A computational theory of skill acquisition and its implications for representation, access, and change in the lexicon during reading acquisition.

A paper presented at the annual meeting of the National Reading Conference.

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In a review of his own and others' work, Perfetti (1992) has outlined a theoretical position on the nature of the lexicon. Three problems are identified as central to understanding the role of the lexicon in reading acquisition: representation, access, and change of representation. Representation refers to the way knowledge about words is cognitively coded. Access refers to the manner in which readers retrieve or activate cognitive codes that represent words. Change of representation refers to the way that the lexicon is gradually altered as a consequence of learning.

Perfetti argued that these problems are those most central to the task of understanding reading acquisition. The purpose of this paper is to describe a general theoretical model of skill acquisition and explore how this model addresses the problems of lexical representation, access, and development in reading acquisition.

**The Multiple-Architectures (MA) Model**

The present work extends the application of a model (McEneaney, 1994b) originally developed in response to weaknesses in proposed connectionist models of reading acquisition (Seidenberg & McClelland, 1989) and reading disability (Seidenberg, 1992; Patterson, Seidenberg, & McClelland, 1989). The model described in this paper is referred to as the Multiple-Architectures (MA) model because it integrates connectionist and traditional information processing modules within a single combined framework that is depicted in Figure 1. This idea of multiple processing modules based on different computational processing implements an idea suggested by Lachter and Bever (1988) and Smolensky (1988). This model also follows the computational implementation of the combined architectures approach by Shavlik & Towell (1990) and Shavlik (1994), who demonstrated a number of advantages of such an approach for learning systems in the domain of concept acquisition. The central premise of the MA model (and what distinguishes it from the work of Shavlik and colleagues) is that in the MA model both symbolic and connectionist processes are available at all stages of learning, and that learning and performance involve a balance between two different processing systems that support radically different forms of knowledge.

![Figure 1. Elements of the MA model.](image)

**Representation in multiple lexicons**

The first contribution the MA model might make to organizing what we know about lexical knowledge is its capacity to account for multiple lexicons on the basis of cognitive processing. Briefly, the assumption of multiple processing modules...
(employing different representational systems) effectively requires multiple lexicons and the characteristics of the rule-based (Rb) and connectionist activation-based (Ab) processing modules map neatly onto the characteristics of the functioning and autonomous lexicons, as described by Perfetti.

The functioning lexicon Perfetti describes supports the earliest stages of acquisition and, among other things, should be prepared to account for the role of orthographic and phonological awareness, GPC rules, and other forms of strategic cognition. This is precisely what Rb cognition is best suited to address and simulation studies by McEneaney (1994a; 1995), Shavlik and Towell (1990) and Shavlik (1994) suggest that a rule-based module has a number of distinct advantages in the earliest stages of learning. It turns out that a few carefully selected rules can be very useful early in learning but that Ab cognition (which learns from supervised feedback) appears to require relatively extensive training before it can reasonably approximate rule-based behavior. Moreover, since rule-based cognition can function under the direct conscious control of learners, and lexical representation is symbolic (and thus manipulable), this form of processing supports an interactive lexicon that can be influenced by non-orthographic sources of information.

Activation-based (Ab) cognition, on the other hand cannot reasonably be presumed to be under conscious control by learners and this is consistent with its relative autonomy and speed. The autonomy of the Ab lexicon may, in part, be a consequence of speed of processing but it lies primarily in the fact that the “content” of the Ab lexicon is not subject to conscious manipulation since lexical entries are stored as distributed representations. In the Ab lexicon, therefore, representations are not retrieved, they are activated and this lends the Ab lexicon a flexibility and a resistance to damage that is not found in the functioning lexicon (which relies on the retrieval of discrete symbolic entries).

**Access in multiple lexicons**

The nature of cognition employed in acquiring and using lexical knowledge also, clearly, has implications for access. Ab cognition provides for faster and more flexible access. Access is faster since there is no need for the retrieval and interpretation of rules or lexical entries. Access is more flexible because the nature of Ab cognition supports both approximate solutions and graceful degradation under conditions of noise or error, which tend to seriously impair functioning in Rb cognition. The problem with Ab access is, however, that it cannot be “explained” because the source of the response was the spread of activation rather than a sequence of symbolically-related rules or events. Connectionist systems, for instance, can learn complex tasks but it is often not clear how the solution has been determined (not unlike experts in a field who no longer rely on the systematic knowledge they acquired in their days as novices.)

The primary advantage of Rb cognition, as noted above, is its capacity to support interactive access. This means that Rb cognition supports strategic “problem-solving” under situations where Ab cognition cannot provide a reasonable solution to the problem at hand (which as noted above is most likely to occur early in skill acquisition.) This is the reason Rb cognition dominates in the early phases of skill acquisition or in situations that differ in dramatic ways from those with which the learning system has prior experience.

**Development in multiple lexicons**

The presence of multiple forms of processing (and their respective lexicons) also has consequences for development. The dimensions of development noted by Perfetti (number of entries and quality of representation), however, are reflected in different ways in the Rb and Ab lexicons. Moreover, the introduction of multiple forms
of processing introduces another dimension for development which is reflected in the way modules interact depending on the stage of skill acquisition and the nature of the task undertaken.

Traditional models of skill acquisition have identified three main stages: cognitive awareness, mastery, and automaticity (Downing & Leong, 1982). In work focusing specifically on reading (Ehri, 1992), stages of acquisition are similar in that they postulate a movement from a more strategic approach early in development (e.g., logographic or phonetic cue word reading based on specific, salient visual cues) to a more completely integrated form of processing based on parallel activation of orthographic and phonological knowledge as processes become automatized.

This development follows naturally from the interaction that occurs in the MA model. Cognition (and instruction) early in skill acquisition is dominated by a strategic Rb approach because this is more effective in the absence of experience. Over time, however, the efficacy of Rb processing declines as the numbers of rules and exceptions increase. Moreover, at the same time, the relative effectiveness of Ab processing is increasing, resulting in a relationship like that depicted in Figure 2.

Summary and Conclusions
Perfetti has observed that, despite superficial contradiction, word reading is simultaneously interactive and autonomous.

According to the model proposed in this paper, word reading must be both interactive and autonomous on account of the fundamental architecture of human cognition, which supports multiple forms of cognitive processing, and as a consequence, multiple forms of knowledge (including word knowledge). The presence of multiple processing modules and multiple forms of knowledge has direct consequences for how word knowledge is represented, accessed and altered across time. The proposed model appears to be qualitatively consistent with a wide range of observations noted by researchers in reading acquisition, and skill acquisition more generally. Given its utility in organizing what we know about the lexicon, it may be that the proposed model will also serve as a useful general framework for conceptualizing the cognition of reading and reading acquisition.

![Figure 2. Dominance of processing type by experience with the task.](image)

References


