Learning Procedures by Imitation of a Teacher

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Imitation is a common form of learning both in humans and animals, and in some ways is as important a method of learning as the more commonly studied classification of examples. This research has focused on procedures that are often taught in education by imitation of a teacher going through the appropriate steps, and in particular, procedures that are taught using squared paper. This restriction makes the task computationally tractable, and yet utilises the same underlying learning mechanisms.

More generally, examples include learning to operate coffee dispensers, ticket machines, video recorders and computer programs. In each case people more often learn how to carry out a procedure by imitating someone else than by reading instructions. The question for cognitive science is how does this learning mechanism work?

A procedure such as long division is often learned by a student following the teacher working through the steps. Other researchers have also called this "learning by doing" (Lieberman, 1993) and "learning by instruction" (Huffman & Laird, 1994), but the essential component is the imitation of the way the teacher carries out the procedure. Other examples would include the manipulation of matrices, and conjugation of French verbs.

Imitation of a teacher carrying out a procedure requires more than verbatim reproduction of the behaviour, and some form of generalisation is required. For example, an event such as making a choice by pressing a button may need to be generalised to pressing another button within the same class, e.g. a different destination in a ticket machine, or a different amount of money in a cash dispenser. In procedures such as long division, generalisation takes place over both the numbers actually used, and their positions on the paper.

The research was conducted by asking experts to explain a procedure by working through the steps of an example. In each case the subjects were asked to explain the procedure to a novice who understood the underlying operations. For example, in teaching long division it was assumed that the student understood multiplication and subtraction. The experts were videod, and the results analysed. By using large squared paper it was easier to observe the detailed operations of the experts. Each step consisted of selecting one or more digits and carrying out an operation. The student had to learn the overall sequence of events and understand it.

A computer program has been developed called LAWE (Learning Algorithms from Worked Examples) which models the task of the student imitating the teacher. The teacher acts as the user of the program and teaches the system a procedure. LAWE observes the teacher carrying out the procedure and learns it, often from a single example. LAWE has learned procedures such as matrix multiplication and the conjugation of French verbs.

LAWE has to generalise over its example or examples in four ways: a. Generalising the positions of the example. b. Generalising the elements of the example, e.g. different numbers or words c. Generalising the sizes of the elements, e.g. from a row of three cells to a row of arbitrary length. d. Generalising across examples including generalisation over different condition states.

The teacher first types in a typical input to the procedure in one or more cells, and then selects the cells which are to be the input to the procedure. He then goes through the steps of the procedure, and when finished clicks the "End" button. LAWE then builds the code of the procedure it has been taught which is a generalisation of the steps that the teacher went through. Often one example is sufficient to teach LAWE a procedure, but if necessary, the teacher can repeat the process. LAWE will accommodate the new example with its existing procedure to produce a revised procedure to handle the new example.

Learning by imitation is such a common experience in human life that the underlying cognitive processes are likely to be fairly general purpose. Four kinds of learning mechanisms have been found to support this skill. First, the learner needs to be able to perceive and encode the individual steps that the teacher is carrying out. Second these steps need to be transformed into some positional independent representation. Third, patterns of behaviour in the temporal and spatial domains need to be detected. Finally, if the procedure is learned from more than one example, then the procedures need to be merged.

References

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