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What is the nature of the mind's pattern-recognition process?☆

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A B S T R A C T

If we look at the human mind as a pattern-recognition device, what is the nature of its pattern-recognizing? And how does it differ from the majority of pattern-recognition methods we have collectively devised over the decades? These broad philosophical questions emerge from the studies of chess thought, and we propose that a major task of the mind is to engage in "experience recognition" (Linhares & Freitas, 2010). One of the basic tenets of that proposal is that pattern recognition, in cognitive science and related disciplines, does not accurately reflect human psychology. As an example, the well-known article by Chase and Simon, "perception in chess", and the benchmark cognitive computational models of chess, by Gobet et al. were criticized. Lane and Gobet (2011) provide serious skepticism concerning some of those arguments, and here we take the opportunity to respond and expand the theoretical constructs of "experience recognition". We postulate that the mind's pattern-recognizing process holds the following properties: it is a highly path-dependent process; it prioritizes internal encodings; it is a self-organizing process in constant change; and it constructs its future information-processing pathways by continuously recognizing the possibilities that lie within the adjacent possible.

> "Thus intuition (or recognition [of patterns]) provides a ready explanation of some of the apparently extraordinary memory feats of which experts are capable in their domain of expertise" (Simon, 1986, p. 243)

> "It has been proposed that intuition may be largely explained by pattern recognition (Simon, 1986). This is the route followed by our models." (de Groot & Gobet, 1996, p. 247)

1. Introduction: what is the nature of the mind's pattern-recognition process?

If we look at the human mind as a pattern-recognition device, what is the nature of its pattern-recognizing? And how does it differ from the majority of pattern-recognition methods we have collectively devised over the decades? While these are broad philosophical questions, we will start from studies of chess thought, and propose that a major task of the mind is to engage in what we term "experience recognition" (Linhares & Freitas, 2010).

Linhares and Freitas (2010) argued that cognitive scientists place too much emphasis on "pattern recognition"—and scarce emphasis on "experience recognition". The study of (static) pattern recognition generally holds a database of known patterns, and a system (or theoretical model), given a *new* pattern, is faced with the task of classifying it against the database store. While the field of pattern recognition has

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brought deeply impactful contributions toward solving some central problems of modern science, to the goal of modeling human cognition we argue in favor of a similar, but in many ways distinct approach. We believe that pattern recognition as it is currently defined may not be the most accurate reflection of human psychology, as it focuses on (generally) static, (usually) visible, entities, rather than the silent, invisible, cognitive *process* through which we experience our surroundings. The focus of "experience recognition", on the other hand, is a process in which the progression of the sensory influx of information is, at any point in time, mapped against a large store of experiences (*trajectories of information processing*).

Traditional (static) pattern recognition generally consists of training upon a data set which is presumed to be representative of all the patterns which will be seen and subsequent classification of every encountered pattern based on what was 'learned'. Dynamic pattern recognition, in turn, achieves 'online' learning, that is, a system remains able to add new patterns to its roster of recognizable elements. This amounts to a constant re-training of the model at every 'time iteration' adding the pattern seen at time t to the training set of $t + 1$. This is a more flexible but yet lacking format, when the goal is a faithful model of human decision-making.

It is important to note that pattern recognition, as a field, is orthogonal to the pursuit of cognitive science: it is an immensely successful field with countless applied results, and does not hold the modeling of cognition as a principal (or even secondary, some might say) goal. We reinforce this notion by adding that the vast majority of pattern-recognition models do neither address fundamental issues of human decision-making, nor should they. Furthermore, we invoke pattern recognition here in order to address the fact that extant literature (Gobet, 1998; de Groot & Gobet, 1996; Gobet & Jackson, 2002; Gobet & Simon, 2000) employs models and arguments that display characteristics and techniques of static pattern recognition.

Computational models based on (static or dynamic) pattern recognition usually are i) context-free, ii) temporal-sequence-independent, and iii) culture-free. The current pattern being processed is (typically) not affected by the previous one(s) seen; the temporal sequence of patterns the system has acquired is (usually) irrelevant; and there are no developed biases: one pattern is as good as any other. Past trajectories of information processing do not seem to affect future processing to a large extent (other than, perhaps, incremental adjustments in pre-selected internal parameters). These characteristics seem to hold for a large number of methods appearing, for example, in journals such as *IEEE Transactions on Pattern Analysis and Machine Intelligence*. We postulate that the mind's pattern-recognizing has enormous *path-dependence*.

Additionally, priming studies and studies from the heuristics and biases school show the enormous extent to which we are *context-bound* (Bargh & Chartrand, 1999). In here, the concept of 'context' is fundamentally different from that explored in standard vector-space models such as Latent Semantic Analysis (Deerwester, Dumais, Furnas, Landauer, & Harshman, 1990). The mind's information-processing is highly path-dependent: someone who has experienced trauma is intrinsically different from someone who has never experienced it, yet is about to. And of course we are also strongly context-dependent: bound by taboos and customs, social norms, political institutions, formal and informal power (and status) structures, etc. (Tomasello, Carpenter, Call, Behne, & Moll, 2005). We postulate that the mind's pattern-recognizing is self-organizing, constantly creating and releasing constraints for further exploration: a process capable of molding itself.

Linhares and Freitas (2010) analyzed cognitive models of chess, influenced by Chase and Simon's (1973) well-known study, "perception in chess". The computational cognitive models in that analysis concentrated in the work of Gobet (1998), de Groot & Gobet, 1996, Gobet and Jackson (2002), Gobet and Simon (2000), which are quite simply the benchmark in chess cognition models. Lane and Gobet (2011) provide commentary and criticisms of Linhares and Freitas (2010). Here we respond to those criticisms, concentrating on the critique of Chase and Simon (1973), which is the most influential work in question, with over 800 citations in the ISI database,[1] and further expand on the aforementioned questions.

Lane and Gobet claim that the views expressed by Linhares and Freitas were "revolutionary" (using the term under quotes), yet no grandiose words like "revolution" or "paradigm" are to be found therein. In fact, the term experience recognition seems a natural convergence of a number of previous ideas, including: Hofstadter's (2001) 'analogy at the core of cognition', Klein's (1999) 'recognition-primed decision' framework, Hawkins' (2005) 'hierarchical temporal memory', and, to a lesser extent, Saariluoma and Kalakoski's (1998) view of 'apperception'.

In the following section we comment on Chase and Simon (1973) and address the concerns raised by Lane and Gobet (2011). In Section 3 we address and expand on necessary traits of experience recognition models.

2. Chess and chunks

In this section we address technical concerns over chess cognition raised in Lane and Gobet (2011) and expand on the concepts initiated in Linhares and Freitas (2010). We shall initiate our discussion by revisiting Chase and Simon (1973).

2.1. A flaw in delineating chunks: further analysis of Chase and Simon (1973)

Chase and Simon (1973) proposed a method for "isolating and studying the perceptual structures that

[1] For reasons of space, we cannot review the entire literature of chess cognition pointed out by Lane and Gobet; we refer the reader to Linhares (2005), Linhares and Brum (2007), and Linhares et al. (2011) for our basic position concerning cognitive computational architectures regarding the chess game. There is one point that bears responding, though: Figs. 1 and 2 of Lane and Gobet's article seem to imply that Linhares and Freitas claimed that "all positions can be entirely distorted", which is not true, obviously (the claim was that some positions can be entirely distorted, which shows that specific location coding cannot explain much). Finally, we of course do not expect to see rapid advances in context-dependence, path-dependence and cultural bindings. It is much easier to point out limitations in computational models than to develop the immense breakthroughs the field aspires toward. It is with respect and a constructive mindset that we criticize the work of others.