Language Acquisition Augmented by Artificial Intelligence
A Brief Project Description

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1 Introduction

This project involves using computer models of human memory to schedule study. Just as physical processes like the weather can be successfully modeled, so too can cognitive processes be modeled. Similarly, just as the weather can be forecasted from computer models, "memory" can be "forecasted" from a computer model of human memory. For example, it is possible to predict with reasonable accuracy what percentage of facts a student will recall at a future date based on when and how long they previously studied.

Because we can predict a student's performance at a test as a function of their study schedule (i.e., when he or she studied), we can also predict what study schedule will maximize the student's performance at test. In this project, we will apply computational methods of scheduling study to real-world educational environments. Specifically, we will work with the Anderson Language Technology Center to provide our services to undergraduates enrolled in foreign language courses at the University of Colorado. In addition to being of educational benefit to students, the successful application of our methods will provide us with valuable scientific data and valuable press coverage.

2 Background

In this section, we briefly introduce a few of the concepts crucial to this project.

2.1 Spacing Effect

Experimental psychologists have identified numerous factors that influence the durability of learning (i.e., retention). One of the most prominent factors, and the one that we have focused our research on, is known as the *spacing effect*. The spacing effect is simply that a person's retention of material is strongly influenced by how the study of it is spaced in time. When individuals study material multiple times, long-term retention generally improves when the study sessions are not crammed together.

On the surface, the spacing effect appears to be an unremarkable example of science confirming common sense — where common sense tells us that cramming is bad in the long term. However, the spacing effect is of interest and of practical value to us because:

1. The spacing of study has a complicated relationship with retention. Cramming is the best thing to do if a student needs to recall material at an upcoming test. Widely spaced study is the best thing to do when material needs to be recalled at a distant future date. To understand the spacing effect is to understand this tradeoff between cramming and spacing, and its dependence on other factors (like when the material will be needed and, unsurprisingly, the intrinsic difficulty of the material).

2. Appropriately choosing the spacing between study can *double* retention. It is very rare to find such a large effect in psychological studies.

3. The spacing effect is robust to experimental manipulation: it reliably occurs over a vast range of study materials, people, and settings.

Because of its complexity, impact on learning, and robustness, we would like to intelligently exploit the spacing effect in an educational environment.

Furthermore, there is the notion of a so-called "optimal" distribution of study. As point two hinted at, there is a spacing of study that maximizes retention. Experiments have shown that this "optimal spacing" of study is a very fine-grained notion. That is, the difference in retention between a student studying via the optimal spacing versus a student studying via a close guess at the optimal spacing can be very large. The important task of exactly pinpointing the optimal spacing is something impossible to do by hand. The next section describes a computational method to perform the pinpointing, which enables us to exploit the spacing effect in an educational setting.

2.2 Cognitive Models

Cognitive modeling is an approach to artificial intelligence motivatived by cognitive psychology. It typically involves the construction of computational "explanations" of particular aspects of human cognition. As the only existing example of genuine intelligence, human cognition is viewed as something that an artificially intelligent system should emulate. These "explanations," which are called cognitive models, can be used in a predictive manner or to further the understanding of cognition.

The aspect of cognition our research deals with the most is memory. Whenever a person learns facts, those facts are said to be "encoded" into memory for later retrieval. There are a variety of cognitive models (i.e., computational explanations) of this encoding and retrieval process. As mentioned in the previous section, we need to be able to pinpoint the optimal spacing of study. Because of this need, we use the model that has shown the greatest ability to predict optimal spacing. It is called the *Multiscale Context Model* and was developed primarily by Prof. Mozer. In addition to its ablity to predict optimal spacing, we value the model because:

- It can easily be "tuned" to a particular set of study material and a particular audience (e.g., students learning vocabulary in an introductory Tibetan class). This is important so that we can pinpoint the optimal spacing.
- It can tell us how uncertain it is in its predictions. For example, it might tell us that a student needs to space two of their study sessions by 7 ± 2 days.

2.3 Review

The spacing of study is very important because it has a large, robust effect on retention. Although we cannot reliably determine the optimal (best) spacing of study by hand, we can make use of a subfield of artificial intelligence research — cognitive modeling. Cognitive modeling provides us with computational explanations of human memory. By using these explanations in a predictive manner, we can determine the optimal spacing and dramatically improve retention.

3 Project Goals

We currently have a vetted cognitive model of memory that can predict the optimal spacing of study for students learning foreign language vocabulary (among other things). To make a prediction of the optimal spacing, the model needs only basic information about how quickly similar students have forgotten the same material. It is our intent to have the model's predictions actually schedule study in a real-world educational environment. To date, our studies have all been in environments much more controlled than a classroom full of students.

Our plans are open to change and suggestion. Not having discussed this with any teachers yet, our current plan is to work with a foreign language course in the following way:

- Ask teachers for a weekly vocabulary list.
- Ask the students to devote some number of hours a certain number of times per week toward studying the list. The specifics of this are up to the teacher.
- Use our model to allocate that time to the studying of individual words.
- As the model obtains feedback from the student (based on quizzes while studying), the model and its predictions will automatically be adjusted.

The end goal of this process is to maximize the cumulative vocabulary memory of the students at the end of the semester. We believe that this project has significant potential to benefit participating students.

4 Details

This is a long-term project, intended to last one to two years. We are funded by the National Science Foundation via the "Temporal Dynamics of Learning Center," a group based at the University of California, San Diego.

Ideally, we would begin working with a foreign language teacher in the spring of 2010. We can provide our vocabulary tutoring system via any electronic medium the teacher we work with wants. It is our opinion that a web-based program would be most accessible to students, but we would also be excited to pursue other avenues (e.g., mobile devices). Mark Knowles, the director of ALTEC, has very kindly agreed to use his expertise to help mediate between us computer scientists and the foreign language faculty throughout this project.