The Nature and Transfer of Cognitive Skill

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Is the whole of human cognitive ability an integrated system of knowledge, strategies and skills, or a collection of individual tasks and goals? Even though most people would gravitate towards the former point of view, the tradition of psychology, cognitive science and cognitive modeling adopts at least the research stance of the latter.

The discussion can be traced back to Thorndike, who rejected the idea of a "formal discipline of the mind", and replaced it with the theory of identical elements. According to this theory, any ability we have is largely independent of other abilities, unless the two share identical elements of knowledge (Stimulus-Response bonds in the time of Thorndike). Singley and Anderson introduced the modern version of this idea: transfer between individual skills is only possible if they share identical production rules.

As a consequence, the current research tradition is to study individual skills and tasks with little regard for interactions between tasks. This is reinforced by many studies that demonstrate a lack of transfer, for example the well-known example in which subjects fail to solve a puzzle about a heart surgeon using a laser to remove a tumor after reading a story about a general who uses his army to concur the capital. Or the fact that even after taking a course in logic, students still fail to solve Wason's selection task.

Most examples of failed transfer, however, play out on a semantic level, in which subjects fail to make the appropriate analogy, even if it is almost forced-fed into them. However, there are several experiments that do show transfer, but the transfer of knowledge seems to play out a more mechanical, syntactic level. In those experiments, subjects can perform or learn particular tasks faster because they have already learn a similar other task. Singley and Anderson's experiment with learning text editors is an example: it is easier to learn a new text editor if you have already mastered a different editor.

A new branch of more recent experiments have a similar structure, but focus on executive control. By training a particular control task, for example task switching, N-Back or working memory, subjects also improve on other executive control tasks, like the Stroop task.

Cognitive models have a hard time explaining transfer between skills. In production system models rules are typically specific to a task, and neural networks models are typically also geared towards a particular task. In my talk, I will propose a solution based on the ACT-R architecture that involves breaking down productions into their smallest components, in which a rule is reduced to either a single comparison or a single atomic action. Models constructed on this basis combine these basic components into compound rules that are still independent of the particular task, but that can be used in other tasks that share the same thinking structures. For example, counting can be helpful in learning to reason in a semantic network, because both tasks involve iteration.

I will demonstrate the generality of the approach with a set of examples (and as time permits): the Singley and Anderson (1985) editor experiments, experiments done by Elio (1986) and Frensch (1991) in which subjects solved complex arithmetic problems, and experiments by Chein and Morrison (2010) and Karbach and Kray (2009) in which training on one task of executive control improved performance on others.