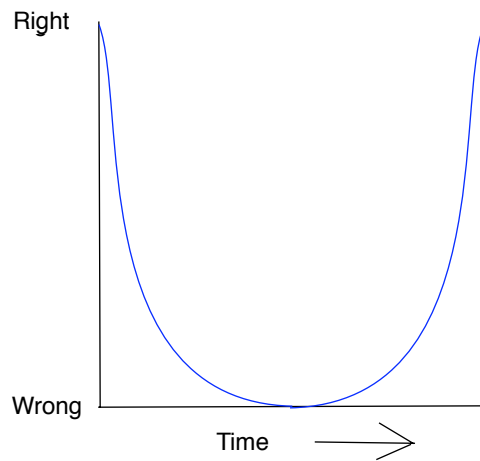# Theory of U-Shaped Learning

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The unusual phenomenon of *U-shaped learning* is found in early childhood cognitive development. For example, a child begins to use the verb 'spoke', subsequently, she may use instead 'speaked', and, later and finally, she again uses 'spoke'. Her learning follows a U-shape as in the figure below.

PI John Case was curious as to whether U-shaped learning might be *necessary* to the learning of particularly difficult collections of tasks. He sought answers in the mathematics of computational learning theory. In high school geometry one can prove non-obvious theorems about possible, idealized figures such as triangles. In computational learning theory one can prove non-obvious theorems about possible, idealized learning machines.

The PI with international collaborators including a grant supported, now finished, doctoral student, Lorenzo Carlucci, proved the following regarding trial and error learning of grammars for formal languages. There *are* a collection of languages and learning machine so that, for each language in the collection, if the machine is shown any data stream of all the elements of the language, after it outputs some number of incorrect grammars, it begins to output no more than three distinct, correct grammars; however, *no* learning machine can learn this collection of languages, with any number of eventual correct grammars, *unless* it exhibits U-shaped learning [1].

The PI with the same collaborators also began to study the necessity of U-shaped learning where, as with humans, there are *memory limitations* on how much data the learning machines can retain [2].

Publications:

[1] L. Carlucci, J. Case, S. Jain, and F. Stephan. Non U-shaped vacillatory and team learning. *Proceedings of The 16th International Conference on Algorithmic Learning Theory (ALT'05)*, volume 3734 of *Lecture Notes in Artificial Intelligence*, pages 241–255. Springer-Verlag, Berlin, 2005.

[2] L. Carlucci, J. Case, S. Jain, and F. Stephan. Memory-limited U-shaped learning. *Proceedings of the 19th Annual Conference on Learning Theory (COLT'06)*, volume 4005 of *Lecture Notes in Artificial Intelligence*, pages 244–258. Springer-Verlag, Berlin, 2006.

Importance: These results about machine learning provide possible insight into an unusual phenomenon in human learning.