Computational models of the development of perceptual expertise:

Commentary on Palmeri et al. (2004)

Fernand Gobet (*), Guillermo Campitelli

Brunel University

Peter Lane

University of Hertfordshire

*Centre for Cognition and Neuroimaging, Brunel University, Uxbridge, Middlesex,

UB8 3PH, United Kingdom

Email: fernand.gobet@brunel.ac.uk

Phone: +44 (1895) 265484

Fax: +44 (1895) 237573

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In a recent article, Palmeri, Wong and Gauthier[1] have argued that computational models may help direct hypotheses about the development of perceptual expertise. They support their claim by an analysis of models from the object-recognition and perceptual-categorization literatures. Surprisingly, however, they do not consider any computational models from traditional research into expertise, essentially the research deriving from Chase and Simon's chunking theory[2,3], which itself was influenced by De Groot's study of chessplayers[4]. This is unfortunate, as a series of computational models based on perceptual chunking have explained a substantial number of phenomena related to expert behaviour and provide mechanisms that directly address the question of perceptual expertise.

This neglect is perhaps due to the belief (p. 378) that "early expertise research focused on problem solving, decision making and reasoning. But recent years have seen growing interest in perceptual expertise […]". This statement is simply incorrect. At least since De Groot's thesis in 1946, and clearly since Chase and Simon's 1973 papers on perception and memory in chess, perceptual processes, and in particular pattern recognition, have played a key role in theories of expert behaviour. Chase and Simon proposed that expertise is made possible by the acquisition of a large number of perceptual chunks (groups of features made familiar through practice and that can be used as a unit), which become increasingly larger as skill develops. They supported their claim by a detailed analysis of the way chessplayers of various skill levels decompose a position into chunks, in both a perceptual task and a memory task. This work has led to a substantial interest in the role of perceptual expertise in domains including board games[5,6], sports[7,8], and medical diagnosis[9].

Research into perceptual expertise has also led to a number of computational models of expert behaviour[10,11], in particular with respect to chess expertise. While early work used information theory[12], later work used mechanisms related to domain-specific heuristics for simulating eye movements[13] and chunking mechanisms for simulating perception and memory[14]. A recent computational model, CHREST (Chunk Hierarchy and REtrieval STructures)[15-21] has integrated these early models, providing an explanation of how pattern-recognition mechanisms develop to enable a rapid identification of external objects, how experts' perceptual chunks help direct their eye movements, and how some chunks evolve into schemata that ground conceptual understanding into perceptual knowledge. Simulations from novices to grandmasters capture the details of data such as the duration and overall pattern of eye fixations; the number, size, and internal structure of the reconstructed chunks; the effect of various distortions on pattern recognition; and the overall improvement curve in memory experiments, both as a function of expertise and of presentation time. Contrasting with the models discussed by Palmeri et al., CHREST simulates the perceptual behaviour of top-level experts, and integrates perceptual expertise with memory, problem solving, and decision making. As reviewed in a recent TICS article[20], the generality of chunking mechanisms is supported by their application to a number of domains, including verbal learning, letter perception, categorization, early acquisition of language, problem solving in physics, and the role of high-level information on perception.

Most of the phenomena discussed by Palmeri et al. either relate to expertise that most people have (e.g., face expertise) or to the type of "expertise" acquired after a few hours of practice at most. By contrast, traditional research into expertise has studied individuals that perform vastly better than the majority in their domain, typically after many years of practice and study. While we recognize this difference in emphasis, we strongly believe, as do Palmeri et al. (p. 378) that essentially the same mechanisms are used in all these domains. By showing how perceptual mechanisms underpin memory and problem solving processes, and backing up their claims by detailed simulations from novices to top-level experts, chunking models go beyond the models discussed by Palmeri et al., which are mostly limited to the (important) processes of identification, recognition and categorization.

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