A Personalized English Vocabulary Learning System Based on Cognitive Abilities Related to Foreign Language Proficiency

Dai-Young Kwon[1], Heui-Seok Lim[1], WonGyu Lee[1], Hyeon-Cheol Kim[1], SoonYoung Jung[1], Taeweon Suh[1] and Kichun Nam[2]
[1]Department of Computer Science Education, Korea University, Seoul, Korea
[e-mail: {daiyoung.kwon, lee}@inc.korea.ac.kr, {limhseok, harrykim, jsy, suhtw}@korea.ac.kr]
2 Department of Psychology, Korea University, Seoul, Korea
[e-mail: kichun@korea.ac.kr]
*Corresponding author: Heui-Seok Lim

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Abstract

This paper proposes a novel of a personalized Computer Assisted Language Learning (CALL) system based on learner's cognitive abilities related to foreign language proficiency. In this CALL system, a strategy of retrieval learning, a method of learning memory cycle, and a method of repeated learning are applied for effective vocabulary memorization. The system is designed to offer personalized learning based on cognitive abilities related to the human language process. For this, the proposed CALL system has a cognitive diagnosis module which can measure five types of cognitive abilities. The results of this diagnosis are used to create dynamic learning scenarios for personalized learning and to evaluate user performance in the learning. This system is also designed in order to have users be able to create learning word lists and to share them simply with various functions based on open APIs. Additionally, through experiments, it has shown that this system helps students to learn English vocabulary effectively and enhances their foreign language skills.

Keywords: Computer assisted language learning, personalized learning, English vocabulary learning, human language process

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1. Introduction

English learning is crucial in order to enter the university and to get a competitive job in non-English speaking countries. Especially, students in Asian countries such as Korea, China and Japan start to learn English in kindergarten and elementary school. This early education of English is most actively undertaken in private rather than in public schools. Investigating the English education circumstances in Korea in the preceding decade, the private education cost for English learning has remarkably increased. It has increased to more than fifteen billion dollars, amounting to 65% of the total cost of private education [1]. It has been estimated that Korean students spend an average of 4 hours per day in studying English between middle school and university. This is 1.5 times more than the average time for OECD countries [2]. According to ETS [3] statistics, 19% of the total number of applicants for TOFEL [4] are Korean. In TOFEL scores, moreover, Korea is ranked 89th among a total of 147 countries [5]. Consequently, considering invested resources and time, it can be concluded that English learning in Korea has been not performed effectively. This inefficiency in English learning is not only a problem in Korea, but also in most other non-English speaking countries, such as Japan, China and Vietnam.

Learning vocabulary is the first step in English learning which is imperative and essential. Most research on English learning in recent years has also emphasized the importance of vocabulary learning [6]. However, learners studying vocabulary share the common problems such as requiring a lot of memorization and forgetting the memorized vocabulary easily. Also, in the case where learners cannot exactly memorize the vocabulary with correct spelling, meaning and pronunciation, using memorized vocabulary is limited to one skill area, such as reading or listening. Accordingly, in vocabulary learning, it is important that the memorized vocabulary should be maintained without being forgotten and that all information of the word should be memorized exactly. For this, various learning strategies and methods have been developed and used. Especially, repeated learning based on Ebbinghaus' forgetting curve [7] is a powerful learning method for maintaining memorized vocabulary. From research based on Repeated learning, several vocabulary learning systems referred to as CALL (Computer Assisted Language Learning) have been proposed [8][9]. These CALL systems have another common feature that English learning proceeds to be personalized to a student's abilities. In these CALL systems, by evaluating the learner's achievements, the learning is personalized. Recently, numerous studies have been conducted to investigate the human language process in the psychology and brain science domain. Through this research, it has been proven that cognitive abilities in the brain largely affects the language learning and that the areas of the brain used in native language and foreign language are different [10][11]. Furthermore, tests based on cognitive abilities have been developed for measuring foreign language proficiency in all language skills (reading, writing, listening and speaking) [12]. These tests can evaluate whether the vocabulary has been acquired, and also how quickly it can be retrieved when needed [11]. Therefore, tests based on cognitive abilities can personalize vocabulary learning more precisely and can maximize the effect of vocabulary learning.

In this paper, by integrating a repeated learning system based on Ebbinghaus' forgetting curve and language proficiency tests based on cognitive abilities, a novel of a personalized CALL system is proposed for English vocabulary learning. This proposed CALL system is designed to have a diagnoses module for language proficiency which is divided into five tests and is used to determine the amount of learning for spelling, meaning and pronunciation. The diagnosis results are also used to create learning scenarios and to evaluate user performance. In a learning module, 16 learning tasks for spelling, meaning and pronunciation are offered and repeated learning is processed with dynamic learning task sequences. The proposed CALL system offers various functions for learners to have them create learning word lists which can be easily shared with Google open APIs [13] and AJAX [14]. Additionally, through two types of experiments with undergraduate students, it is shown that the proposed CALL system is effective not only for memorizing vocabulary, but also for enhancing the retrieval ability for this vocabulary.

This paper is organized as follows. Section 2 introduces various studies related to learning methods and language proficiency tests for foreign language learning. Section 3 presents the vocabulary learning model for the proposed CALL system. Section 4 explains the system design in detail Analyses of the experimental results are explained in Section 5, and Section 6 concludes this paper.

2. Related Work

2.1. Learning Strategies and Methods Based on Cognitive Abilities

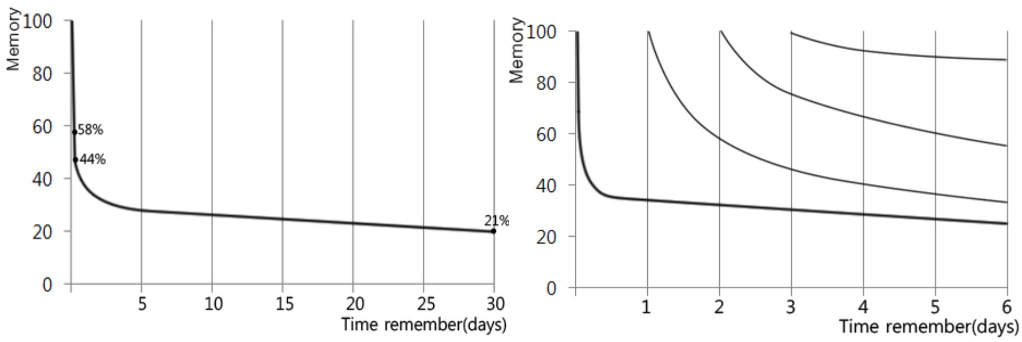


Fig.1. Ebbinghaus' forgetting curve.

Ebbinghaus (1885) investigated the principle of forgetting through experiments which has shown that several words were memorized and the number of memorized words decreased as time passed [7]. Shown as in **Fig. 1**, memorized content starts to be forgotten immediately after the end of learning. After twenty minutes, 42% of memorized content is forgotten; after one hour, 54% is forgotten; after one month, 79% is forgotten. However, as also shown in **Fig. 1**, when learning is repeated once a day for 4 days, over 90% of the learned content is retained [15]. Therefore, repeated learning based on Ebbinghaus' forgetting curve can be greatly effective for vocabulary learning. Repeated learning can be divided into two types: explicit learning and implicit learning. As implicit learning is closely related to language knowledge, it is therefore important in language learning [16]. In vocabulary learning, implicit learning can be performed by presenting a word included in several sentences repeatedly or by teaching words with semantic relations (for example: doctor & nurse).

Martin (2004) showed that the learning by teaching method is very effective for foreign language learning [17]. Learning by teaching means that learners create their own learning content and teach themselves [18]. Its effectiveness is explained by three principles: elaboration, active learning, and the frame effect. Elaboration enhances the elaborative memory of information as learners handle elaborative information in the process of creating their own learning content. Active learning encourages learners to study voluntarily by improving the learning motivation through active participation in a class. For example, by explaining to other students and helping them to understand. The frame effect helps students to see invisible information as a learner through the process of creating learning content as a teacher [19].

2.2 Foreign Language Proficiency Tests Based on Cognitive Abilities

2.2.1 Reading Span Test

Reading span refers to the size of a sentence that can be read at once. It can be used for measuring the capacity of working memory [20]. According to experimental research conducted among bi-linguists and English learners, bi-linguists were found to have a larger reading span and faster reading speed. From the viewpoint of cognitive ability, this suggests that learners with a larger working memory capacity and more rapid reading speed can learn foreign languages more effectively and become experts at it [21]. Additionally, it is found that reading span is closely related to language comprehension [22]. Therefore, the larger reading span and reading speed learners have, the more expert bi-linguists they become.

2.2.2 Lexical Decision Task

The lexical decision task (LDT) is a procedure for measuring how quickly people classify proposed contents as words or non-words. [12] It has been widely used in psychology and psycholinguistic experiments for investigating semantic memory and lexical access. Generally, in the lexical decision task, the reaction times and the error rates in the various conditions of presented words are measured for one or more language skills (reading, writing, speaking and listening). Through LDT experiments between basic ESL (English as a Second Language) learners, advanced ESL learners and English native speakers, Harrington (2006) showed that the differences in reaction times and error rates in each group are obvious [10]. Accordingly, the lexical decision task can be used as a measuring tool for proficiency in English.

2.2.3 Priming Effect

Priming refers to the phenomenon whereby prior stimulus (include unawareness level) influences response to a later stimulus; that is, the ability of detection or confirmation for a stimulus is promoted as using previously acquired information [23]. As the relation of earlier stimulus and later stimulus, priming can be divided into several groups, such as semantic priming and associative priming. The priming effect means that a significant difference is presented between the cases of the pair of stimulus words whether it is related or not, when priming works. Accordingly, in semantic priming, the priming effect means a decrease in detection time when pair words have a semantic relation rather than no relation [24]. When a foreign language is used as a stimulus in priming, the semantic priming effect is influenced by the proficiency in the foreign language with no relation to the learning time [11]. Also, it is evidence that implicit and explicit memories in the human language process are different [23].

2.3. Computer Assisted Language Learning (CALL) System

The major advantages of a CALL system are that it can offer a powerful self-access facility free from the restrictions of time and location and gives personalized learning content for the individual learners [25]. Recently, smart.fm [8] and Honguci Wang's CALL system [9] show these advantages very well. Smart.fm is a web-based system that offers three types of vocabulary learning based on Ebbinghaus' forgetting curve, which are multiple-choice

questions, dictations and games. It is a user-created content system in which users can build up word lists and share them freely with other users. Honguci Wang (2008) proposed a mobile learning system for vocabulary learning. It offers personalized vocabulary learning based on item response theory and learning memory cycle using Ebbinghaus' forgetting curve. Through experiments, Honguci Wang (2008) showed that the learning memory cycle using Ebbinghaus' forgetting curve is effective for memorizing vocabulary [9].
Investigations have also been conducted on foreign language learning based on the human language process model in the brain science domain. Lexia [26] is an English learning program to overcome dyslexia based on the human language process model in the brain. It offers a diagnosis service to measure the language processing ability in the brain and consists of five learning steps customized from the diagnosis results, such as phoneme distinction, pronunciation, lexical meaning, and sentence understanding. Lexia is insufficient for application to English learners in non English-speaking countries, but it shows that language learning based on the human language process model in the brain can enhance foreign language proficiency.

3. Repetitive Retrieval Vocabulary Learning Model

To acquire good foreign language skills (reading, listening, speaking and writing), all vocabulary information, namely spelling, pronunciation and meaning, should be learned precisely in the vocabulary learning process. Accordingly, vocabulary learning requires a large amount of stabled memorization, continuously. This continuous memorizing exhausts learners and in the result, it leads them to conclude that vocabulary learning is difficult.

Repetitive retrieval learning is an effective method in vocabulary learning because a learner studies vocabulary while repetitively performing the tasks to retrieve information of vocabulary without memorizing it directly [27]. In the proposed CALL system, as shown in **Fig. 2**, repetitive retrieval vocabulary learning is designed to have two steps with eight learning tasks in each.

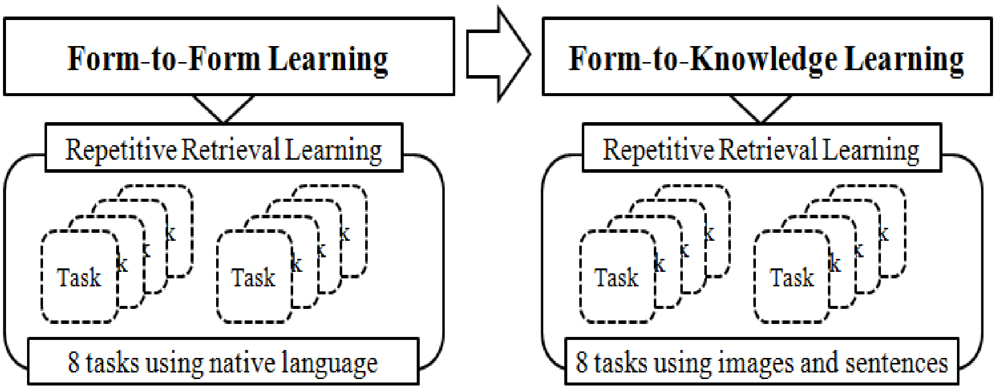


Fig. 2. Repetitive retrieval vocabulary learning model

The first step is Form-to-Form learning. This is a course to memorize the information for words, such as spelling and pronunciation, and to connect this memorized information with native language responses by repetitively performing the six tasks in **Table 1**.

Table 1. Form-to-Form learning tasks

Learning Task	Task explanation	Object
Presenting learning word	A learner sees an English word with a native response word and an English sound for defined seconds.	To form phoneme information of an English word.
Dictating word	A learner sees and dictates an English word with sound for defined seconds	To form phoneme and grapheme information of an English word.
Reading a native word and selecting an English word	A learner selects an English word, looking for a native response word.	To link the spelling of an English word to a native response word.
Reading an English word and selecting a native response word	A learner selects a native word, looking for an English response word.	To link the spelling of a native word to an English word.
Listening to an English word and selecting an English word	A learner selects an English word, listening for an English response word.	To link the spelling of an English word to phoneme information of an English word.
Listening to an English word and selecting a native response word	A learner selects a native response word, listening for an English word.	To link phoneme information of an English word to the spelling of a native response word.
Reading a native response word and dictating an English word	A learner dictates an English word, looking for a native response word.	To link the spelling of a native response word to the spelling of an English word.
Listening to an English word and dictating an English word.	A leaner dictates an English word, listening for an English response word.	To link phoneme information of English word to the spelling of an English word.

The second step is Form-to-Knowledge learning. This is a course to learn the semantic information of vocabulary for the memorized words in Form-to-Form learning, through repetitively performing six tasks using images and sentences in Table 2.

Table 2. Form-to-Knowledge learning tasks

Learning Task	Task explanation	Object
Presenting learning image of word	A learner sees an image of a word with a native response word and an English word and sound for defined seconds.	To form phoneme and grapheme information of an English word.
Watching image and selecting an English word	A learner sees an image for an English response word.	To link the spelling of an English word to grapheme information of an English word.
Reading an English word and selecting image	A learner selects an English word, looking for a response image.	To link grapheme information of an English word to the spelling of an English word.
Listening to an English word and selecting a image	A learner selects a response image, listening for an English word.	To link grapheme information of an English word to phoneme information of an English

		word.
Watching image and dictating an English word	A learner dictates an English word for a response image.	To link the spelling of an English word to grapheme information of an English word.
Watching an English word and using an example sentence	A learner looks at a presented English word and an example sentence for defined seconds.	To link syntactic/semantic information of an English word to the spelling of an English word.
Reading an English sentence and selecting an English word	A learner selects an English word to fill a blank, looking for an English sentence.	To link syntactic/semantic information of an English word to the spelling of an English word.
Reading an English sentence and dictating an English word.	A learner dictates an English word to fill a blank, looking for an English sentence.	To link syntactic/semantic information of an English word to the spelling of an English word.

In the proposed CALL system, the scenario and ratio of all 16 learning tasks in the two steps are personalized based on the learner's diagnosis results for foreign language proficiency. This is explained in section 4.2.

4. System Design

4.1 Overall Architecture

As shown in **Fig. 3**, the whole system consists of three parts: Diagnoses, Contents management & Personalization and Learning & Evaluation. In the diagnoses part, the working memory related to human language process is measured by a verbal span test and foreign language proficiency is also measured by a lexical decision test and priming test for personalization. Additionally, a standard response time test is performed for instant feedback and dynamic learning task scenario in the learning module. The results of the diagnoses for foreign language proficiency are classified into three levels: high, medium and low. This is used to determine the ratio of learning tasks related with each diagnostic test.

In the contents management & personalization part, learners can create their own word lists and share them with others with simple user interfaces based on AJAX [14] and Google open APIs [13], which offers translating, searching images and sentences, and TTS (Text to Speech). In this part, word lists created by learners transform into retrieval vocabulary learning tasks, mentioned in section 3, based on the diagnosis results. In the learning and evaluation part, learners process the vocabulary learning based on retrieval vocabulary learning tasks and the instant feedback based on standard response time test are offered for evaluation. According to the instant feedback, the sequence of learning tasks, in the dynamic learning task scenario, can be changed during the learning process and is also offered. Lastly, when the learning process is completed, the evaluation results of the learning task are sent to the learning contents and personalizing part. Through the evaluation results, retrieval vocabulary learning tasks can be re-created.

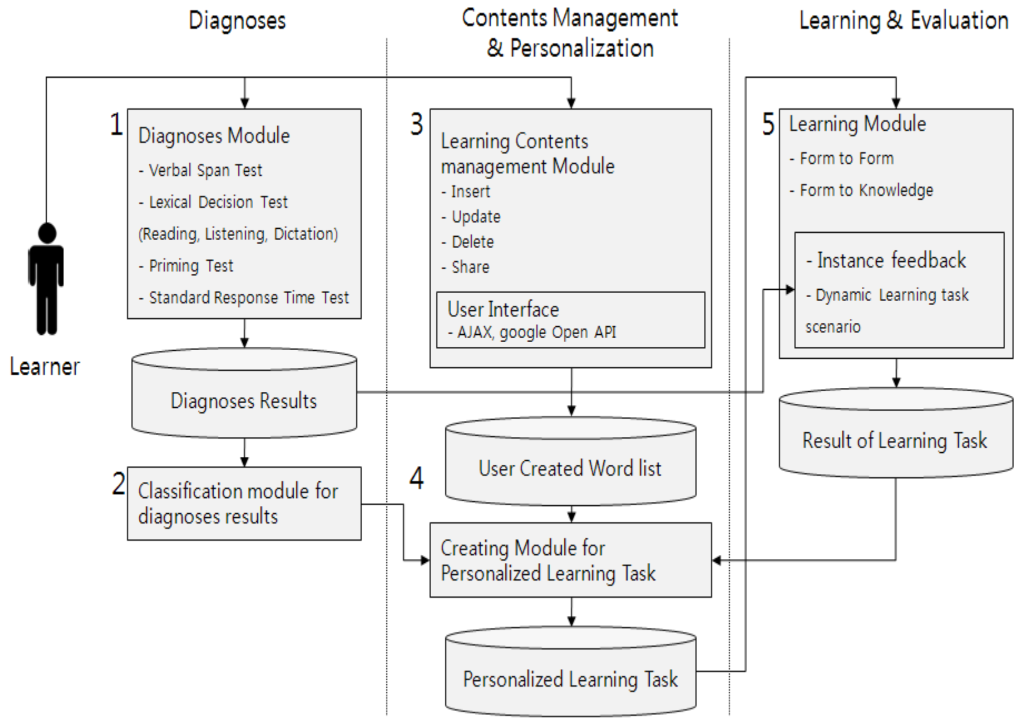


Fig. 3. System architecture of the proposed English vocabulary learning system.

4.2 Diagnoses Module

The diagnoses module consists of three cognitive ability tests for foreign language proficiency and a standard response test for learning tasks. The three cognitive ability tests are a verbal span test, a lexical decision task and a priming test. The lexical decision task is further divided into three tests: reading, listening and dictation. The standard response test is to offer an instant feedback. All the tests are developed to have pre-tests for instructions.

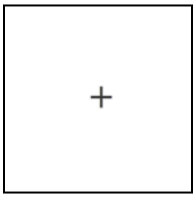
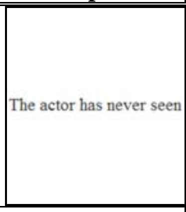
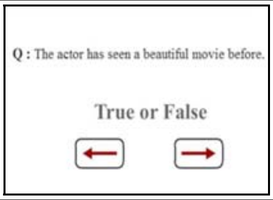
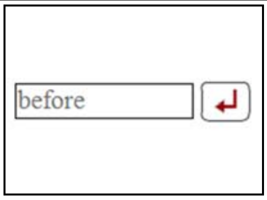
4.2.1 Verbal Span Test

The verbal span test is for measuring the size of a user's memory for foreign language vocabulary and working memory. It was developed based on several studies related to reading span test as mentioned in section 2.2. Diagnosis results of the verbal span test are used to determine the size of the number of presenting vocabulary at once and the size of the number of choices in multiple-choice questions for personalization. The details of personalization are explained in section 4.4.

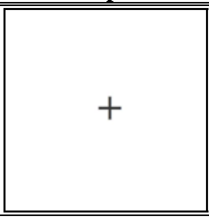
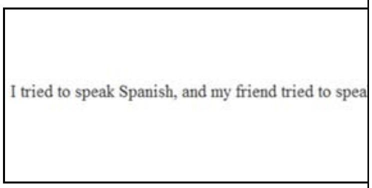
As shown in **Table 3**, the verbal span test consists of 4 steps, with each step repeated as the test advances a level. In the first step, a small black cross is presented in the center of the screen for 500ms to induce the learner’s concentration. The second step presents a sentence that includes a word at the end that the learner should memorize. In third step, a question is presented to determine whether the learner comprehended the presented sentence or not. Lastly, in the fourth step, blanks to input the words the learner memorized in the second step are presented. As the number of increasing level in the test as step 2 and step 3 are repeated and the blanks are presented in the fourth step. The level at which the learner gives the wrong answers in the second or third step indicates the size of the learner’s working memory related to foreign language learning.

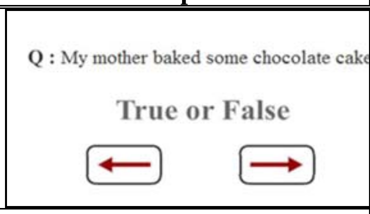
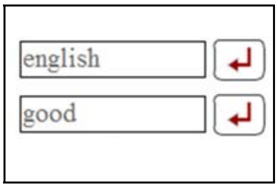
Table 3. Screens images for the verbal span test

Level 1

Step 1	Step 2	Step 3	Step 4
			
Concentration	Presenting a sentence	Presenting a question	Dictating the last word in a presented sentence

Level 2

Step 1	Step 2	Step 3
		
Concentration	Presenting a sentence	Presenting a question

Step 2	Step 3	Step 4
		
Presenting second Sentence	Presenting a question	Dictating the last words in the two presented sentences

4.2.2 Lexical Decision Task (LDT)

In the proposed CALL system, the Lexical Decision Task (LDT) is divided into three types: Reading LDT, Listening LDT and Writing LDT. They were developed based on the several studies related to LDT mentioned in section 2.2. In all LDTs, respond times and error rates are measured as a result and 75 words are used for stimulus. Each LDT is performed separately and each result is used independently for personalization. The details of personalization using LDT are explained in section 4.4 and section 4.5

Reading LDT : Reading LDT is for measuring a learner's language proficiency in reading and the results are used to determine the ratio of retrive learning tasks, as mentioned in section 3, related with reading ability as shown **Table 4**.

Table 4. Retrieval learning tasks related to reading LDT

Step	Reading LDT

Form-to-Form learning	Reading a native word and selecting an English word
	Reading an English word and selecting a native response word
Form-to-Knowledge learning	Reading an English word and selecting an image
	Watching an image and selecting an English word

As shown in **Table 5**, reading LDT consist of 4 steps, with all steps repeated according to the number of stimulus words. In the first step, a small black cross is presented in the center of the screen for 500ms to induce the learner's concentration. The second step presents a blank for 100ms. The third step presents a target word for 800ms. Lastly, in the fourth step, the learner decides whether a target is a word or non-word by using the arrow keys.

Table 5. Screen images for Reading LDT.

Step 1	**Step 2**	**Step 3**	**Step 4**
+		cup	Word ← Nonword →
Concentration	Blank Screen	Target Word	Making a Decision

Listening LDT: Listening LDT is for measuring a learner's language proficiency in listening. The results are used to determine the ratio of retrieval learning tasks, as mentioned in section 3, related with listening ability as shown in **Table 6**.

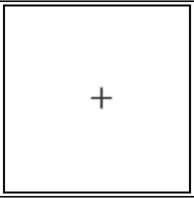
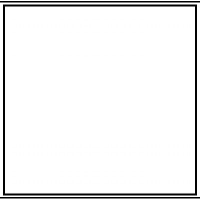
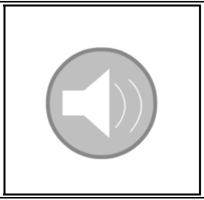
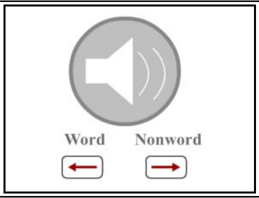
Table 6. Retrieval learning tasks related to listening LDT

Step	**Listening LDT**
Form-to-Form learning	Listening to an English word and selecting an English word
	Listening to an English word and selecting a native response word
Form-to-Knowledge learning	Listening to an English word and selecting an image

As shown in **Table 7**, reading LDT consists of 4 steps, with all steps repeated according to the number of stimulus words. In the first step, a small black cross is presented in the center of the screen for 500ms to induce the learner's concentration. The second step presents a blank for 100ms. In the third step, the pronunciation of a target sounds once for 800ms. Lastly, in the fourth step, the learner decides whether the target is a word or non-word by using the arrow keys.

Table 7. Screen images for Listening LDT.

Step 1	**Step 2**	**Step 3**	**Step 4**

			
Concentration	Blank Screen	Target Sound	Making a Decision

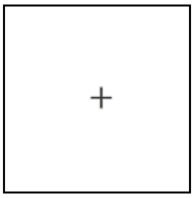
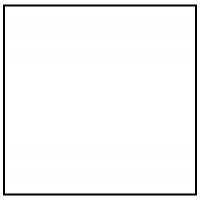
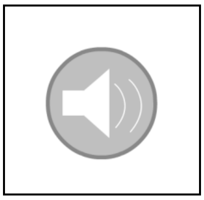
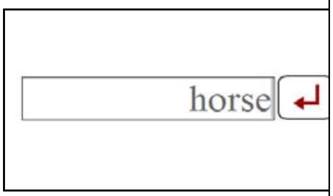
Dictation LDT : Dictation LDT is for measuring a learner's language proficiency in dictation. The results are used to determine the ratio of retrieval learning tasks, as mentioned in section 3, related to dictation ability as shown in **Table 8**.

Table 8. Retrieval learning tasks related to dictation LDT

Step	Dictation LDT
Form-to-Form learning	Reading a native response word and dictating an English word
	Listening to an English word and dictating an English word.
Form-to-Knowledge learning	Watching an image and dictating an English word
	Reading an English sentence and dictating an English word.

As shown in **Table 9**, reading LDT consists of 4 steps, with all steps repeated according to the number of stimulus words. In the first step, a small black cross is presented in the center of the screen for 500ms to induce the learner's concentration. The second step presents a blank for 100ms. In the third step, the pronunciation of a target sounds once and non-words are not used. Lastly, in the fourth step, the learner dictates the target word by using the keyboard.

Table 9. Screen images for Dictation LDT.

Step 1	Step 2	Step 3	Step 4
			
Concentration	Blank Screen	Target Sound	Dictation

4.2.3 Priming Test

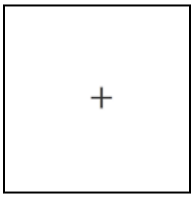
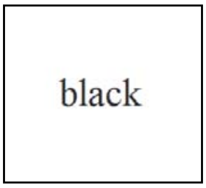
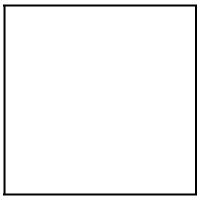
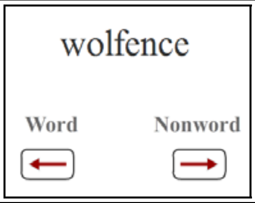
This is for measuring a learner's retrieval ability for foreign languages. In other words, it measures how fast a foreign language can be employed when that foreign language is required. This test, therefore, can be used to measure speaking ability indirectly. In the priming test, a gap between the response times of pairs of related words and pairs of non-related words is measured as a test result. It was also developed based on several studies related to priming tests as mentioned in section 2.2. Priming test results are used to determine the ratio of retrieval learning tasks related to retrieval ability for foreign language as shown in **Table 10**.

Table 10. Retrieval learning tasks related to priming test

Step	Priming test
Form-to-Knowledge learning	Reading an English sentence and selecting an English word

As shown in **Table 11**, the priming test consists of 4 steps, with all steps repeated according to the number of stimulus words. In the first step, a small black cross is presented in the center of the screen for 500ms to induce the learner's concentration. The second step presents a word as a primer for 150ms; the third step presents a blank for 100ms. Lastly, in the fourth step, a target word is presented and the learner decides whether it is a word or non-word by using the arrow keys.

Table 11. Screen images for priming test

Step 1	Step 2	Step 3	Step 4
			
Concentration	Priming word	Blank Screen	Target Word & Making a Decision

4.2.4 Standard Response Time Test

This is for measuring the base response times used for immediately evaluating user performance in the learning module. Immediate evaluation of user performance is conducted by comparing the response time taken in the learning tasks with the measured basis response time in this test. Therefore, it is designed to have all types of the learning tasks used in the learning module and high frequency words are used as a stimulus to measure the response time of the learning task for already known words. Additionally, this immediate evaluation is used to create dynamic learning task scenarios in the learning module for personalized learning. This is explained in detail in section 4.5.

4.3 Classification Module of Diagnosed Results

To use the results of the diagnoses (Reading LDT, Listening LDT, Dictation LDT and Priming Test) for personalization, the values should be classified according to the learner's level of foreign language proficiency. In this system, foreign language proficiency is divided into three levels: high, medium and low. The K-nearest neighbors (k-NN) algorithm is used as a classify method.

Table 12 shows the learning data for k-NN classification. The high level group consists of early bi-linguists; the medium level group of those with TOEIC scores of 700~900; and the low level group of those with TOEIC scores of 400~600. Each group consists of 30 volunteers.

Table 12. Language proficiency levels for classification

Level	Criteria for classification	Students(N)
High	Early bi-lingual	30
Medium	TOEIC score 700~900	30

Low	TOEIC score 400~600	30

As shown in **Fig. 4**, the mean of reaction time ('y' axis) and the deviation of reaction time ('x' axis) in each diagnosis result are used as a classification feature. In the graph, the points represented as a small triangle indicate the results of diagnoses in high level language proficiency; the points represented as a small square indicate medium level language proficiency; the points represented as a small diamond indicate low language proficiency; and the black point indicates learner's diagnoses results. K is set to 10 in this system.

In **Fig. 4**, the black point representing the learner's diagnoses result is classified as being at the medium level as 7 points are in the medium level and 3 points are in the high level for all 10 points.

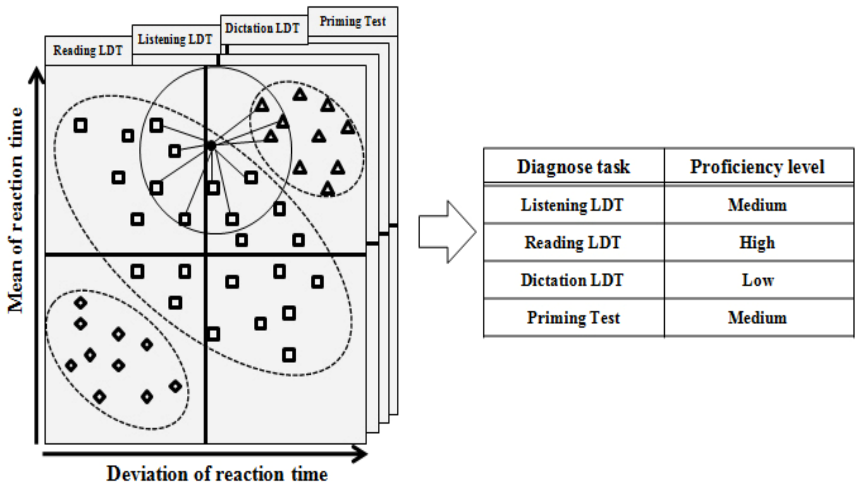


Fig. 4. Classification process with k-NN algorithm

The learner's level of language proficiency classified by the k-NN algorithm is used to define the ratio of the learning task related to each of the diagnoses (Reading LDT, Listening LDT, Dictation LDT and Priming Test) in the learning module for personalization.

4.4 Personalized Learning Features

- ***The number of words to learn at same time***: In the proposed CALL system, when learning starts, a learning word list is divided into several sets and each set is started to be learned in a certain order. To maximize each user's memory ability, each set has the maximum number of words that a learner can memorize at one time, which is determined by the Verbal Span test.
- ***Words and the number of options included in multiple-choice questions***: This indicates the size of feasible choice sets in the learning module. These choice sets consist of the other words in a learning word list, so it can have the effect of implicit learning. The size of choice sets is determined by Verbal Span Test.
- ***Learning sequence as re-learning based on Ebbinghaus' forgetting curve***: The proposed CALL system offers repetitive learning at 10-minute, daily and monthly intervals based on Ebbinghaus' forgetting curve. Therefore, as learners' evaluation score and learning speed, learning sequences are changed though learners start to learn the same

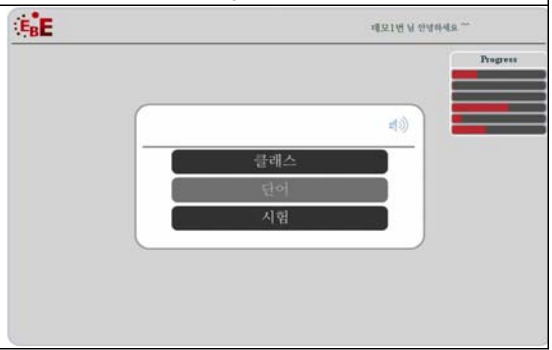
word list at the same time.

- ***Amount and ratio of learning tasks based on three LDTs and Prime test***: As the learner's foreign language proficiency from the diagnoses results, the amount and ratio of each learning task is determined. This can help learners to enhance insufficient language skills such as reading or listening. This is explained in detail in Section 4.5.3.
- ***Dynamic learning task scenario***: In the proposed CALL system, as an evaluation of a learning task, the next learning task is determined for effective memorization. This is explained in detail in Section 4.5.3.

4.5 The Learning Module

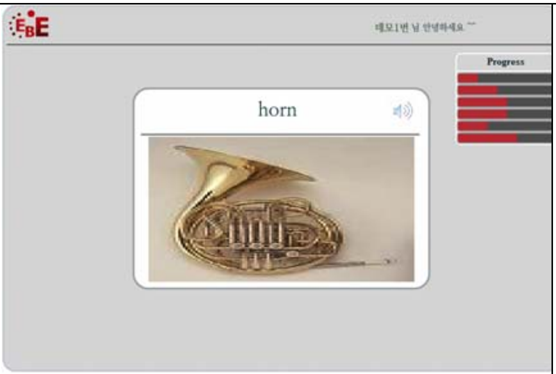
4.5.1 Implementation of Retrieval Learning Tasks

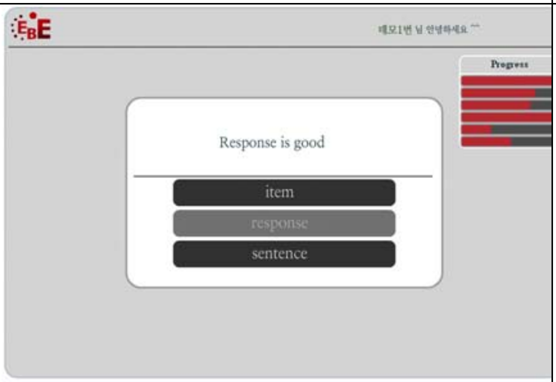
Table 13. Form-to-Form learning tasks

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>Presenting a learning word</td><td>Reading a native word and selecting an English word</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Reading an English word and selecting a native response word</td><td>Reading a native response word and writing an English word</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

<table>
<tr><td>Dictating a word</td><td>Listening to an English word and selecting a native response word</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Listening to an English word and selecting an English word</td><td>Listening to an English word and dictating an English word</td></tr>
</table>

Table 14. Form-to-Knowledge learning tasks

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>Presenting a learning image of a word</td><td>Watching an image and selecting an English word</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Watching an English word and selecting an image</td><td>Listening to an English word and selecting an image</td></tr>
</table>

	
Reading an English sentence and selecting an English word	Watching an image and dictating an English word
	
Reading an English sentence and selecting an English word	Reading an English sentence and dictating an English word

4.5.2 Instant Feedback

In the learning module, as the learner's response is analyzed, instant feedback is offered. The criterion of instant feedback is calculated using Eq. (1). In Eq. (1), t_i is the response time from the learning task in the learning module and T_i is the response time from the standard response time test mentioned in section 4.2.4. Accordingly, w represents the gap between the response time from the learning task and the response time from the standard response time test, which indicates how fast the current learning vocabulary is retrieved as compared with already-known vocabulary. Thus, if w is lower than 0, current learning vocabulary is determined to be well-learned vocabulary.

$$w = t_i - T_i \qquad (1)$$

As shown in Table 15, instant feedback consists of five types: incredible, perfect, great, good and bad. Incredible means that the current learning vocabulary has been memorized well and that learning for current vocabulary is more advanced than good to perfect. Bad means that the learner knows nothing of the current vocabulary or has forgotten the vocabulary. In this case, the learner should start to learn that vocabulary again.

Table 15. Types of instant feedback based on response time

Instant feedback	Condition
Incredible	ω < 0(ms), evaluating the current vocabulary is learned completely
Perfect	0 ≤ ω < 400(ms), evaluating the current vocabulary is not retrieved instantly
Great	400 ≤ ω < 1000(ms), evaluating the current vocabulary can be retrieved
Good	1000 ≤ ω (ms), evaluating the current vocabulary can be retrieved slowly
Bad	Answer is incorrect; evaluating the current vocabulary should be re-learned

4.5.2 Determination of the Ratio Learning Tasks Based on Instant Feedback and Classifications of Diagnosis Results

The number of executions of each retrival learning task is determined by instant feedback results and classification level of foreign language proficiency based on diagonoses results. **Table 16** presents the matrix of scores for determining the execution number of retrival learning tasks by instant feedback and foreign language proficiency.

Table 16. Score matrix for determining ratio of retrieval learning tasks

proficiency level / instant feedback	Low	Medium	High
Incredible	10	10	6
Perfect	6	4	3
Great	4	3	2
Good	0	0	0
Bad	0	0	0

As shown in **Table 16**, the learning module indicates that the learning task is completed when the total score is over 10. By using Eq. (2), the total score is calculated. In Eq. (2), i means a certain retrieve learning task, f means feedback values and w means the weight.

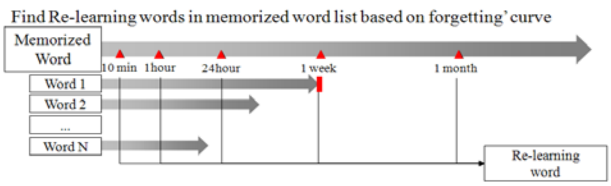
$$Total\ score_i = \sum_{0}^{n} f_n w_i \tag{2}$$

For example, in the retrieve learning task of 'Reading a native word and selecting an English word', if a learner's proficiency is medium in reading, the task can be completed by the learner getting one 'Incredible' feedback, a 'Perfect' feedback 3 times, or a 'Great' feedback 4 times.

4.5.3 Dynamic Leaning Task Scenario

In the learning module, a sequence of retrieve learning tasks is dynamically organized by instant feedback and the repetitive learning method based on Ebbinghaus' forgetting curve mentioned in section 2.1. As shown in **Table 17**, according to the instant feedback in the current learning task, the next learning task is determined and, when a word is learned completely, the word considered in the re-learning cycle based on Ebbinghaus' forgetting curve is added to a learning list sized to working memory measured in the verbal span test mentioned in section 4.2.1.

Table 17. Algorithm of dynamic learning task scenario

Input : *Instant feedback* **Output : *sceneNumber, wordNumber*** **IF** *feedback* is “Bad” Increase *count of “bad” feedback* **IF** *count of “bad” feedback* > 3 Repeat current scene. **ELSE** set next uncompleted scene *to sceneNumber* **END** **ELSE** Figure out each feedback **IF** sum of feedback is larger than 10 The scene has been completed **END** **IF** all scenes have been completed Delete completed word in the learning word list. **<u>Determine next word</u>** Insert *Nextword* in the learning word list.	 **Determine next word** Output : *nextWord* Find *re-learning word* in the completed word list **IF** *Re-learning word* exists Set *re-learning word to nextWord.* **ELSE** Set *New word* in non-memorized word list *to nextWord*. **END** Return (*nextWord)*

5. Experiments

5.1 Experimental Design

For the experiment, 52 undergraduate students were recruited ranging in the age of 21 to 29. They were divided into three groups: the experiment group, control group 1 and control group 2. The experiment group consisted of 19 participants and have had learned the vocabulary using the proposed CALL system. Control group 1 consisted of 11 participants and have had learned the vocabulary by rote. Control group 2 consisted of 22 participants and have had learned the vocabulary with a repeated learning method. The participants in all three groups memorized 40 words a day for a total of 120 words over three days. These 120 words were selected from low frequency words which the participants had never seen for accurate experiment results.

Fig. 5 presents the procedure of the experiment. All the participants in the three groups learned 120 words over three days and, after a week, DRT (Delayed Recall Task) and reading LDT (Lexical Decision Task) were carried out. DRT (Delayed Recall Task) was carried out by two methods. One was that an English word was shown and a native word was answered; the other was reverse of this first type. Reading LDT was carried out in the same manner as the LDT procedure mentioned in section 4.2.2.

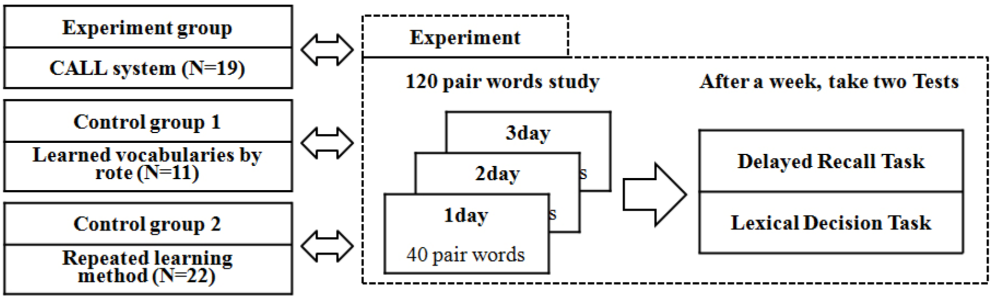


Fig. 5. Experiment procedure for DRT and LDT tests

5.2 System Evaluation

5.2.1 Delayed Recall Task

In the DRT test, the results for participants who gave incorrect answers to over 80% of all questions were removed for more accurate analyses. **Table 18** shows the descriptive data of the experimental results for the DRT test.

Table 18. Descriptive data of experimental results in the DRT test.

Group	Mean	Std. Dev	N
Experiment group (CALL system)	47.23	17.19	13
Control group 1 (Learned vocabulary by rote)	32.09	3.70	11
Control group 2 (Repeated learning method)	46.52	16.22	21

The mean of the experiment group's scores was the highest of the three groups, and control group 1 was the lowest. The gap between the three groups was verified by an F-test and the post-hoc was carried out by Dunnett.

Table 19. Analysis results of the DRT test

Source	SS	df	MS	F-value	p	Post-hoc
SSB (Between Sum of Squares)	1814.14	2	907.07	4.258*	.021	(Eg, Cg1) (Cg1,Cg2)
SSW (Within Sum of Squares)	8946.17	42	213.00			
Total	10760.31	44				

* $p < .05$

As shown in **Table 19**, a significant difference is an evident between the experiment group and control group 1. In the case of control group 1 and control group 2, a significant difference is also present. In the case of the experiment group and control group 2, however, a significant difference is not present. The reason of the similar results between the experiment group and control group 2 is that the effect of the repeated learning method is based on Ebbinghaus' forgetting curve.

5.2.2 Reading LDT

The reading LDT test was carried out for the experiment group and control group 2 who did not show a significant difference in the DRT test. In the DRT test, both the participant results and learning words below 20% of the correct answer rate were removed for accurate analyses and response times of correct answers were reflected. As shown in **Table 20**, the average response time for the experiment group was 801.2ms, while control group 2 was 868.6ms. A significant difference was also shown between the experiment group and control group 2 by the t-Test.

Table 20. Analysis results of the reading LDT test

Group	Mean	Std. Dev	t-value	p
Experiment group (CALL system)	797.63	112.62	2.087*	.044
Control group 2 (Repeated learning method)	866.75	93.79		

* p < .05

The reading LDT test shows a significant difference between the experiment group and control group 2, proving that learners using the proposed CALL system retrieve memorized vocabulary more rapidly than those of control group 2 using the repeated learning method. This suggests that the proposed CALL system offers a more effective method of vocabulary learning from the point of enhancing reading skill, as learners quickly use the memorized vocabulary when needed.

6. Conclusion

In this paper, we proposed a novel personalized CALL system based on cognitive abilities diagnoses for foreign language proficiency. In the proposed CALL system, a retrieval learning strategy, a learning memory cycle method and repeated learning method were integrated for effective vocabulary learning to enhance language skills. From the experiments conducted, the proposed CALL system showed significant results compared to the other learning methods. In particular, through the LDT experiment, it was shown that the proposed CALL system can enhance language skills. This CALL system, however, is just a pioneering effort in foreign language acquisition research. Therefore, the proposed CALL system should require more experiments to validate its cognitive effects with various methods, such as ERP (Event Related Potential). Currently, the proposed CALL system has been opened and freely serviced via the website of our university.

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Daiyoung Kwon is a Ph.D student in the Department of Computer Science Education at Korea University. He received his B.S and M.S degrees in Computer Science Education form Korea University, Seoul, in 2000 and 2006. His research interests include algorithmic thinking learning, educational programming languages and cognitive experiments for evaluating thinking abilities.

Heuiseok Lim received his B.S., M.S. and Ph.D. degrees in Computer Science from Korea University, Seoul, in 1992, 1994 and 1997, respectively. He is an associate professor in the Department of Computer Science Education at Korea University in Korea. He worked at SITEC of Samsung for two years after his PhD. He is a member of ACL and many other research groups. His research interests are in brain-neuro language processing and computer science education to enhance people's computational thinking.

Won-Gyu Lee is a Professor at Korea University, Dept of Computer Science Education in Seoul, Korea. His M.S and Ph.D. degrees in Computer Science from Tsukuba University. From 1993 to 1996 he was a senior researcher at Korea Arts and Culture Service. He was the president at Korea Association of Computer Education in 2002. Currently, he is the chief director of Creative Informatics & Computing Institute at Korea University. His research interests include computer science education, information retrieval and Database.

Hyeoncheol Kim is a Professor at Korea University, Dept. of Computer Science Education, in Seoul, Korea. He received BS and MS in computer science from the Korea University and the University of Missouri-Rolla, respectively. He received Ph.D in computer and information sciences from the University of Florida. he worked at GTE Data Services Inc. and Samsung SDS before he joined Korea University in 1999. His research interests include machine learning, human learning and learning software developments.

Soonyoung Jung received his B.S., M.S. and Ph.D. degrees in Computer Science from Korea University, Seoul, in 1990, 1992 and 1997, respectively. From 1997 to 2000, he was a senior researcher at Korea Advanced Integration Technology., ECO Inc. He is currently a Professor in the Department of Computer Science Education at Korea University, Seoul, Korea. His research interests include web-based education systems, database systems, knowledge management systems, and mobile & ubiquitous computing.

Taeweon Suh is an assistant professor in the Department of Computer Science Education, Korea University. Prior to joining academia, he was a systems engineer at Intel Corporation in Hillsboro, Oregon, USA. His research interests include embedded systems, computer architecture, multiprocessor, and computer education. He has a BS in Electrical Engineering from the Korea University, Korea, and an MS in Electronics Engineering from the Seoul National University, Korea, and PhD in Computer Engineering from the Georgia Institute of Technology, USA. He is a member of ACM and IEEE.

Kichun Nam is a Professor in the Department of Psychology at Korea University in Seoul, Korea. He received B.A. and M.A. degrees in Psychology from Korea University in 1985 and in 1987 respectively and Ph.D. in Psycholinguistics from University of Texas at Austin, USA in 1995. He was a senior researcher at language processing and natural language processing research centers, and has worked at the artificial intelligence laboratory at KAIST. He is currently the chief director of Wisdom Science Research Center at Korea University. He is the author of 4 different psychology-related books and holds 9 different patents regarding his research areas. Dr. Nam's area of interest includes cognitive neuroscience, psycholinguistics, Korean and foreign language processing, neuro-imaging, and artificial intelligence