000 hours of practice. Judgements about how to learn (how to read a text, how to solve a problem, etc.) may well come to us automatically. However, if we have had little immediate feedback on how well those procedures have worked for us, or if we have typically not used that feedback to re-think our learning practices, then it may be that some of our learning procedures are sub-optimal.