How Experience Affects Perception in Expert Decision-Making

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You don't need to study human decision-making to predict that experts will outperform novices in tasks related to their domain of expertise. Through both laboratory-based study and watching people perform tasks in real-life scenarios, researchers have learned that extensive knowledge, built through experience, is the primary differentiator between an expert and a novice. But do experts perceive situations and problems differently than do novices? This paper will argue that experts' vast stores of knowledge provide them with a two-fold advantage over novices. First, chunks act as pre-compiled perceptual elements that can rapidly be recalled and assembled into a rich, detailed mental representation of a situation. Second, the ability to quickly build such a perception allows experts to attend to more subtle aspects of a situation that are typically overlooked by novices. These advantages lead experts to perceive situations related to their domain of expertise differently from novices and make improved decisions as a result.

What kinds of decisions?

All decisions require perceptual processes to extract factual information from the external world that can be used to help develop an answer to a problem. The only way to bring information into your brain – the organ responsible for analysis and decision-making – is through the senses. Some decisions, however, only require a minimum of perceptual involvement. For example, many decisions of choice rely primarily on internal preferences. Examples include deciding when to go to bed, when to go running, and whether to save for retirement or go on a vacation. In these situations, decision-making only tangentially involves perception. Less subjective, typically more complex problems, however, involve perception to a much greater degree.

Like decisions that minimally involve perception, decisions that involve perception often begin with a sensory input. During their study of a variety of military commanders and firefighters, Klein and his team found that 46 to 96 percent of decisions begin with an almost immediate recognition of a situation. After this initial recognition of the situation, decision-makers perform additional investigative steps to verify that their mental representation of the situation is correct (Klein 1998).

This mental representation is where perception is so heavily involved, since the representation itself is a perceptual model. While there are many processes involved in decision making (Bechara, Damasio et al. 2000), spatial imagery has been found to encode essential spatial relations that are used in verbal reasoning, problem solving in physics, mathematics, and chess (Hegarty 2004). The use of spatial imagery has been positively correlated with correct answers to elementary mathematical problems (Hegarty and Kozhevnikov 1999) and chess masters seem to rely almost exclusively on their mental representation of the game while deciding their next move. This last claim is based on the fact that the number of errors made by chess masters in high-stakes tournaments does not seem to vary with whether the master is blindfolded or can see the board (Chabris and Hearst 2003).

Thus, perception weighs heavily in decisions where people construct mental models of the problem or scenario to build an understanding of the world around them. Such situations include a range of reasoning and mathematical problems, as well as dynamic decision-making environments, where complex situations require the detection and identification of cues that can help a decision-maker differentiate between the effects of her own actions and exogenous changes caused by the environment (Brehmer 1995; Gonzalez, Vanyukov et al. 2005).

The import role of perception in decision-making

The mental representation of a problem – the perception of a situation – is central to the decision-making process. This perception is what you know about a problem and all judgments made are based on this perception. As a result, the detail of how perceptions are represented in the brain is of great importance to understanding the strengths and weaknesses of human decision-making. One line of research that illustrates this point seeks to discover whether the structure of mental representations leads people to make systematic errors.

Since the 1940s, one thread of psychology research has shown that mental models[1] underlie deductive reasoning, a crucial form of reasoning used in decision-making. One finding from this research is that mental models represent only what is true and neglect what is false. This *principle of truth* seems to lead people to draw incorrect conclusions

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[1] As defined by Johnson-Laird, mental models are a narrow form of mental representation that are "iconic as far as possible, but certain components of them are necessarily symbolic" (Johnson-Laird 2005). For the purposes of this paper the distinction is not relevant and the terms will be used interchangeably.

from a set of facts, since they tend to ignore elements of falsity. For example, given the following:

> Only one of the following premises is true about a particular hand of cards:
> - There is a king in the hand or there is an ace, or both.
> - There is a queen in the hand or there is an ace, or both.
> - There is a jack in the hand or there is a 10, or both.
>
> Is it possible that there is an ace in the hand?[2]

People will tend to respond "Yes" when, in fact, it is impossible for an ace to be in the hand. If there were an ace, then the first two premises would be true, violating the first stated fact that only one of the premises is true. Because the question involves the violation of two rules, a falsity, people tend not to notice their error (Johnson-Laird 2005).

Another slightly more concrete example of how all judgments are based on the perception of a situation can be found in managerial research literature. While studying dynamic decision-making through the use of a supply-chain simulation game, Sterman found that people often fail to account for the quantity of goods in the supply line when placing orders for more goods. This misperception of the true quantity of goods scheduled to arrive led Sterman's subjects to order approximately twice the quantity they needed (Sterman 1989). Again, this example illustrates that the perception of a situation is the only source of information upon which decision-making judgments are based.

Memory and expertise

While expertise has limits to overcoming systematic errors introduced by the characteristics of mental representations, the importance of perception to decision-making outcomes is clear: the more complete and accurate the representation, the more correct will be the decision based upon that representation. It is for this reason that experience has such a positive effect on the ability for experts to make decisions.

When people observe a situation, they are able to sense multiple stimuli and build a perception based on the cues they interpret. But as we will see, the quality of the

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[2] Example quoted directly from Johnson-Laird (2005).

perception can be improved by recognizing that a present situation is related to experiences from the past, and then using information learned during these past experiences to inform the present.[3] In a theory proposed by William Chase and Herbert Simon during the early 1970s, known as chunking theory, this information is stored as large libraries of *chunks*. These chunks are a collection of elements that have strong associations with one another, but weak associations with elements that belong to other chunks (Gobet, Lane et al. 2001). Chunks represent different things across domains. In chess, patterns of elements represented by chunks are move sequences, or chess piece configurations on the board. In the study of reading ability, each of the three layers of McClelland and Rumelhart's interactive activation model (feature, letter, word) can be seen as chunks that associate elements from the preceding layer (McClelland and Rumelhart 1988). In the instance-based learning theory (IBLT), the relatively abstract chunk is termed an *instance* and thought to contain an information triplet – the decision-making situation, the past action taken, and the outcome of the decision (Gonzalez, Lerch et al. 2003). A flexible concept that has been shown to reliably predict human performance in a range of domains, chunking theory is widely accepted.

Explaining the difference between an expert and a novice, then, could be seen as a simple difference in number of chunks that reside in memory – the greater the library of chunks, the more expert a person. Chase and Simon estimate that an expert has a repository of at least 50,000 chunks (Simon and Schaeffer 1992; Gobet and Simon 2000) and can take upwards of ten years to accumulate (Anderson 1993). Such an approach, however, doesn't seem to account for evidence that experts evaluate problems differently from novices.

In addition to simply storing more information, there is considerable evidence that experts also organize problems according to "deep structure" (Chi, Feltovich et al. 1981; Klein 1998; Bransford, Brown et al. 2000). For example, Chi and her colleagues asked

[3] An interesting minutiae of the recognition process, some have suggested that in the absence of known stimuli, a simple *recognition heuristic* is used to place added weight, or value, on any chunk or object that *is* recognized. This special *noncompensatory* weight would mean the simple act of recognition could carry a significant amount of influence over how people evaluate a situation and choose a course of action. Through tests designed to narrowly test this claim, this heuristic has been disproved; people adaptively weight stimuli according to their observed predictive value (Newell and Shanks 2004).

both doctoral students in physics (experts) and undergraduates (novices) to categorize 24 physics problems. Although both groups were able to classify the problems and demonstrate an understanding of the concepts contained in the problem, the experts classified problems significantly differently from the novices. Whereas novices relied upon the surface features of a problem, such as the presence of an inclined plane or the presence of the keyword "friction", experts grouped them according to the major physics principle that governed the problem. Mary Omodei made a similar observation while describing wildfire firefighters. Omodei described how experienced firefighters will look at smoke color for additional information about how a fire is burning, whereas lesser experienced fighters will simply consider flame height (Omodei 2006).

This ability to perceive and probe the deeper, often more abstract, structure of a problem or task seems to be a function of a second-order categorization that is associated with the basic memory chunk, something that Chi et al. (1981) term a *schema*. These schemata are thought to be composed of the mental categories that people use to organize information and knowledge associated with a chunk, including potential problem solutions. Chi et al. hypothesize that during the initial analysis of a situation, cues are interpreted into features that activate a schema. Once activated, this schema suggests tests that can be used to determine its appropriateness. This hypothesis has garnered support from those studying in the field of learning. There, researchers have observed that expert students work forward from observable facts, building solutions with "top-down, breadth-first progressive refinement" (i.e., using chunk associations and appropriateness tests provided by a schema) while novices work in the opposite direction. Approaching the problem in terms of deeper, more meaningful representations and working from there brings experts closer to better solutions from the start (Anderson 1993).

The evidence supporting schemata illustrates the point that experts not only can recognize more situations (larger chunk library), but that they generally utilize a higher quality organizational system in their classification of problems. This enhanced structure allows experts to identify paths of exploration that are likely to be more fruitful, as well as produce higher quality perceptual representations from the start.

Expertise and decision-making

Decision outcomes are greatly improved by memory systems. In chess, a grand master can routinely beat a lesser-ranked player. In supply-chain management, an experienced manager will typically make fewer errors and maintain higher operating efficiency than someone with less experience. In firefighting, experienced personnel can better predict fire behavior and make decisions to maintain personal safety. But how exactly do the heavily populated memory systems of experts contribute to this improved performance?

At a high level, there are at least six processes and systems in the brain that are involved in decision-making. These include sensory inputs, working memory, chunking processes, long-term memory (e.g., chunks and schemas), decision-making processes (e.g., deductive reasoning faculties), and a perceptual situational representation. A suggestion of their relationships is depicted in Figure 1.

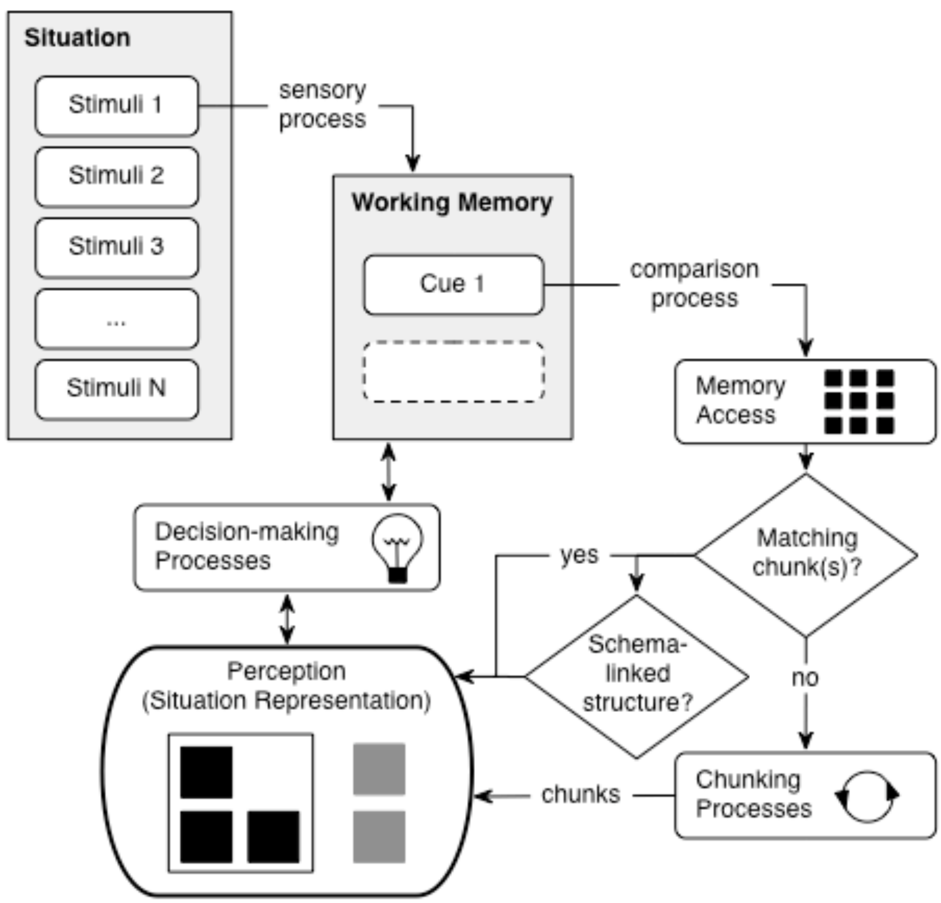

Figure 1 – A suggested mental schema for decision-making

This primary purpose of Figure 1 is to illustrate how memory chunks and schemas serve to enhance a person's perception of a problem or situation. At the top of the figure is a situation composed of many stimuli. Sensory processes translate these external stimuli into cues in a person's working memory. The size of working memory is limited, depicted here as containing only two slots, which places a constraint on how many cues can be processed simultaneously. From working memory, the cue or set of cues is checked to see if it has a corresponding chunk. During this act of recognition, chunks that encode a similar situation are either found or they are not; the large number of chunks in an expert's memory increases the chance that something is found. Furthermore, linkages between chunks and schemata are activated and a flood of pre-sorted, pre-compiled information flows into a perceptual representation of the situation. Thus, in experts, a relatively few number of cues can trigger a deluge of information based on the fast retrieval of stored information. Novices, on the other hand, are not as easily able to form a rich perception. When they search their memory for a similar situation, encoded as a chunk, they are not likely to find anything. Without a match, they must rely on various sense-making and chunking processes to analyze the information that they have sensed. Processing cues requires a lot of effort, attention, and occupies working memory – preventing the investigation of more cues in the environment. As a result, the novice's perception is much less complete and does not have the richness that is provided by an expert's chunks and associated schemata.

The effects of this dynamic can be seen in the performance of chess masters and class B players when allotted different amounts of time per move in a competitive game. Using a panel of grand masters who categorized the quality of moves, researchers were able to find that the quality of master-level players remained approximately constant between 2.25 minute regulation move periods and 6 second per move blitz conditions. Class B players, on the other hand, were observed to have a dramatic reduction in move quality under the blitz conditions. Thus, when placed under intense time pressure, the fast performance of expert memory retrieval has been shown to yield a better representation in a shorter period of time (Klein 1998).

Decision-making processes are shown in their own box since they have been demonstrated to function independently from working memory. More specifically, working memory has been shown to be dissociated from decision-making process, although the latter depend to some extent on working memory (Bechara, Damasio et al.

1998). Decision-making processes interact with both working memory and the perceptual representation of the problem, applying logic and working to find inconsistencies in the representation (Shreeve 1995). In addition to working with an inferior perceptual representation, the decision-making processes in novices must also compete for working memory with the sense-making and chunking processes that are simultaneously trying to decipher a scenario. In experts, working memory remains relatively free to explore the more subtle details of the situation, resulting in a more refined perceptual representation.

Conclusion

This paper has shown how the vast stores of knowledge that give rise to expertise provide experts with a richer, more detailed mental representation of a situation than can be built by a novice. In addition to the high level of fidelity, experts are able to quickly build such representations because recognition is principally a recall-based process. The speed with which memory access works frees experts' working memory, allowing them to attend to more subtle aspects of a situation that are typically overlooked by novices, thereby helping experts to further refine their already superior perceptual representation. While it is clear that experience is the primary determinant of expertise, there is still much work to be done. In particular, there seems to be a dearth of understanding about how the processes of recognition work to pick out the individual cues in a scene and match them to stored chunks. There is also a need for the continued study of common misperceptions in decision-making tasks. Better understanding the recognition process will help improve teaching and training methods, and hopefully enable new forms of technology vastly more capable than is possible today. Uncovering systematic errors in perception will help researchers continue to tease out the inner workings of the brain and its many, interrelated processes.

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