The Intuitive Practitioner:
Cognitive Aspects on the Development of Expertise

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Abstract
In recent years the interest in expertise and proficiency has been raising, in educational research, knowledge management as well as in cognitive science. The expert's know how or procedural knowledge is often hidden even for him or her self, it is tacit. ”*We can know more than we can tell*”.(Polanyi, 1967) This paper is an "Integrative research review", trying to show new aspects of experience-based learning and the development of expertise. Several new results from brain imaging studies and from neuropsychology gives reason to believe that experts utilize nondeclarative, implicit memories to perform better. These results delivers new ways of understanding how experts perceive, assess, decide and take action.

Keywords: Implicit learning, Situated knowledge, Pattern recognition, Tacit knowledge, Intuition.

1 Introduction

Patricia Benner who published the first study using the Dreyfus model of development of expertis adresses an expert nurse in the following way: "*If you take a moment to evaluate your practice, you'll see that you can look at your patients and notice the smallest changes in them. When something is wrong, you can almost feel it, even if it doesn't register on a monitor. You observed subtleties-a slight variation in breathing pattern or an alteration in color. From past clinical experiences, you know when there's about to be a major change in a patient's status, and combining experience with scientific knowledge, you instinctively prepare for treating that challenge. You are an expert nurse. Your responses are shaped by a watchful reading of the patient without recourse to conscious deliberation. Your performance is fluid, almost seamless. When you recall an event, you focus on informed action, rather than organization, priority setting, and task completion*".(Benner, 1997)

In recent years the interest in expertise and proficiency has been raising, in educational research, knowledge management as well as in cognitive science. John Stevenson defines expertise as the ability to do something well; "*Better than others just starting out on the undertaking*" (Stevenson, 2003), He proposes several interesting research questions; What do we mean by doing something well? What enables an individual to do something well? Why does this capacity improve with practice? Is this capacity confined to a specific field, or is it general? Can the capacity be learned, and how? Where is it located?

The quest of eliciting knowledge from experts has eluded science since the beginning of the development of artificial intelligence in the 1960s'. The database of an Expert System has to be loaded with knowledge from human experts and these experts seems unwilling or incapable to tell about their rules and methods. When we are using standard interview techniques we are probing the conscious, rational and logic mind of the interviewee. The informant may want to please us and tell us what is appropriate, logic and sound. Our data will be full of general rules and standard procedures and not the individuals' own subjective way of coping with problems. The experts "know how" is hidden even for him or her self, it is tacit. ”*We know more than we can tell*”.(Polanyi, 1967) This tacit knowledge is apprehended in an implicit way often outside our own awareness. It is often used automatically and is therefore difficult to elicit by introspection.(Nisbett & Wilson, 1977) In modern psychology several Dual or Multiple Cognitive Systems theories have been designed and they have given us new ways of understanding tacit knowledge, expertise, intuition, insight and automation. (Cronin, 2004; Epstein, Lipson, Holstein, & Huh, 1992; Ericsson & Charness, 1997; Lieberman, 2000; Nightingale, 1998; Arthur S. Reber, 1989; Sloman, 1996; Sun, Slusarz, & Terry, 2005) The purpose of this paper is to shed some light on experts and expertise using results from different domains of Cognitive Science and discuss the implications for research and educational design.

2 Method

Cognitive science consists of many different domains of research; psychology, neurophysiology, neuropsychology, neuromedicine and others. Modern science is drilling deep holes to find new knowledge and the adapted method of specialisation and reduction has made its different domains separated from each other. This paper is an "Integrative research review", trying to find and show new aspects of experience-based learning and the development of expertise. "*Integrative reviews summarize past research by drawing overall conclusions from many separate studies that are believed to present the state of knowledge concerning the relation(s) of interest and to highlight important issues that research has left unsolved. From the reader's viewpoint, an integrative research review is intended to replace those earlier papers that have been lost from sight behind the research front and to direct future research so that it yields a maximum amount of new information*."(Backman, 1998; Cooper, 1984; Light & Pillemer, 1984) Its reliability and validity can only be assessed by the extent to which the devised model can "explain" the phenomena it is addressing.

The complexity of the human brain makes it essential to use appropriate tools in the design of the model. Modern technology, dealing with complex systems, has developed intellectual tools, a systems approach, for this purpose.(L. Björklund & Klasander, 2004) The first cognitive constraint to address is our brain's limited resource of working memory, in which all conscious cognitive processing occurs. The working memory can handle only a very limited number, possibly no more than two or three interacting elements. (Paas, 2003) Therefore the complex has to be described in an appropriate scale of detail with just a small number of separate units. A second aspect of a systems approach is the importance of functional descriptions.(Lars Björklund, 2006) Functional modelling provides an abstract, yet direct, method for understanding and representing an overall product or artifacts function." (Hirtz, 2002) In Technology a difference is made between the structure and the function of an artifact and this is also recognized in Science, especially in the Biosciences.(Hmelo-Silver, 2004)

Three system levels are identified and described in this paper;

1. Abilities and behavior of experts as described in studies in different domains of practice.
2. An intermediate psychological level where the individual behavior of novices and experts are studied and described using controlled experimental methods.
3. A neurophysiologic level where brain-structures and their corresponding functions are studied.

The first level has been studied for a century, the intermediate level for half a century and the lowest level is a contemporary highly evolving area of research. The author is trying to find causal connections between these levels of descriptions to enhance our understanding of the development of expertise and endorse directions for future research.

3 Results and synthesis

3.1 Experts and expertise

The nature of expertise has been studied extensively in the last 100 years, either by the inspection of the truly exceptional individuals chosen by their well established and recognized discoveries, works, results and innovations or by studying relative expertise and the development of higher level of abilities and skills. (Chi, 2006) The earliest literature was focusing on exceptional individuals; composers, chess players, athletes, writers, scientists, innovators and others and was trying to find intrinsic causes and explanations to the outstanding expertise of an individual. Co-variation with talent, genetics and general IQ was searched for but was found very weak. A common result of these studies was that the expert had practised more and had acquired more knowledge in a specific domain and that this knowledge was structured, organized and better represented.(Chi, 2006) Contemporary research takes a more relative view of expertise, studying what differentiates an expert from a novice in a specific domain of practise. The level of expertise is not absolutely defined but viewed in relations to other individuals on a lower level of proficiency. The causal reason for expertise used to be the idea of a higher, faster, more abstract general thinking ability. Today this view is changing; "*Thinking at its most effective depends on specific, context-bound skills and units of knowledge that have little application to other domains. To the extent that transfer does take place, it is highly specific and must be cued, primed and guided; it seldom occurs spontaneously. The case for generalizable, context-independent skills and strategies that can be trained in one context and transferred to other domains has proven to be more a matter of wishful thinking than hard empirical evidence*".(Perkins & Salomon, 1989)

An interesting strand of research emanates from Herbert and Stuart Dreyfus and their description of human abilities and the development from Novice to Expert in five stages.(H. L. Dreyfus & Dreyfus, 1986) The behaviour and abilities of the individual are according to their model developed during deliberate practice, caused primarily by two factors; an influx of contextual and situational data and a personal responsibility for the outcome of decisions and actions. The rule-following novice will in time be more contextual aware and use more experienced-based intuitive knowledge. Their model have been used in many areas of expert research; teaching,(Berliner, 1986) nursing, (Benner, 1984), managing (Stefl, 2003) and several others.

Traditional research on expertise and the users of the Dreyfus model have defined their stages of proficiency in different ways and care must be taken not to mix them. Initially the following descriptions of different levels of expertise where recognised: Naïve, Novice, Initiate, Apprentice, Journeyman, Expert and Master.(Hoffman, 1998) The Dreyfus brothers particularized the following stages of development: Novice, Advanced beginner, Competent, Proficient and in the final stage the intuitive Expert.

3.2 Psychological studies of unconscious, implicit learning

Psychologists have been performing a multitude of experiments during the last part of the 20th century focusing on memory and learning-processes but models of human reasoning and behaviour are even older. Ryle distinguished between knowing how and knowing that.(Ryle, 1949) Bruner (1969) contrasted memory without record and memory with record. In the 1970s a similar distinction was discussed in the artificial intelligence literature between procedural and declarative knowledge. The study of implicit memory emerged from the decade of the 1980s at the forefront of memory research.(Schacter, 1992) Implicit memory is an unintentional nonconscious form of retention that can be contrasted with explicit memory, which involves conscious recollection of previous experiences. Brain damaged amnesic patients with severe impairments of explicit memory can exhibit intact implicit memory, a fact has been recognised by practising doctors for a long time.(Damasio, 1996). In experimental psychology several different models for learning and behaviour have been proposed. Reber used the concept of implicit learning to be able to explain unconscious learning of abstract grammar rules.(A.S. Reber, 1967) The idea of a dual cognitive system grew out of a multitude of experimental results during the last decades of the 20th century. Logan proposed a model of an implicit memory based on pattern recognition, the "instance theory". (Logan, 1988, 2002) Several similar models using dissociation between explicit and implicit memories have been proposed but the task of modelling the black box of the brain has been hard using only external tools. Implicit learning is now seen as non-episodic learning of complex information in an incidental manner, without awareness of what has been learned. It associates environmental stimuli that are relevant for behaviour.(Dienes & Fahey, 1998; Frensch & Runger, 2003; Seger, 1994)

3.3 Structural level: Neurophysiology

New brain imaging tools, functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), made the black box of the brain transparent. It is now widely accepted that many brain systems are capable of learning and storing information. Some of these function explicitly and give rise to conscious declarable memories, while others function implicitly and store memories that are accessed and used automatically and unconsciously. Many brain-systems are using memory and its underlying neuronal plasticity to allow them to adjust and perform their function (emotional control, sensory processing, motor regulation, etc.) more effectively.(Phelps & LeDoux, 2005) Contemporary models of the brain uses a hierarchy of several memory systems, divided into Declarative and Nondeclarative memory systems, see Figure 1.

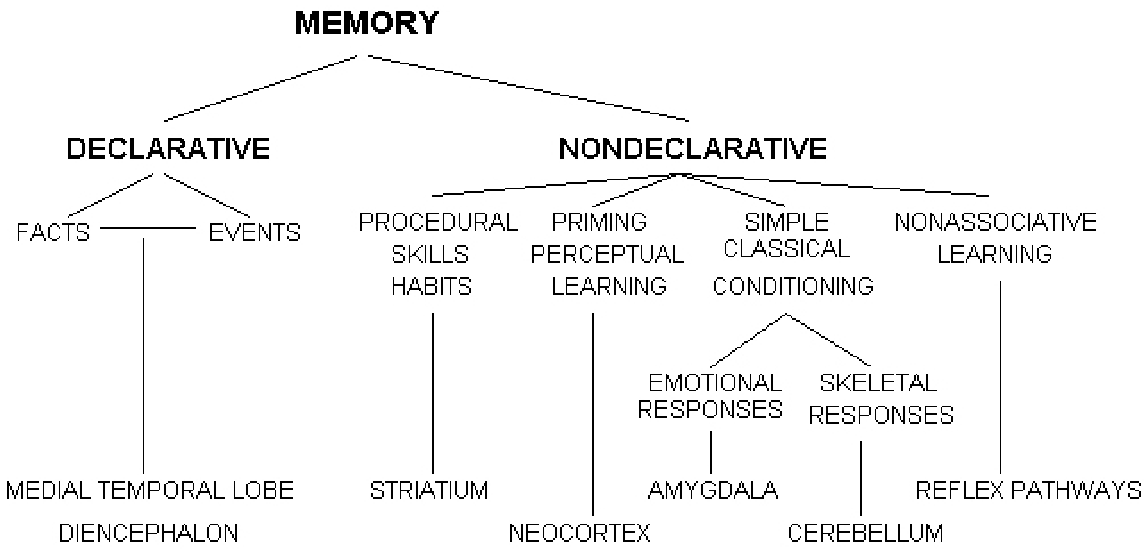

Figure 1 a taxonomy of long-term memory system.(Squire, 2004)

The memory systems of the brain operate in parallel to support behaviour, sometimes competitive, sometimes supportive. The various memory systems can be distinguished in terms of the different kinds of information they process and the principles by which they operate. In the case of declarative memory, an important principle is the ability to detect and encode what is unique about a single event, which by definition occurs at a particular time and place. In the case of nondeclarative memory, an important principle is the ability to gradually extract the common elements from a series of separate events.(Squire, 2004) The hippocampus is crucial for conscious, explicit memory(Degonda et al., 2005) and components in the striatum/ caudoputamen and amygdala are dedicated to the processing of reward, reward contingencies, or positive affective states. For example, dopaminergic transmission in the caudoputamen, which is implicated in a range of positive affective and reward processes, may play a role in safety conditioning.(Rogan, Leon, Perez, & Kandel, 2005) The caudate nucleus supports incremental learning of stimulus-response associations, or more specifically, the acquisition of place-appropriate responses leading to habitual. In contrast, the hippocampus is central to the rapid acquisition of declarative knowledge about the environment, generating a so-called cognitive map.(Voermans et al., 2004) Studies have found a series of subcortical visual structures that plausibly comprise a subcortical pathway terminating in the amygdala. This pathway, proceeding from the retina to the superior colliculus to posterior nuclei of the thalamus and on to the amygdala, bypasses detailed cortical processing and is thought to provide the amygdala with lower-resolution but more rapidly processed visual input (LeDoux, 1996). Some accounts emphasize the bias of this system for stimuli that are informative about potential dangers.(Pasley, Mayes, & Schultz, 2004) The basolateral amygdala modulates the cognitive and habit memory processes mediated by the hippocampus and caudate nucleus, respectively and may therefore “amplify” cognitive processes and direct attention to matched patterns. it has the capacity to process higher-order knowledge.

3.4 Synthesis and linkage

3.4.1 Automation and capability for dual tasks.

Experts often develop automaticity for the repetitive operations that are needed to accomplish their goals. They show high accuracy in reaching appropriate solutions, even under time constraint. (Berliner, 1994; Chi, 2006; de Groot, 1946; Groot, 1965; Sternberg, 1998)

In psychology there are several studies of automation and dual task capability. In a study of golf experts the authors find that “*expertise leads to proceduralized control that does not require constant attention. Resources are free to devote to secondary task demands*”.(Beilock, Wierenga, & Carr, 2002; Swan, Otani, Loubert, Sheffert, & Dunbar, 2004)

A neurophysiologic study in wayfinding connects specific brain structures to this phenomena: “*The first, place learning, is dependent on the hippocampus (explicit memory) and permits the formation of a cognitive map that is flexible enough to facilitate navigation via a novel route. The second, response learning, is dependent on the caudate nucleus and supports an action based representation that is inflexible (only supporting navigation via the same well-learned route) but which may have the advantage of mediating fast, automatic responses*”.(Hartley, Maguire, Spiers, & Burgess, 2003)

3.4.2 Contextual, situated knowledge and pattern recognition.

Expertise is specific to a domain, developed over hundreds and thousands of hours. Experts recognize meaningful patterns faster than novices. They impose meaning on ambiguous stimuli and make substantially more inferences from and assumptions about the information presented to them than do novices. Their inferences, assumptions, and predictions allow them, like hockey pro Gretsky, to "*go where the puck is going to be*." Experts can detect and see patterns and features that novices cannot see. (Benner, 1984; Berliner, 1994; Cellier , Eyrolle, & Mariné, 1997; Chi, 2006; S. E. Dreyfus, 2004; Sternberg, 1998)

Implicit learning and memory has been linked to an ability to detect fast subliminal events but also to recognize complicated patterns and sequences otherwise undetectable from reportable declarative memory. Transfer performance is linked to the degree of similarity of the context. (Chen, 1995)

Initially hippocampal learning, rules, are used to control action but after a long time of repetition caudate nucleus takes control, reacting on primed stimuli. The striatum is not only involved in the implicit automatization of serial information through prefrontal cortex-caudate nucleus networks, but it also plays a significant role for the selection of the most appropriate responses in the context created by both the current and previous stimuli, thus contributing to better efficiency and faster response.(Peigneux et al., 2000) The evaluative function of amygdala and caudateputamen will also gain from experience and make the expert better in recognizing outcome of perceived contextual patterns.

3.4.3 Problem solving and flexibility.

Experts are more likely to be able to plan their solutions at a descriptive meta-level. Experts exhibit a forward inference/ reasoning rather than a backward inference in problem solving. They predict accurately the difficulty of their own problem solving capability but have problems in predicting difficulties for other experts and novices.(Dhillon, 1998; Priest, 1992; Sternberg, 1998) Experts are flexible opportunistic planners, they develop self-regulatory processes and are quick to change tracks whereas inexperienced novices exhibits a functional fixedness. The moment of action and the parameters of the action seem to be defined in the course of the interaction between the expert and the task. The experts solves problems in a non reductive manner, describing order as an emergent property of decentralized interactions in a system, and considers nonlinearity and random factors.(Berliner, 1986; Cara & Lagrange, 1999; Jacobson, 2001)

Several psychological experiments have studied the relations between different modes of thought and the generation of 'creative' and original ideas. Conscious thought may be focused and convergent, unconscious thought may be more associative and divergent.(Dijksterhuis, 2006; Nightingale, 1998)

Studies of activites in the brain during problem solving show how novices and experts use different structures.(Göcker, 1997)

3.4.4 Tacit knowledge and intuition.

It is difficult for experts to describe exactly how they do what they do, especially with respect to their use of judgment, experience, and intuition. This is called the knowledge-acquisition problem.(S. E. Dreyfus, 2004) Not only in artistic judgement but in all their ordinary judgements of the qualities of things, experts recognise and describe deviations from a norm very much more clearly than they can describe the norm itself. (Schon, 1987) Experienced teachers are able to function on automatic pilot. Much of the interaction between teachers and students is automatic, over-learned patterns of behaviour that teachers could invoke and perform without conscious effort. Experienced teachers appear to have organized their knowledge of students and classrooms in particularly effective patterns that could be retrieved unconsciously from long-term memory via classroom cues. (Johansson & Kroksmark, 2004; Kagan, 1988; Kroksmark, 1997)

The idea of "a Somatic Marker" linked to memory was proposed by Damasio to explain intuitive assessment of situations, fear reactions, gut feelings and bias.(Damasio, 1996; Gärdenfors, 2000)

This hypothesis has been confirmed, as fMRI studies of the brain support a role of the amygdale in choice behaviour, both in the appraisal of inherent value of choice and the signalling of prospective negative outcomes. Amygdala is used for the recording of emotionally important patterns, if the feedback is missing or is weak, no patterns will be recorded. (Daw, O'Doherty, Dayan, Seymour, & Dolan, 2006; Kahn et al., 2002; Smith, Stephan, Rugg, & Dolan, 2006)

4 Conclusions and implications

Results from brain imaging studies and from neuropsychological experiments gives strong reasons to believe that experts utilize nondeclarative, implicit memories to perform better. The emotion sensed when a situation is assessed by amygdala or striatum may be what we refer to as intuition or gut-feelings and corroborates the models of tacit knowledge by Polanyi and holistic pattern-recognition by Dreyfus. On the other side, implicit learning is probable the cause for biases, prejudice and preconceptions. Most of the brain-structures involved in expert behaviour are separate from declarative memory structures and cannot be introspected, any verbal description is a construction made from other explicit data. If the knowledge of experts is tacit, new interview methods must be found, maybe the Repertory Grid Technique can be used for the elicitation process.(L. Björklund, in press) The knowledge, experts use in clinical reasoning is an ability to sense familiarity and automatic evaluation, directly linked to personal experience. This enhanced way of perceiving the world is what the Master is trying to teach the Apprentice and it is almost impossible to apprehend this by your self using personal reflection or conscious analysis, you need to learn by doing! Further research on experts and expertise using a model of several parallel implicit memory structures will be prosperous and important.

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