speak on the screen, there would be a sudden disconnect. The voices would very obviously not be coming from where the lips were seen to move on the screen. Then, after a few seconds, everything would be OK again, as the ventriloquism effect kicked in and the viewer's brain bound the voice with the relevant lips. My undergraduate project involved trying to capture this experience in the lab, with two televisions and simply switching the sounds coming out of the two monitors and seeing what happened.

What is the best advice you've been given? I think this would have to be the sage and strategic advice from Jon Driver to very explicitly make the link between the experimental psychology research that we were conducting in the lab and the latest insights emerging from the then nascent field of cognitive neuroscience. That, or the advice from someone to always pitch your explanations, for example when you are being interviewed, as if you were talking to an intelligent teenager (with a general interest but little background knowledge) in the pub. That is always who I have in mind when talking to the media these days.

What is your greatest research ambition? Well, for the moment, that would have to be to get to the bottom of 'the correspondences', those surprising matches that we all make between pitch and colour, shapes and tastes, scents and textures. Where do they come from and why do they exist? How many different explanations do we need and how can we use them to create immersive and engaging multisensory experiences in a variety of contexts. Next year, I hope to see the book I am writing with the philosopher Ophelia Deroy coming out on this theme — though for the moment we are spending all our time trying to distinguish this ubiquitous phenomenon from the much rarer and idiosyncratic phenomenon of synaesthesia.

On the one hand, the correspondences are so simple, easy to demonstrate and document, but on the other I think they raise some really profound questions about the nature of our multisensory experience.

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Quick guide

Expertise

K. Anders Ericsson

What is expertise? The word 'expert' is derived from the same root as experience and experiment, which refers to efforts to learn from experience. When someone has gained special skills or knowledge representing mastery of a particular subject through experience and instruction, we call this person an expert. As experts are often able to perform well beyond the level that less skilled people ordinarily attain or even think they could ever attain, experts have been viewed as mysterious and are sometimes revered, much like those considered to be geniuses.

The modern scientific study of experts and their expertise can be linked to the emergence of programmable computers in the 1950s. Herbert Simon, winner of the Nobel Prize in Economics, proposed that it was possible to understand the basis of outstanding abilities of experts and simulate their thought processes with computer programs. The demonstration that relatively simple computer programs can perform intellectually challenging tasks, such as solving complex integration problems and finding solutions to difficult puzzles, made researchers reconsider our ability to understand the performance of experts. If we could describe in detail how some individuals develop into experts during an extended period of experience in a given domain of skill then such findings might provide thrilling insights into the processes that can improve performance.

What exciting discoveries led to the recent interest in expertise? In the early 1960s Herbert Simon co-authored a paper (Simon and Simon, 1962) that argued that grandmasters of chess were typically viewed as "intellectual prodigies, who perform feats of memory and discovery unachievable by mere mortals" (p. 425). More specifically, "[G]grandmasters frequently "see" decisive, winning moves whose benefits are not obvious to weaker players even after the moves have been pointed out to them. A number of chess masters can play many games simultaneously without sight of play." (p. 425). During World War II Adriaan de Groot arranged to have world-class chess players think aloud (give verbal expression to their concurrent thoughts) while they searched for the best move for a position taken from a game among chess masters. He discovered that the players systematically generated and then evaluated alternative sequences of chess moves, rather than relying on their amazing intelligence and superb intuition. In the early 1970s Bill Chase and Herbert Simon found that chess masters could virtually perfectly reproduce a briefly presented chess position with over 20 pieces, whereas a beginning chess player could only recall around four pieces. Most importantly, when chess boards with the same chess pieces randomly rearranged were presented then the elite chess players' recall was reduced virtually to the level of the beginners' and they could only remember 4–6 pieces. The vastly superior memory abilities of the elite chess masters were restricted to meaningful chess positions. These findings suggest that the superior performance of experts must be acquired by active participation in the domain. In fact, Simon and Chase found that a minimum of ten years of active chess study was required before players were able to win consistently at international competitions. Most importantly, Simon and Chase proposed that similar factors influenced the acquisition of expertise in other domains, such as sport, language and science.

In the 1970s researchers started to elicit experts' knowledge in order to make it available for the acceleration of the acquisition of expertise for beginners and less accomplished individuals. Similarly, computer scientists interviewed experts to extract their general decision rules in order to build computer programs (expert systems), which would be able to generate decisions, similar to the experts. These interviews of experts revealed that experts do not primarily rely on general rules and most of their knowledge was difficult to retrieve because it was situation specific. When the experts were presented with specific situations and actual cases their ability to report their thoughts increased, but surprisingly the accuracy of some of the experts' judgments were often not superior to their less accomplished peers. Thus the questions become: 'How have experts been traditionally identified?' and 'How can we identify experts, who are worthy of time-consuming study?' In most domains of expertise, unlike chess and sports, it is not obvious who the experts are. For example, how do we find the best teachers, doctors, coaches, or managers? A typical method was to seek out the best teachers and the best doctors by having their colleagues or supervisors make nominations. Based on the chess research and the '10-year rule' many researchers defined anyone with over 10 years of professional experience as an expert. Others defined experts by their extended academic training and their associated advanced degrees, such as a masters or Ph.D. in a field.

Should we study 'experts' even if their performance is not better than less experienced individuals? When individuals begin working in a domain of expertise they have to rely on the knowledge that they have acquired from their prior training and apply learned rules to decide what to do. With increasing experience the decision-making becomes less effortful and eventually the decisions are made intuitively. Highly experienced experts seem to be able to make complex decisions and perform difficult procedures as easily as average people drive their car or type on a computer keyboard. When researchers have set out to measure the performance of experts using objective criteria, such as having doctors and nurses make predictions about patient outcomes or having wine experts and regular wine drinkers describe wines of unknown origin (blind tasting), the experienced experts' decisions or judgments were often no better than those of less experienced individuals. In domain after domain objective testing of experts' performance did not differ from non-experts. In these domains individuals do not receive accurate and immediate feedback on their professional judgments. For example, a doctor's incorrect medical diagnosis of a patient may only be uncovered months or years later. At the time experts typically make their judgments the correct answer is not known, so no feedback is available. For example, when Tetlock had stock brokers and other professional forecasters along with college students make predictions for future events the experts' accuracy determined several months later did not surpass that of the college students. These findings led some researchers to change their focus away from the study of experts identified with social criteria, to the study of experts with reproducibly superior performance on representative tasks. It is possible to measure the performance of individuals on tasks with known correct answers. For example, a medical expert can be asked to diagnose X-rays or electrocardiograms (EKGs) of past patients, for whom the correct diagnosis was eventually determined. Similarly, it is possible to present chess players with chess positions and ask them to select the best move — which is determined by chess programs that today are rated to be vastly superior to the human world champion.

Figure 1. Practice makes perfect.
While it is generally true that arduous practice is necessary to attain a high level of skill, the study of experts like professional musicians indicates that continued improvement requires constant feedback to isolate weaknesses and refine strengths. (Photo: Wikipedia.)

How do individuals with superior performance differ? Across domains, expert performers demonstrate a superior ability to generate better actions using acquired mental representations and skills for the generation, anticipation and monitoring of their actions. Expert performers show specific advantages in their superiority over less skilled peers. For example, athletes do not have inherently faster reaction times and do not detect simple stimuli, like lights or sounds, faster than non-athletes, but they have developed perceptual abilities to detect cues that anticipate where a baseball pitch will go, or where a karate attack is aimed. Similarly, memory superiority, like that described for chess players, is limited to stimuli in the domain. Athletes, such as successful quarterbacks, do not necessarily score higher on tests of intelligence (IQ) than the general population. Although scientists and musicians as groups have higher IQs than the average population (likely due, at least in part, to admission standards of higher education), higher IQ scores are not associated with higher performance among skilled performers in their respective domains.

How do expert performers attain their superior performance? In many domains of expertise longer experience does not by itself lead to higher levels of performance — simply doing the same thing for long periods does not increase the quality of performance, it merely makes it less effortful and automatic. To find the type of learning that has reliably produced exceptionally high performance for centuries, Ericsson, Krampe, and Tesch-Römer turned to the domain of music (Figure 1). They found that the key to improvement is ‘deliberate practice’, namely engaging in practice activities assigned by a teacher with a clear, specific goal of improvement and where the practice activities provide immediate feedback and opportunities for repetitions to attain gradual improvements. They found that professional violinists and the best students at an international music academy in Berlin had spent an average of 10,000 hours of solitary deliberate practice by age 20, which was around 2,500 and 5,000 hours more than two groups of less accomplished violinists at the same academy. This finding rejected the popular view that more ‘gifted’ musicians needed less practice.

In the last 20 years the search for deliberate practice activities has been extended to numerous domains, such as medicine, nursing, ballet, sports, SCRABBLE, scientific research, psychotherapy and teaching. Current research is now finding relations between the amount of engagement in particular intensive practice activities and desired beneficial changes in the brain and other parts of the body. Future research aims to develop a detailed understanding of how designed practice activities can build complex physiological adaptations and mental representations that are associated with increased superior performance among professionals and increased achievement among amateurs.

Where can I find out more?

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Primer

Selective attention in birds

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The natural world constantly inundates our senses with an abundance of information. Selective attention enables us to navigate this abundance intelligently by selecting the information that is most relevant, at each moment in time, for differential processing and decision-making. The attributes of attention have been studied in humans for over a century. In his influential 19th century treatise, *The Principles of Psychology*, philosopher and psychologist William James defined attention as: “… the taking possession by the mind, in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought … It implies withdrawal from some things in order to deal effectively with others.” (James, 1890). James’ definition elegantly captures two key hallmarks of attention: the enhanced processing of task-relevant information (target information) and the suppression of task-irrelevant information (distracting information).

Over the past decades, behavioral scientists have developed sophisticated psychophysical tasks that quantify these hallmarks of attention. One popular task involves cueing a subject to attend to a particular location, and comparing her ability to detect or discriminate stimuli at the cued location (‘targets’) versus stimuli at other, uncued locations. The consistent observation across many studies is that spatial cueing increases perceptual accuracy (*d’*, a performance measure based on signal detection theory) in detecting or discriminating targets and decreases the reaction time to respond to targets at the cued location versus at other, uncued locations. Consequently, these two metrics (increased accuracy and decreased reaction time) have become recognized as the quantitative signatures of attention in humans.

In this Primer we shall consider the evidence for selective attention in birds, and outline what we know of the underlying neural mechanisms and behavioral advantages of such selective attention.

Behavioral evidence for selective attention

Given that selective attention serves the basic function of enabling animals to behave intelligently in a complex, unpredictable world, it is likely that this capacity appeared early in evolution. It has been well documented that our close relatives, old world monkeys such as macaques (*Macacca mulatta*), have this capacity. How about our more distant relatives? Do birds (class *Aves*), for example, which diverged from us more than 250 million years ago, also have selective attention?

Birds certainly exhibit a variety of behaviors that apparently require selective attention. For example, birds of prey, such as falcons (*Falconiformes*), eagles (*Accipitriformes*) and owls (*Strigiformes*), display impressive abilities to locate and track well-camouflaged prey across large distances, and capture it ‘on-the-wing’ with remarkable precision in both space and time. Alternatively, birds that forage on the ground, such as chickens (*Galliformes*) and pigeons (*Columbiformes*), as well as tree-foragers, such as songbirds (*Passeriformes*), exhibit similarly remarkable feats of selective spatiotemporal stimulus processing, as they repeatedly make rapid, accurate decisions about the next target for pecking while searching highly cluttered environments for food. In both cases, birds must select one out of many potential targets, analyze the target’s identity and location, and ignore irrelevant, distracting stimuli.

Surprisingly, laboratory studies that have investigated the capacity of birds for selective attention have produced controversial or inconclusive results. A large body of early studies investigated the capacity of birds to attend to stimulus features (feature-based attention). For example, in highly cited work (Reynolds, 1961), pigeons