

# TIME-DECAYED USER PROFILE FOR SECOND LANGUAGE VOCABULARY LEARNING SYSTEM

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## ABSTRACT

Vocabulary learning is the foundation of second language learning. Many E-learning systems have been developed to help learners to learn vocabulary efficiently. Most of these systems employ Ebbinghaus Forgetting Curve to make the review schedule for learners. However, learners are different in learning ability and the review schedule based on Ebbinghaus Forgetting Curve may be not fit for every learner. To solve the problem, this paper proposes the time-decayed user profile (TUP) to store the personalized Forgetting Curves for each learner. First, TUP is defined and then two algorithms, TUP Training Data Generation algorithm and TUP updating algorithm, are designed to train TUP. The experimental results show that the proposed time-decayed user profile can model the personalized learning characteristics of learners accurately.

## KEYWORDS

Vocabulary learning, Ebbinghaus Forgetting Curve, User profile, Personalization, E-learning.

## 1. INTRODUCTION

Vocabulary learning is the foundation of second language learning (Horwitz, 1998; Laufer, et al. 2001; Read, 2007). So many E-learning systems have been developed to help learners to learn vocabulary efficiently. In most of these systems, Ebbinghaus Forgetting Curve is employed to make the review schedules for learners (Read, 2001).

German psychologist, H.Ebbinghaus, found that the forgetting started immediately after the learning and the process of forgetting is not uniform. At the beginning, the speed of forgetting is high, and then the speed of forgetting will reduce. Retention and forgetting are the function of time and the experimental results are described as Ebbinghaus Forgetting Curve (Wixted, 1997), as shown in Figure 1. In Figure 1, the abscissa axis denotes the elapsed time since learning, the ordinate axis denotes the retention of acquired knowledge, and the curve denotes the law of retention after learning. The forgetting curve graph shows that humans tend to halve their memory of newly learned knowledge in a matter of days or weeks unless they consciously review the learned materials.

Ebbinghaus Forgetting Curve is built on many learners' learning process, which is a general law for most of humans and doesn't consider the individual characters of each learner. However, learners are different in learning ability because each one has different memory habits, memory modes, and memory characteristics, which makes their forgetting curves different (Webb, 2005; Schmitt, 2008). Therefore, the review schedule based on Ebbinghaus Forgetting Curve made by e-learning system may be not fit for every learner, which will reduce the efficiency of learning.

To solve the above problem, this paper proposes a personalized user profile, named as time-decayed user profile (TUP), for vocabulary E-learning systems, which has the following characteristics:

(1) Personalization. The individual forgetting curve for each learner will be generated, based on his learning process, to personalize the learning ability of different learners.

(2) Rank vocabulary based on difficulty. The forgetting curve is also different when a learner learns words of different difficulty ranks. Generally, the difficult words are much more likely to be forgotten than easy words.

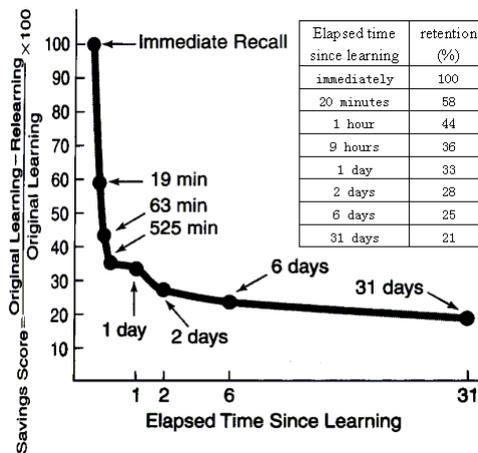


Figure 1. Ebbinghaus Forgetting Curve (Wixted, 1997)

(3) Dynamically update. The user profile will be updated dynamically in order to catch the learning ability of a learner in different periods and status.

The rest of the paper is organized as follows. Section 2 defines the proposed time-decayed user profile. Section 3 discusses how to generate the personalized time-decayed user profile for each learner. Some experiments are shown in Section 4 to validate the proposed user profile. Finally, summaries are made in section 5.

## 2. TIME-DECAYED USER PROFILE

The user profile in E-learning system should record the individual characters of learners. In the learning process, the retention will decay as time goes on, which is focused on by the proposed user profile. Therefore, we name the proposed user profile as Time-decayed User Profile (TUP)

Generally, the difficult words are much more likely to be forgotten than easy words. The user profile should record the abilities of a learner in learning vocabulary of different levels. Therefore how to rank the vocabulary for TUP should be discussed firstly.

### 2.1 Rank Vocabulary based on Difficulty

The target vocabulary for learning should be ranked into different difficulty levels. Then we can generate the learning tasks or build the forgetting curve for each difficulty level. Furthermore, the learning history of each word, such as the learning times, the time of recent learning, and so on, is used to generate the forgetting curve, which should be attached to each word in the vocabulary. The vocabulary model satisfying the above requirements is defined as following.

*Definition 1:* Let  $V$  be the vocabulary and the **vocabulary model with difficulty ranks** for  $V$ , denoted by  $R$ , is defined as

$$R = \{R_1, R_2, \dots, R_i, \dots, R_n, (R_1 \cap R_2 \cap \dots \cap R_n = \emptyset), (R_1 + R_2 + \dots + R_n = V)\}, \quad (1)$$

where  $n$  is the number of difficulty ranks in  $V$ .

There exist many vocabulary difficulty ranks in fact. For example, in China the College English Test grades the vocabulary into six difficulty levels from CET1 to CET6. If  $V$  is the CET vocabulary, then  $n$  may be set to 6.

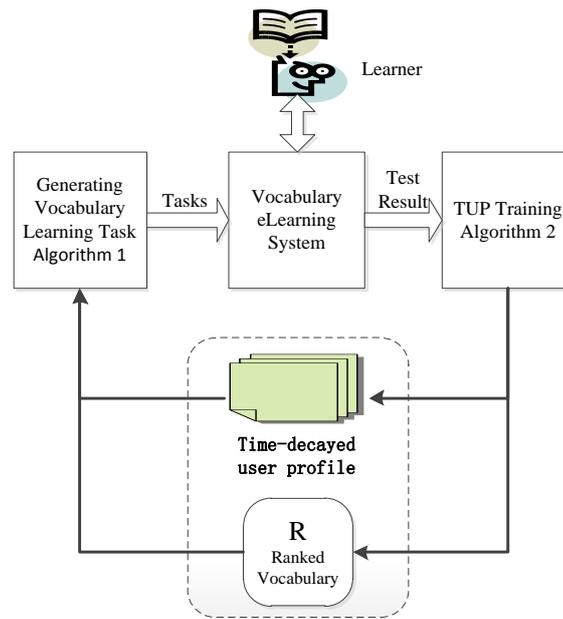


Figure 2. TUP Training Process

In  $R$  each  $R_i$  is a set of words and each word, denoted by  $w$ , is defined as

$$w = (r, lt, et), \quad (2)$$

where  $r$  is the rank that the word belongs to,  $lt$  is the learning times that the user had already done,  $et$  is the elapsed time since the latest learning on the word.

## 2.2 Time-Decayed User Profile

To personalize the characteristics of a learner in vocabulary learning process, user profile should record the personalized forgetting curve for each difficulty rank of vocabulary. The user profile satisfying the above requirements is defined as following.

*Definition 2:* The **time-decayed user profile**, denoted by  $TUP$ , is defined as

$$TUP = \{R, fc_1, fc_2, \dots, fc_i, \dots, fc_n\}, \quad (3)$$

where  $R$  is the vocabulary model with difficulty ranks as defined in (1),  $R$  records the learning status of each word as defined in (2).  $fc_i$  records the forgetting curve of the vocabulary of the  $i^{th}$  rank, which is defined as

$$fc = \{(et, ret) \mid 0 \leq et \leq 31, 0 \leq ret \leq 100\}, \quad (4)$$

where  $et$  is the elapsed time since learning,  $ret$  is retention at the time  $et$ , which is calculated by

$$ret = \frac{original\ learning - relearning}{original\ learning} \times 100. \quad (5)$$

In Equation (5), *original learning* is the number of words in vocabulary learning task, *relearning* refers to the number of words that are forgotten and need to be reviewed, and the *ret* is the final score of retention at the time  $et$ .

According to Ebbinghaus Forgetting Curve, when the elapsed time since learning is bigger than a month, the retention words will be remembered for a long time. Therefore it is enough to set the upper bound of  $et$  as 31 days.  $et$  can also be a decimal to record the elapsed time less than a whole day, for example,  $et = 0.5$  means the elapsed time is 12 hours.

For a new learner, the values of  $fc$  can be initialized according to Ebbinghaus Forgetting Curve. To a specific elapsed time  $et$ , the corresponding  $ret$  can be initialized as

$$ret = e^{-et/r}, \quad (6)$$

where  $r$  is the difficulty rank of vocabulary. Another way is to initialize the forgetting curve based on the average of other learners' forgetting curves.

### 3. TIME-DECAYED USER PROFILE TRAINING

The training of TUP is the process to acquire the characteristics of a learner in vocabulary learning process. The acquisition is a dynamic process and the atom unit of acquisition is based on each elapsed time on each difficult rank. The general process of training the user profile is shown in Figure 2, which includes the following three steps.

#### 3.1 Generate Vocabulary Learning Task

Vocabulary learning tasks are groups of words to test the mastery level of a learner. According to the definition of TUP, the learning task should be able to test the mastery of words belonging to different difficulty rank at different elapsed time. The learning task is defined as

$$T = \begin{bmatrix} T_{1,1} & \dots & T_{1,31} \\ \dots & T_{i,j} & \dots \\ T_{n,1} & \dots & T_{n,31} \end{bmatrix}, \quad (7)$$

where each  $T_{ij}$  is an atom learning task to test the mastery level of words belonging to difficulty rank  $r_i$  at the elapsed time  $j$ .

The process of generating vocabulary learning task is described in Algorithm 1.

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#### **Algorithm 1: TUP Training Data Generation**

**Description:** Generate the vocabulary learning tasks for a learner to collect training data for Algorithm 2 to train the time-decayed user profile for the learner.

**Input:**  $R$ , the vocabulary with difficult ranks  
 $m$ , the number of words in each subtask.

**Output:** Learning Task,  $T$

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1. For  $r = 1$  to  $n$
  2. For  $et = 1$  to  $31$
  3. While  $k < m$
  4.     Select a word  $w$  from  $R$  randomly
  5.     If ( $R.w.r = r$  and  $R.w.et = et$  and  $w \notin T_{ij}$ )
  6.          $T_{ij} = T_{ij} \cup R.w$
  7.     Endif
  8.    Endwhile
  9.    If  $T_{ij}.length < m$  Then
  10.       Select  $(m - T_{ij}.length)$  words from  $R_r - T_{ij}$
  11.    Endif
  12. Endfor
  13. Endfor
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### 3.2 Get the Feedback from E-learning System

Vocabulary E-learning system interacts with learners, performs the vocabulary testing tasks, tests the mastery level of each testing subtask in (7), and generates test results for the user profile updating in the next step.

Because the design of E-learning system is not the main work of this paper, here we just give the definition of test results, which is denoted as

$$TR = \begin{bmatrix} tr_{1,1} & \dots & tr_{1,31} \\ \dots & tr_{i,j} & \dots \\ tr_{n,1} & \dots & tr_{n,31} \end{bmatrix}, \quad (8)$$

where each  $tr_{i,j}$  is the result of learning task  $T_{i,j}$  and the value of  $tr_{i,j}$  is calculated by (5).

### 3.3 Update the User Profile

Based on the test results of E-learning system, the forgetting curves of each difficulty rank can be generated and used to update the user profile, which is shown in algorithm 2.

In algorithm 2,  $\infty$  in test results means that there is no result for the test subtask, the values of  $fc$  is initialized according to (6).

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**Algorithm 2: TUP Updating Algorithm**

**Description:** Generate the new forgetting curves to update the TUP according to the test results from E-learning system.

**Input:** TUP

Test Results, TR

**Output:** TUP (Updated)

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1. For  $r = 1$  to  $n$
  2. For  $et = 1$  to  $31$
  3. If  $(tr_{r,et} = \infty)$  Then
  4.      $ret = e^{-j^r}$
  5. Else
  6.      $ret = tr_{r,et}$
  7.     If  $ret > FC.fcr.ret|_{et-1}$  Then
  8.          $ret = FC.fcr.ret|_{et-1}$
  9.     Endif
  10. Endif
  11.  $FC.fcr = FC.fcr \cup (et, ret)$
  12. Endfor
  13. Endfor
- 

## 4. EXPERIMENTS

Three experiments are shown in this section to validate the effectiveness of the proposed user profile.

**Data Set:** In these experiments, we use College English vocabulary as the data set. College English is a second language course in Chinese university, which is ranked from level 1 to 6. The vocabulary is also divided into 6 ranks. So the difficult rank of the vocabulary in the experiments is 6.

**Experiment Participants:** We select 60 none-English major students from different departments in a university. Among these students, 20 students are freshmen whose English level is level 1~2, another 20 students are sophomores whose English level is level 3~4, the last 20 students are juniors whose English

level is 5~6. Also students are selected according to their scores in English course to ensure each group consists of students with different levels: good level, middle level, and low level.

All 60 students are divided into two groups randomly: one is experimental group, the other is control group. Each group has 30 students.

#### 4.1 Experiment on evaluating the Accuracy of TUP

**Experimental Goal:**

This experiment is designed to validate the accuracy of TUP.

The accuracy of TUP refers to the degree that the forgetting curves fit the actual situations of the learners. We first generate a learning/test task for each learner according to the forgetting curves in his TUP. The learning/test task consists of the words are just forgotten according to the forgetting curves. If the test result shows that the learner really forgets these words, and then the forgetting curve is accurate, otherwise it is not. The total accuracy of a forgetting curve is the average of each time on the curves.

**Experimental Process:**

- (1) Make a study plan for duration of 31 days, the duration of learning time in each day is 30 minutes.
- (2) Select a student from the experimental group to participate in the learning process according to the study plan. During the learning process, the user profile of the student is trained. At last, the user profile has forgetting curves with the length of 31 days.
- (3) Generate test tasks for the student according to the forgetting curves in his user profile.
- (4) The student does the test and the score of each test is recorded to calculate the accuracy.
- (5) Repeat the steps from (2) to (4) for each student in the experimental group and consequently we get 30 results.
- (6) Calculate the average accuracy of the forgetting curve of each difficult rank based on the above 30 results
- (7) Calculate the total average accuracy of all the average values in step (6).

**Experimental Results:**

The experimental results are shown in Figure 3. In the figure each line is the accuracy of a forgetting curve belonging to a difficult rank. For example, R1 refers to the accuracy of the 1<sup>st</sup> rank of the vocabulary (The words of College English level 1). Each point on the line is the average of the accuracy of the results of 30 students. The total average of the accuracy is 0.852.

#### 4.2 Experiment on comparing the Accuracy between TUP and UP

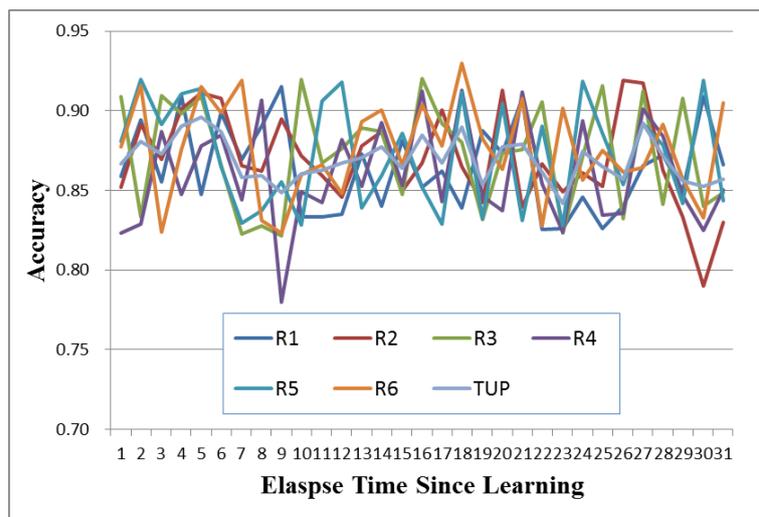


Figure 3. The Accuracy of TUP

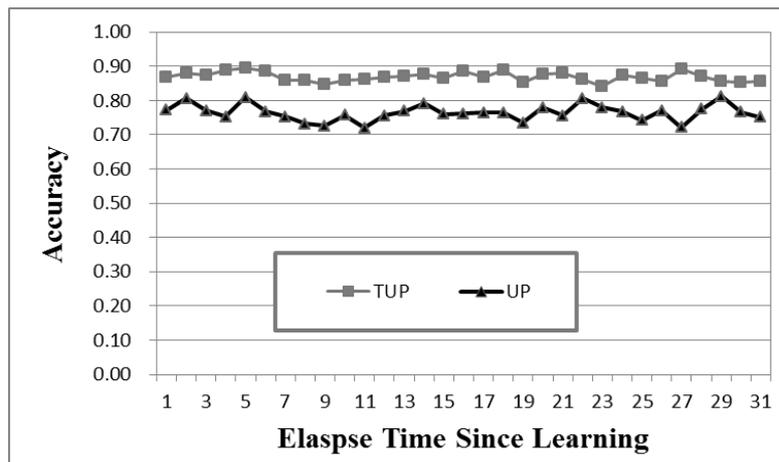


Figure 4. The accuracy comparison between TUP and UP (Ebbinghaus Forgetting Curve)

#### **Experimental Goal:**

The goal of this experiment is to compare the accuracy of the proposed TUP with the UP that uses Ebbinghaus Forgetting Curve.

#### **Experimental Process:**

The process of the experiment is the same as the first experiment. The participants of the experiment are the students of control group.

#### **Experimental Results:**

The experimental results are shown by the line UP in Figure 4, which is the average of all students of control group. The average result of Experiment 1 is also shown by the line TUP in Figure 4 for comparing with UP.

The results show that TUP (the time-decayed user profile) does better than UP (the user profile using Ebbinghaus Forgetting Curve), which also means that TUP can be used to make the review plan in vocabulary e-learning system to improve the SLVL efficiently.

### **4.3 Experiment on the Effectiveness in improving Vocabulary Learning**

#### **Experimental Goal:**

The goal of this experiment is to compare the effectiveness between TUP and UP in improving vocabulary learning.

#### **Experimental Process:**

- (1) Make a study plan for duration of 31 days and the duration of learning time in each day is 30 minutes.
- (2) All the students of the experimental group do the learning with the help of TUP. At the same time, all the students of the control group do the learning with the help of UP (the same as Experiment 2)
- (3) After the plan is completed, each student will be tested with the purpose of how they have mastered these respectively words.
- (4) Calculate the average of students from different grades (freshmen, sophomore, and junior) in each group (the experimental group and the control group) respectively.

#### **Experimental Results:**

The result shown in Figure 5 declares that the TUP is more effective in improving vocabulary learning compared with UP.

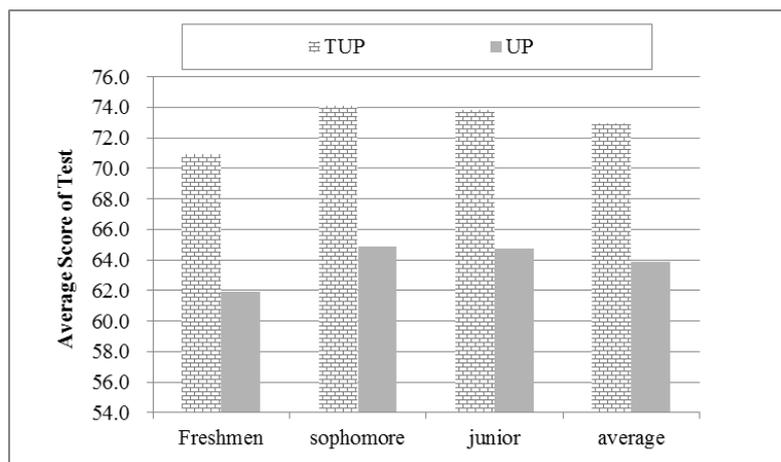


Figure 5. The effectiveness comparison between TUP and UP in improving vocabulary learning

## 5. CONCLUSION

Vocabulary learning is the foundation of second language learning, and a rich vocabulary makes the skill of listening, speaking, writing and oral easier to perform. Many E-learning systems have been developed to help learners to learn vocabulary efficiently. In most of these systems, Ebbinghaus Forgetting Curve is employed to make the review schedule for learners. However, learners have difference in learning ability, so the review schedule based on Ebbinghaus Forgetting Curve may not be fit for every learner. To solve the problem, this paper proposed the time-decayed user profile (TUP) to store the personalized Forgetting Curves for each learner. First TUP is defined and then two algorithms, TUP Training Data Generation algorithm and TUP updating algorithm, are proposed to train TUP. The experimental results show that the proposed time-decayed user profile can model the personalized learning characteristics of learners accurately.

The future work of this paper includes the following:

- (1) Develop an e-learning system with user-friendly interface to support larger experiments.
- (2) Validate the proposed user profile in larger experiments which means more participants and longer experimental period.

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