An Audio-Based Approach to Mobile Learning of Japanese Kanji Characters

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Abstract

We describe the design and implementation of an audio-based computer system for mobile, non-visual learning of the meaning and writing of "kanji" characters: the thousands of multi-stroke Chinese characters used in the Japanese logographic writing system. Our system is designed for use by non-native learners of Japanese as a foreign language. The key feature of our system is its innovative use of a purely audio-based system for a learning task that is normally considered to be a primarily visual task (the task of learning kanji). By using a purely audio-based approach, our system allows mobile, any-time, any-place learning of kanji. This any-time, any-place learning capability is especially important because it greatly increases the ability of the student to review and practice kanji in mobile learning situations even while visual attention is not available. Evaluation results show that the instructional method used by our system leads to development of the memory skills needed for kanji fluency.

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Introduction

One of the most visually apparent features of the Japanese written language is its use of *kanji*, the logographic characters imported into Japanese from the Chinese written language. Students of Japanese as a Second Language (JSL) may have had no prior exposure to kanji; this is, in particular, likely the case if the JSL student's mother language uses an alphabetic writing system, as is the case with English. To attain written fluency in Japanese, the JSL student must learn as a starting point at least the few thousand kanji that are in daily-use in written Japanese. This typically presents a very difficult memorization task to the JSL student. To assist in this task, we developed a mobile system to allow the JSL student to review kanji anytime and anywhere by use of a novel audio-based approach implemented on a mobile platform.

In this paper, we first describe some background about the usage and learning of kanji. Next, we describe a popular kanji learning method - which we adapted for our system - laid out in James Heisig's textbook *Remembering the Kanji* (Heisig, 1986). We describe our adaptation of this learning method for audio-based mobile learning, present our implemented system architecture, and illustrate how our system fits into the overall kanji learning scenario. We present initial evaluation results, which confirm that our approach is effective in helping students remember the composition of complex kanji. Finally, we review related works, and conclude with directions for future work.

Background on Kanji and Written Japanese

Figure 1 shows a typical sentence in Japanese and its English translation. In general, written Japanese contains two types of characters, indicated in Figure 1 by overlining and underlining.

The first type of characters, marked in the figure with overlines, are called ***kana*** characters and are visually simple in form. They generally are used in written Japanese to show inflectional endings, conjunctions, or other grammar-related sentence structure. Kana can be learned by the JSL student in at most several days of effort, as there are less than 100 fairly simple kana symbols to learn.

The second type of characters, marked in the figure with underlines, are the ***kanji*** characters and are visually complex in form. They generally represent the semantic content of the sentence such as nouns, verbs, adjectives, and adverbs. Unlike the kana characters, kanji require much more effort to learn, due to their visual complexity and their sheer number. Although there are tens of thousands of valid kanji, the Japanese government has designated 1945 kanji, the so-called joyo kanji, as daily-use kanji. Japanese publications are generally encouraged to limit their usage to this list, though in practice more are used in printed matter, e.g. for proper nouns or special vocabulary. The minimum task for the JSL student, then, is to learn approximately 2000 daily-use kanji with complex forms. Because of the difficulty of this learning task, we are interested in mobile technologies that can help JSL students learn kanji characters.

For effective JSL kanji education, two concerns needs to be addressed:

1. What information should the JSL student learn about kanji?

2. How should the JSL student learn this information?

The answers to these questions influence the design of a mobile kanji learning system.

What the JSL student should learn about kanji

Learning each kanji requires a number of memorization tasks. For full written fluency, the student must learn the following for each kanji (Kano, Takenaka, Ishii, and Shimizu, 1990; Garnier and Mori, 1991).

Visual form

First, the visual form of the kanji must be committed to memory. Figure 2a shows a simple kanji character consisting of five strokes. The student must learn to recognize this form when it appears, differentiating it from potentially similar-looking characters. Furthermore, the student must be able to write this symbol from memory, recalling the necessary strokes.

Individual meaning

Next, the meaning of the kanji must be learned. One kanji may have more than one meaning. For instance, the kanji in Figure 2a by itself means “book,” or “main.”The kanji in Figure 2b means “sun.”These are the individual meanings of each the kanji. However, when combined, the kanji may change meaning, as shown below.

Compound formation and compound meaning

Individual kanji may be combined into a compound word, or compound kanji, as shown in Figures 3a and 3b. Combining the two kanji as shown in Figure 3a results in a compound kanji meaning “today”; however, combining the same two kanji in a different order shown in Figure 3b results in a compound kanji meaning “Japan”. The JSL student thus needs to learn valid compound formations and their meanings.

Pronunciation

Finally, the pronunciation of the kanji must be learned. Because the kanji characters were imported to Japan from the Chinese written language, each Japanese Kanji character generally has at least two pronunciations. One pronunciation type is called the kun-yomi, and is the Japanese native pronunciation of the word corresponding to the kanji's meaning. The kanji in Figure 3a has a kun-yomi of “hon.” The other pronunciation type is called the on-yomi, and is the similar to the Chinese pronunciation of Chinese word corresponding to the kanji's meaning. The kanji in Figure 3a has an on-yomi of “moto.” There may be more than one on-yomi. Also, there may possibly be a nanori, a proper-noun pronunciation.

How the JSL student should learn about kanji

While there is little debate about *what* the JSL student needs to learn for kanji fluency, the question of *how* the JSL student should learn the information is debated (Richmond, 2005). Different textbooks take different approaches.

Figure 4 illustrates one style of learning, which we call a “depth-first” approach. In this approach, a student aims to learn everything about one particular kanji before proceeding to the next. This means that the student memorizes visual form, individual meaning, compound words and meanings, on-yomi, and kun-yomi for each kanji in sequence. Each kanji is learned "in depth" before moving to the next one.

Figure 5 illustrates another style of learning, which we call a “breadth-first” approach. In this approach, a student learns some information, such as meaning and writing only, for each kanji, then quickly progresses to the next. The aim is for the student to first learn some information about a very broad range of kanji, then later return to learn more deep information, such as pronunciations or compound words.

We believe the breadth-first approach is more effective, because it allows the student early on to quickly absorb a basic understanding of a large number of kanji. For our mobile learning system, we based our approach on a breadth-first method proposed in a popular textbook by Heisig (1986), *Remembering the Kanji*.

Heisig's Method for learning kanji

Our system uses a modified version of the breadth-first method presented in James Heisig's textbook (Heisig, 1986). The method, because it is a breadth-first method, focuses only on how a student can learn the writing and meaning of the approximately 2000 daily-use kanji. It ignores issues of compound kanji or pronunciation, leaving these for later study.

Hierarchical component-based decomposition of complex kanji

Heisig's method combines simple kanji or parts hierarchically into more complex kanji or parts. Each kanji or part is assigned a unique name that also relates to its meaning. As noted earlier, one kanji can have more than one meaning, but this method chooses only one uniquely-named meaning for each kanji. The student therefore learns correct but possibly incomplete information about the kanji. This is in agreement with a breadth-first approach, where the emphasis is placed on quick learning of essential information for a large number of kanji, rather than in-depth study of all nuances of each kanji.

Figure 6 shows how simple kanji parts hierarchically combine to form a more complex kanji. The first row shows a simple visual shape, which is assigned a meaning of “cliff.” Because this shape is simple, it contains no smaller component parts. (Note: this particular shape is actually only part of a kanji character, not a complete kanji character, so it only appears as part of other complex kanji, and never appears as a complete character by itself. The shape thus carries no complete semantic meaning. Therefore, the meaning word assigned to this shape, “cliff,”is somewhat arbitrarily chosen from the shape's etymological origin.)

The second row in Figure 6 shows another simple visual shape, which is assigned a meaning of “mouth.” Though simple, this shape is a complete kanji and indeed means “mouth.” As before, because the shape is so simple, it contains no smaller component parts.

The third row in Figure 6 shows a visually more complex shape. Its meaning is “stone.” Compositionally, it can be viewed as being composed of the smaller shapes for “cliff” and “mouth.” Simpler kanji or parts therefore combine hierarchically to form more a more complex kanji. By extension, the kanji for “stone” also appears in other, yet more complex kanji.

Using this method, there are approximately 200 non-decomposable simple kanji or kanji parts; the rest of the kanji to be learned are combinations of these simpler parts.

Visual vs. Non-visual learning

The method of Heisig's textbook presents but does not emphasize learning of the visual form of the kanji (shown in the left column of Figure 6). Instead, focus is placed on learning the whole-to-part relationships (e.g. “stone” = “cliff” + “mouth”), which can be expressed verbally.

Figures 7 and 8 illustrate the difference between visual and non-visual kanji learning. Figure 7 shows a ubiquitous technique emphasizing visual memory, so-called “stroke order diagrams”(The Kanji Cafe, 2006). Figure 7 shows stroke order diagrams for three separate kanji. Each diagram is read left to right, and shows the order and placement of strokes necessary to compose a kanji visually. These types of diagrams appear in many kanji textbooks (e.g. Kano et al, 1990; Garnier and Mori, 1991) and imply that the student should devote a significant part of the learning effort to visual memorization of the shape and strokes of the kanji.

On the other hand, Figure 8 shows a representative excerpt from Heisig's textbook, which emphasizes non-visual memory. Of particular note is that, for the most part, there are no stroke order diagrams (though for early stages of learning some do appear early in the textbook).

Instead of a stroke-by-stroke diagram, there is simply an image of the kanji. The kanji image is primarily intended for use as a visual reference conveying the correct shape, not as an object in and of itself to be memorized. The real memorization work involves remembering the connection between the kanji meaning expressed as a word, and the names of the smaller parts making up that kanji. For example, the top kanji in Figure 8 is assigned a meaning keyword of "need," and is hierarchically decomposed into two shapes - the top shape being called "old west," and the bottom shape being called "woman." The next kanji, labeled "loins,"consists of the left shape, "part of the body,"and the right shape, called "need,"which is identical to and hierarchically builds upon the previous kanji. Therefore, instead of visually memorizing individual kanji strokes, the bulk of the student's memorization effort goes into memorizing more abstract verbal part-to-whole relationships.

<u>Adapting Heisig's textbook method for audio-only mobile learning</u>

For our mobile learning system, we decided that the textbook method of Heisig (1986), if extended and taken to its logical extreme, would have potential to allow mobile learning of kanji in a new way that had not yet been implemented by other kanji learning systems. The textbook displays but does not emphasize the visual aspect of kanji learning. Taking this further, for our mobile learning system we chose to completely eliminate all visual information. The result is a novel audio-only system for learning kanji writing and meaning.

Our audio-only method is possible because the the whole-to-part relationships of kanji shapes are expressed verbally, with unique keywords used for each kanji or kanji part. The verbal whole-to-part relationships can be conveyed with spoken audio. Of course, learning the visual form of kanji is necessary for ultimate kanji competency. Therefore our system is not intended to replace textbook learning. Instead, our system is designed to complement textbook learning by allowing mobile review anytime and anywhere using the audio channel only.

Implementation of our mobile, audio-only kanji learning system

System architecture

Figure 9 shows our implemented system architecture and data flow. First, we constructed a text database of 2000 kanji meanings and parts. Next, we fed this data into an offline speech synthesizer, creating as output 2000 spoken audio files, each containing the spoken name of a kanji meaning, followed by a pause, followed by the spoken name of that kanji's component parts. These 2000 audio files were uploaded onto a Sharp Zaurus PDA mobile device, which played back the audio files in random order, repeatedly.

Learning scenario and system use

Our mobile system is intended to be used within the overall kanji learning scenario as shown in Figure 10. We divide the learning process into three stages.

Textbook learning is stage 1, shown at the top of Figure 10. During textbook learning, the student memorizes: (1) the meaning word associated with the kanji, (2) the names of the component parts making up the kanji, and (3) the visual form of the kanji.

Repeated review is stage 2, shown in the middle of Figure 10. This is the most time-consuming learning stage, intended to impress or confirm the impression of the learned information into long-term memory. This phase specifically is where our mobile system helps. After learning some number of kanji in stage 1, the student uses our system for constant, mobile review. First, the system randomly chooses one kanji from the database and speaks the word corresponding to the meaning of the chosen kanji, using audio-only output. Next, the system pauses for 4 seconds. During this pause, the student's task is mentally to try to recall the names of the component parts of the kanji (illustrated in the Figure 10 by the thought bubble). Finally, after the pause, the system automatically speaks the names of the component parts making up the kanji. The student mentally checks if his/her answer was correct. The system then automatically repeats, and proceeds to the next kanji. In this way, the system provides continuous repeated review of the kanji meaning-to-part relationships.

Proficiency in kanji skills is stage 3, shown at the bottom of Figure 10. This last stage occurs after mobile learning and should reflect the kanji skills learned by the student. Since our system aims to assist in learning of only kanji meaning and kanji writing (using a breadth-first approach), the student should, after learning, be able to perform two kanji tasks:

a. Given a kanji meaning, recall its writing, and

b. Given a kanji writing, recall its meaning.

The two skills for the student to master are shown in Figure 10 as items 3a and 3b. They can be seen as related memory tasks, but in different directions. Figure 11 illustrates the memory tasks in more detail and graphically shows different the memory tasks as occurring in different directions.

The first memory task (Figure 10 item 3a, and Figure 11 arrows (1) and (2)), is: given the meaning word "need," the student should be able to recall the written form of the associated kanji. Specifically, the student recalls the form by remembering the meaning-to-parts relationship that "need" is made up of "old west" plus "woman" (Figure 11, arrow (1)); then remembering the individual shapes for "old west" and "woman"; and finally writing the shapes for "old west" and "woman", yielding the correct kanji shape (Figure 11, arrow (2)).

The second memory task (Figure 10 item 3b, Figure 11 arrows (3) and (4)), is related to the previous memory task, but requires recall in the opposite direction. In this case, the student is given the kanji shape and must recall the meaning. In Figure 11, the student must identify the component parts of the kanji shape and remember their names (Figure 11, arrow (3)), which in this case are "old west" and "woman." Then, remembering the learned association that "old west" and "woman" combine to form "need" (Figure 11, arrow (4)), the student finally recognizes that the given kanji means "need."

Key features of system

A complement to textbook learning

Because our system provides no visual learning or feedback, it is not intended to replace textbook learning (phase 1), but instead complements learning with Heisig's textbook by assisting in time-intensive review learning (phase 2), enabling mobile, anytime, anywhere learning.

Audio-only modality

We use audio as the only output modality, not video. Specifically, we use audio of spoken words of the kanji meanings and part names. One key reason why an audio-only modality is possible is because of the uniqueness of words used for kanji meanings and parts. Every kanji meaning word or part name in Heisig's textbook is unique and is associated with only one visual kanji element. Therefore, because all of the spoken words are unique, there is no ambiguity in eliminating the visual kanji elements and expressing the kanji compositions purely verbally using spoken audio in our system.

Passive, non-interactive, heads-up system design

Our mobile system design is requires no input from the user. In terms of physical user interaction with the device, it is a passive system, not an interactive system. However, the system design incorporates a pause after the audio prompt to the user (Figure 10, phase 2), during which the user is intended to mentally answer the query posed by the system. Therefore, though the system is physically passive, the system design allows the user to mentally interact.

On the one hand, this design decision means that the system has no opportunity to receive student input, so the system cannot evaluate student performance, which can be seen as a disadvantage. On the other hand, the passive design is an advantage, because it allows easy, continuous, repeated review of the material anytime and anywhere - all valuable features of a mobile learning system design. Particularly in the case of such a large memorization task as learning 2000 complex kanji, constant review is necessary, and we believe that our passive system design maximizes the mobile learning opportunities.

With our design, after starting the system, the student needs neither physical effort nor visual attention to continuously learn kanji in mobile and ubiquitous learning scenarios. Therefore, the system can be seen as a “heads up” system that can be used even if the user's visual attention is focused elsewhere. For instance, a student can constantly listen to our system in the background while cooking, riding a bicycle, or exercising - all tasks in which the user's hands and eyes are not available, and where other kanji learning systems would be impossible to use. With our system, the student only needs to focus aural attention on our system output, and mentally engage with the prompts and feedback of the system. If the user is temporarily distracted (by for instance a phone call), the system does not need to be paused: it can be simply ignored. When the student's aural attention is again available, the student can - with no loss of time or effort for system interaction - choose to focus on and benefit from the learning system, maximizing the benefit and minimizing the effort.

One-directional review method

A final point about our system design is that it uses one-directional review, not two-directional review. This means that the system gives the student a kanji name, then requires the student to remember the parts of the kanji needed to write it (Figure 11, arrow (1)). The system does not explicitly train the user in the opposite direction (Figure 11, arrow (4)). This is because we believe that training in only one direction saves time and does indeed lead to development of memory skills in both directions. The effectiveness of this teaching method was the subject of our evaluation.

Evaluation

Because our mobile kanji learning system uses an adapted version of Heisig's method, we wanted to evaluate the effectiveness of the method, to ensure student learning. The effectiveness of the method is measured by the acquired skill of the student. The desired skills a student should acquire after learning with our system are to be able to recall the writing (Figure 10 item 3a, Figure 11 arrows (1) and (2)) and to recall the meaning (Figure 10 item 3b, Figure 11 arrows (3) and (4)) of the learned kanji.

Although the student must ultimately learn both to recall the writing given the meaning and to recall the meaning given the writing, our system only explicitly drills the student in one direction, namely, recalling the parts necessary for writing given the meaning (Figure 11 arrow (1)). We do not explicitly drill the student on recalling the meaning (Figure 11 arrows (3) and (4)). This design decision runs contrary to many kanji learning systems (which explicitly drill the student in both directions), and was based on suggestions in Heisig (1986) - suggestions which, however, were only briefly mentioned and not supported with empirical data.

The evaluation question is as follows: does our design decision of drilling the student in only one direction (given meaning, recall writing) lead to learning of both of the necessary kanji skills (given meaning, recall writing; given writing, recall meaning)? We hypothesize that the answer is yes. If the answer is yes, then we have evidence that our system makes effective use of the student's kanji learning time; if no, then our system is not training the student with sufficient kanji skills.

Simplifying assumption for evaluation purposes

Full kanji competency does require some visual learning; however, our argument, as stated earlier, is that the *majority* of learning effort need not go into visual memorization, but instead the *majority* of learning effort goes into learning the verbally-expressed whole-to-part relationships describing the hierarchical composition of kanji.

Based on this assumption, we further assume that learning effort required for the visual memory tasks in Figure 11 (arrows (2) and (3)) is small, compared to the learning effort required for the non-visual memory tasks (arrows (1) and (4)). Concretely: if, given a kanji meaning, the student has learned to recall the parts, then the additional learning effort required to then recall the writing is relatively small. Similarly, given a kanji's visual form, recalling the part names of the visual components is relatively easy; the harder, more voluminous, and more important task is remembering the kanji meaning associated with the part names.

Therefore, for our evaluation, we made the simplifying assumption of ignoring the learning effort necessary for arrows (2) and (3) in Figure 11; these steps are drawn inside of dashed lines to indicate that we ignore them during evaluation.

Referring to Figure 11, our simplified evaluation question then becomes: does training in direction (1) lead to development of memory skills in both direction (1) and direction (4), as is needed for kanji competency?

Evaluation Method

To conduct our evaluation, we implemented a WWW-based training and memory quiz as follows.

Participants

Anonymous participants were recruited by an electronic message posted to selected USENET forums. The recruitment message stated that subjects were desired for a web-based experimental quiz testing language and memory. A URL to the WWW server running the experiment software was given. Over a one-month period, sixteen participants responded to the message and completely participated in experiment.

Procedure

We implemented a WWW-based training and quiz program accessible via a WWW browser. The quiz program would first train users to memorize kanji meanings and parts. Then, the program quizzed their memory with a fill-in-the-blank quiz. We conducted two conditions for the experiment.

Condition 1 (9 subjects) was named "remember meaning." This condition does *not* correspond to the teaching method used in our system. There were three parts to this condition. First, the subject was given a kanji meaning and its component part names (Figure 12). The subject was instructed to memorize *only* the meaning, and to be able to recall the meaning given the parts. Ten such kanji were presented to the user for memorization. Second, the subject was given a fill-in-the-blank quiz on the memorized information. Given the parts of a kanji, the subject was required to fill-in-the-blank of the kanji meaning (Figure 13). Third, the subject was given a surprise quiz in the reverse direction. Though the subject was not asked to memorize this information explicitly, the subject was asked to fill-in-the-blanks for the kanji parts, given the kanji meaning (Figure 14). The purpose of the surprise quiz was to test if learning implicitly took place in the opposite direction than was learned. Referring to Figure 11, the subject explicitly learned in the direction of arrow (4), was quizzed in direction of arrow (4), then as a surprise had to also recall information in the opposite direction of arrow (1).

Condition 2 (7 subjects) was named "remember parts." This condition corresponds to the teaching method used in our system. As before, there were three parts to this condition. First, the subject was given a kanji meaning and its component part names (Figure 15). The subject was instructed to memorize *only* the part names, and to be able to recall the part names given the meaning. Ten such kanji were presented to the user for memorization. Second, the subject was given a fill-in-the-blank quiz on the memorized information. Given the meaning of a kanji, the subject was required to fill-in-the-blanks of the kanji part names (Figure 16). Third, the subject was given a surprise quiz in the reverse direction: the subject was asked to fill-in-the-blank for the kanji meaning, given the kanji parts, to test for any implicit learning effects in the opposite direction (Figure 17). Referring to Figure 11, the subject explicitly learned in the direction of arrow (1), was quizzed in direction of arrow (1), then as a surprise had to also recall information in the opposite direction of arrow (4).

<u>Evaluation Results</u>

We evaluated the number of questions correctly answered for each condition, in both the memorized direction and the opposite direction. The results appear in Table 1.

The ability to recall information in the direction explicitly memorized was higher in condition "remember meaning" (47%) than condition "remember parts" (24%). However, the opposite is true when recalling in the opposite direction. The ability to recall information in the direction *opposite* that explicitly memorized was lower for condition "remember meaning"

(22%) and higher for condition "remember parts" (71%). Finally, overall memory performance, in both the memorized and the opposite direction, was lower for condition "remember meaning" (35%) and higher in condition "remember parts" (48%).

Discussion

We interpret our experimental data as follows. First, subjects learning meanings could recall the learned information better than subjects learning parts could recall the learned information. We attribute this to the greater inherent difficulty of learning the part information.

Second, however, explicitly learning parts given meaning did lead to good memory in the opposite direction, recalling meaning given parts. This was not true for subjects who explicitly learned meaning given parts. This shows that the effort put into the more difficult task of learning parts given meaning also leads to implicit learning of meaning given parts. In Figure 11, this means that explicitly learning in direction (1) implicitly leads to learning in direction (4) as well, but the reverse is not true. This is also reflected in the total memory performance in both directions (third column of Table 1), which was better for students who explicitly learned parts rather than those who explicitly learned meaning.

It should be noted, however, that this online memory quiz lasted approximately half an hour for each participant, therefore using short-term memory and not long-term memory. However, learning 2000 kanji for language fluency, through repeated review using our mobile kanji learning system, is a long-term memory task, not a short-term memory task. Nevertheless, we still believe that the results of a long term memory experiment would be similar to those of this short term memory experiment, and that the conclusions we can draw from the results still stand.

In conclusion, the data supports our hypothesis that focusing learning effort in the direction of “given meaning recall parts” leads to acquisition of memory skill in both the direction “given meaning recall parts”as well as the direction “given parts recall meaning.” Therefore, the learning approach offered by our system is an effective use of the student's time and leads to the necessary recall skills for kanji competency.

Related Work

We are not aware of other work which uses spoken audio and a component-based approach as in our system. For instance, KanjiGym Light (Grunewaldt and Rauther, 2006) is a computerized review program designed for students using Heisig's textbook. Given a randomly selected kanji meaning, the student must write the kanji using the mouse in an empty on-screen window. The system then displays the correct writing, and the student then clicks on “yes” or “no” to indicate if their response was correct or not. In contrast to our audio-based system, KanjiGym Light requires active use of the student's hands and eyes during the entire learning process.

KDrill (Brown, 2006) is a multiple-choice flash-card program written for desktop PC's. It allows quizzes in both directions: given a kanji image, the student must recall the meaning; alternatively, given a kanji meaning, the student must recall the kanji image. It does not quiz students on the whole-to-part component relationships within a kanji. It also quizzes the student on compound kanji, which we specifically decided to omit from our system. KDrill, like KanjiGym light, again requires use of the student's hands and eyes during the learning process.

In contrast to our sensorially-minimal audio-only approach, a sensorially-rich approach is taken by Wagner and Barakonyi (2003), who present an augmented-reality system for learning kanji, using hand-held displays and kanji cards on a table. A hand-held display acts as a magic lens; when the display is physically held in front of a card containing a kanji character, the display shows an augmented reality image of an object corresponding to the kanji's meaning. The described system only works with ten kanji cards, and likely would be difficult to scale up to work with the 2000 kanji needed for native-level kanji study; in particular, the optical pattern recognition software would likely have difficulty differentiating 2000 kanji shapes, many of which are visually very similar. Also, the system visualizes concrete kanji representing nouns, such as “car” or “tree”; on the other hand, it is not clear how more abstract kanji could be visualized as objects (e.g. kanji representing states of mind, actions, and so forth). Finally, the focus on visual object representations for the kanji indicates that this system is intended for different learning scenarios from those of our mobile audio-only system.

Some handheld electronic Japanese-English dictionaries offer component-based indices to allow component-based lookup of individual kanji characters. (Atarashii Jisho, 2003). However, such dictionaries do not provide a quiz function for the kanji components; furthermore, the component information is not expressed in spoken-audio form as with our system, and thus again requires use of the student's eyes and/or hands. Also, such dictionaries are typically intended for use by native Japanese speakers or advanced JSL students who already have a firm grasp of kanji, whereas our system targets beginning JSL students with limited kanji skills.

Regarding the breadth-first learning method of Heisig's textbook, there has been to our knowledge only one academic investigation of this method, by Richardson (1998). Richardson attempted to outline the theoretical underpinnings of the method, and also adapted the method for the Chinese language. However, Richardson specifically did not attempt to assess the effectiveness of the method: “I did not empirically test either Heisig’s [method] for the learning of kanji or my Chinese adaptation of his [method]. My interest was that of extending the examination of relevant theoretical and empirical issues...” (Richardson, 2003). Our evaluation data therefore provide new empirical support for the effectiveness of a one-directional learning and review method.

Conclusion and Future Work

We presented a novel audio-based system for mobile learning of kanji. In contrast to almost all other kanji learning systems and books - which assume that visual attention must be used during all stages of learning kanji - our system challenges that assumption and teaches the writing of kanji through part-to-whole relationships using spoken words and an audio-only modality. This allows mobile kanji learning anytime and anywhere. With our system, in contrast to other kanji learning systems, students can review kanji even when hands or visual attention are not available.

Our system uses a one-directional review method. Given a kanji meaning, students are prompted to recall the kanji parts; the other direction is not drilled. We evaluated the effectiveness of the one-directional learning strategy and found that it does lead to acquisition of memory skills in both directions needed for kanji competency.

Future work includes long-term user studies using the system for extended periods of time, and evaluating not only memory of the kanji part-to-whole relationships as we did here, but also the actual long-term kanji reading and writing skill acquisition of the student.

References

Atarashii Jisho (2003). Retrieved November 14, 2006 from http://www.densijiten.co.jp/column/column.php?column_id=20030910

Brown, P. (2006). *KDrill info page*. Retrieved November 14, 2006 from http://www.bolthole.com/kdrill/

The Kanji Cafe (2006). *Stroke Order Diagram Editor-Retrographer (SODER) Volunteer Project*. Retrieved November 14, 2006 from http://kanjicafe.com/using_soder.htm

Kano, C., Takenaka, H., Ishii, E., and Shimizu, Y. (1990). *Basic Kanji Book*. Japan: Bojinsha Co., Ltd.

Garnier, C., and Mori, T. (1991). *Japanisch ohne Muehe* (German-language edition, D. McEwan, Trans.) France: Assimil.

Grunewaldt, L., and Rauther, R. (2006). *KanjiGym Light*. Retrieved November 14, 2006 from http://www.kanjigym.de

Heisig, J. (1986). *Remembering the kanji I: A complete course on how not to forget the meaning and writing of Japanese characters*. Tokyo: Japan Publications Trading Co., Ltd.

Richardson, T. W. (1998). *James W. Heisig's system for remembering kanji: An examination of relevant theory and research—and a 1,000-character adaptation for Chinese*. *Dissertations Abstracts International 59(06A), 2002.* Bell and Howell Information and Learning [formerly UMI] Publication No. 9838097.

Richardson, T. W. (2003). *Comments on a Dissertation Dealing with James W. Heisig's Approach to Kanji memorization*. Retrieved November 14, 2006, from http://www.kanjiclinic.com/richardson.htm

Richmond, S. (2005). A re-evaluation of kanji textbooks for learners of Japanese as a second language. *Journal of the Faculty of Economics, KGU, Vol. 15, July 2005*, 43-71.

Wagner, D., and Barakonyi, I. (2003). *Augmented Reality Kanji Learning*. Proceedings, The Second IEEE and ACM International Symposium on Mixed and Augmented Reality, Tokyo, Japan.

Author Note

Norman Lin received his B.S. and M.S. degrees in Computer Science from the University of Oklahoma, in the United States of America, in 1992 and 1994. Over the next decade, he worked in the software industry in lead software development positions with emphasis on virtual reality, computer graphics, and 3D game development. He founded his own company in Austria, in the European Union, and worked on VR applications with the Ars Electronica Center in Linz, Austria. In 2003, he joined ATR (Advanced Telecommunications Research Institute) in Kyoto, Japan, as a research engineer in the Media Information Science Laboratory. He is currently pursuing his Ph.D. degree in Information Science at Nagoya University under Professor Kenji Mase. His research interests include ubiquitous/wearable computing, computer-mediated communication, tangible interfaces, and media technology for second language (L2) education. He has published two books on 3D computer graphics.

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(IEICE) of Japan, Virtual Reality Society of Japan, and ACM and a senior member of IEEE Computer Society.

Table 1

	could recall memorized direction	***could recall opposite direction***	***total recall***
Condition 1, remember meaning	47% (43/90)	22% (20/90)	35% (63/180)
Condition 2, remember parts	24% (17/70)	71% (50/70)	48% (67/140)

Results of memory quiz

Figure Captions

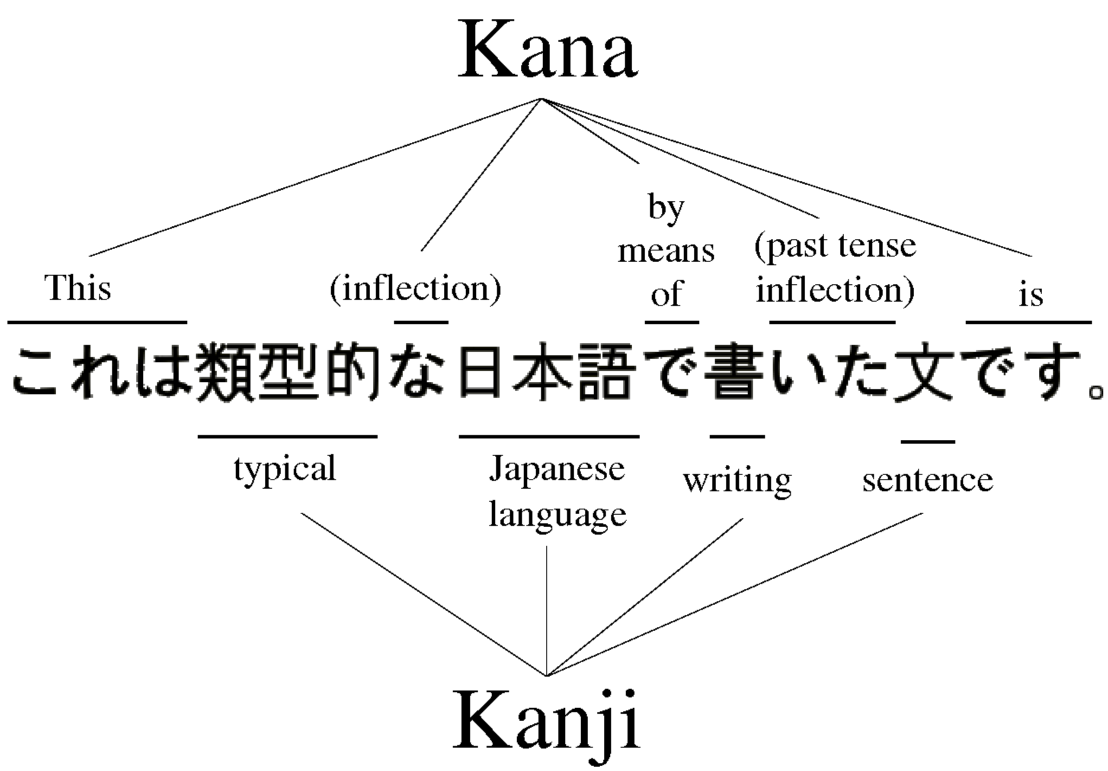

Figure 1. A typical written Japanese sentence, illustrating kana and kanji characters.

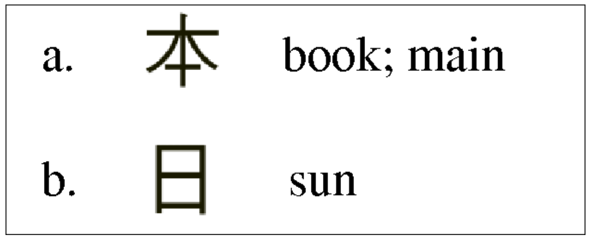

Figure 2. Individual kanji characters. (a) Kanji character meaning “book” or “main”. (b) Kanji character meaning “sun”.

a. 本日 today

b. 日本 Japan

Figure 3. Kanji compounds. (a) A compound kanji meaning “today”. (b) A compound kanji meaning “Japan”.

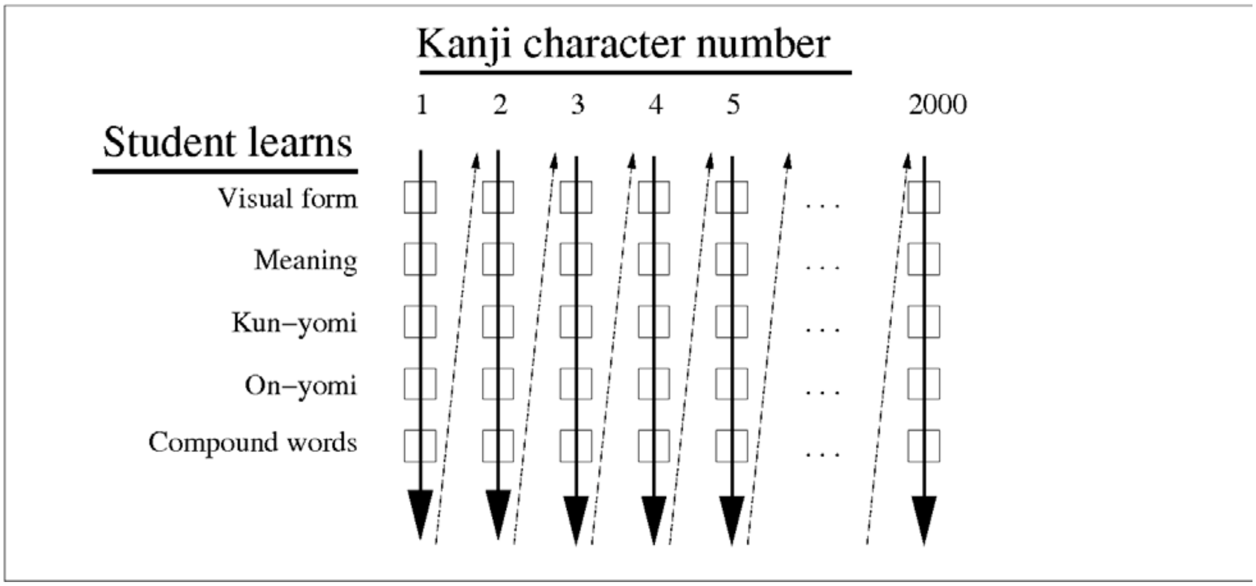

Figure 4. Depth-first approach to learning kanji.

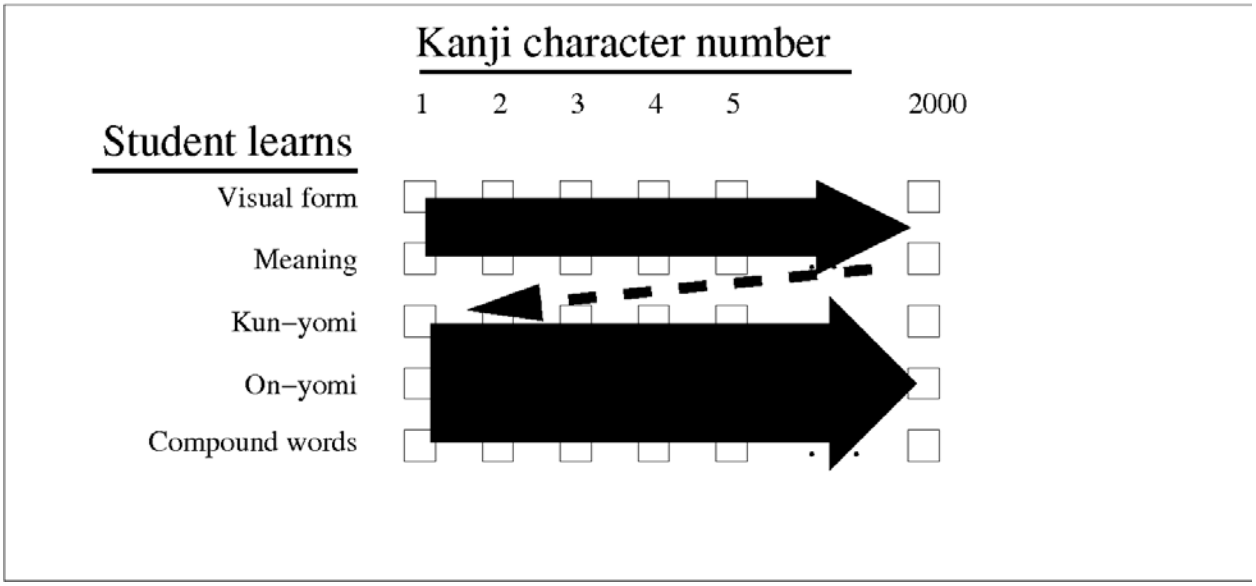

Figure 5. Breadth-first approach to learning kanji.

VISUAL	MEANING	PART NAMES
厂	cliff	(none)
口	mouth	(none)
石	stone	cliff, mouth

Figure 6. Simple kanji parts hierarchically combine to form complex kanji.

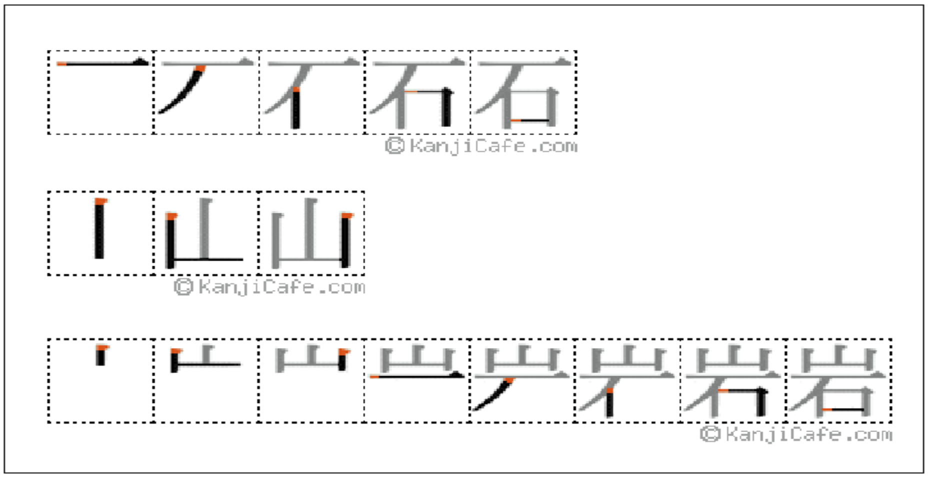

Figure 7. Visual learning of kanji shapes with stroke-order diagrams (The Kanji Cafe, 2006).

1604 要	*Old West . . . woman.* [9]	need
1605 腰	*Part of the body . . . need.* [13]	loins
1606 票	*Old West . . . altar.* [11]	ballot
1607 漂	*Water . . . ballot.* [14]	drift
1608		signpost

Figure 8. Non-visual learning of kanji shapes with verbal whole-part relationships (Heisig, 1986).

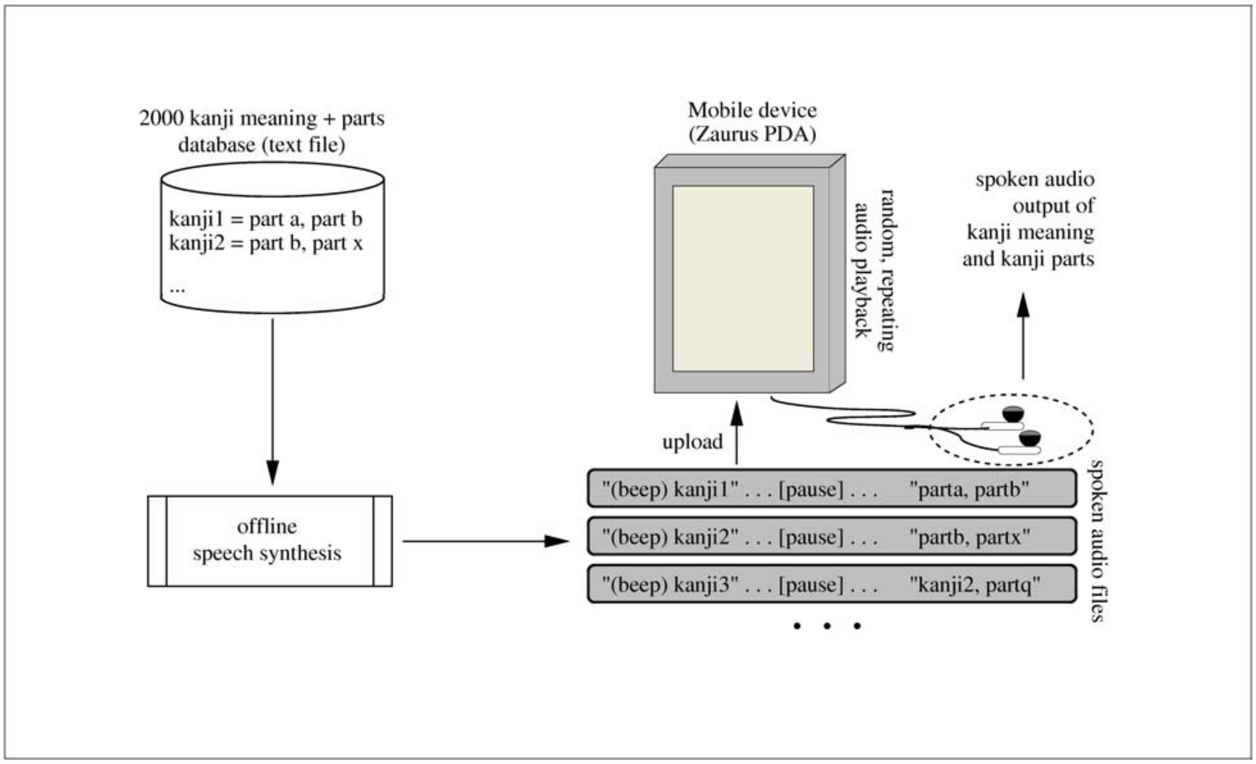

Figure 9. Architecture of mobile, audio-only kanji learning system.

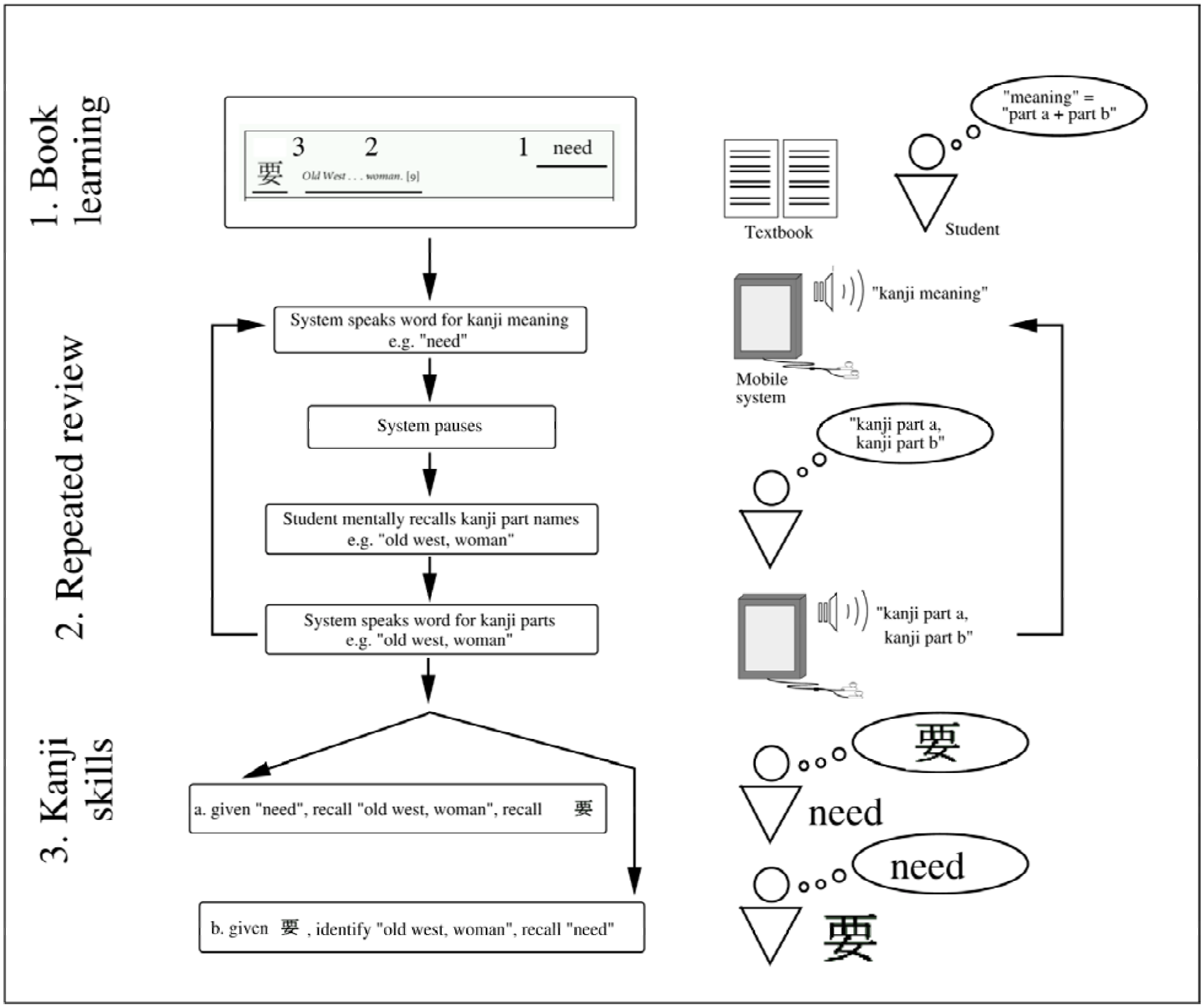

Figure 10. Role of mobile learning system in overall kanji learning process.

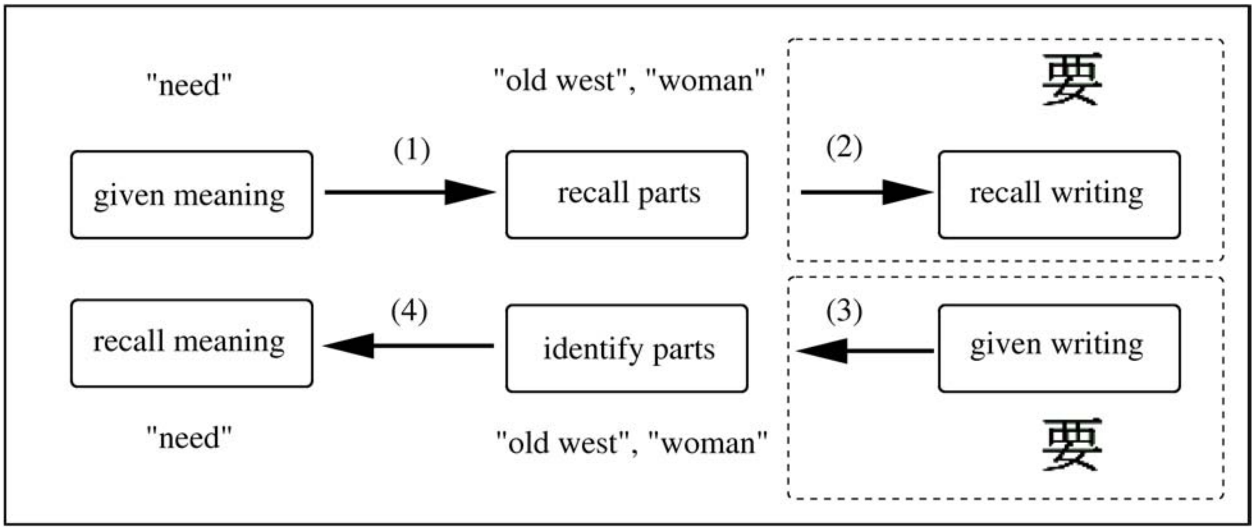

Figure 11. Kanji skills to be learned by the JSL student, in two directions. Dashed lines indicate skills not included in experimental evaluation.

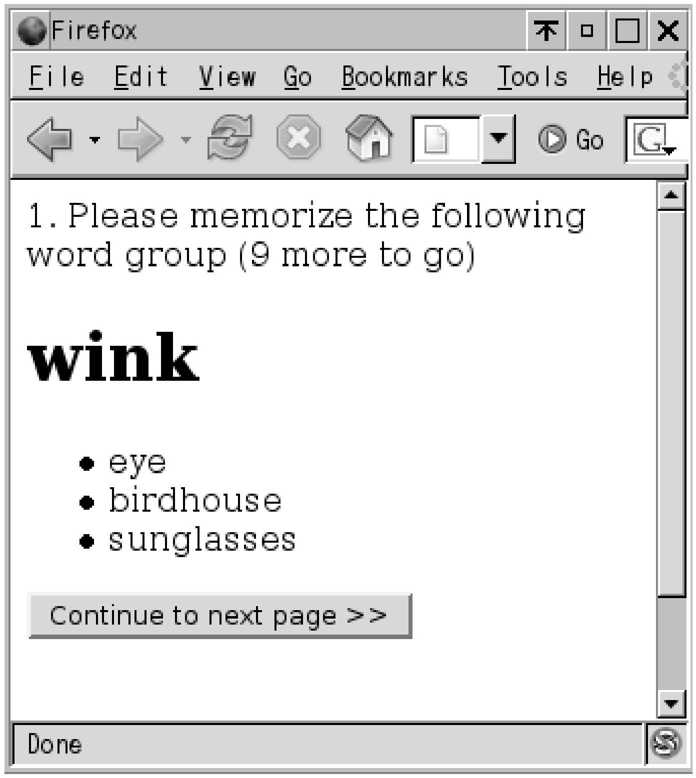

Figure 12. Evaluation: web-based quiz, learning phase (condition "remember meaning")

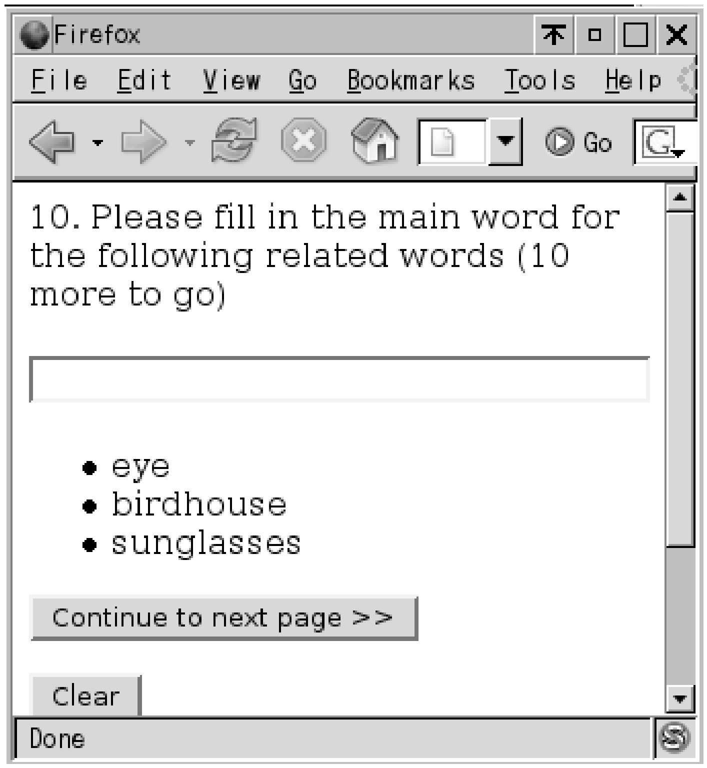

Figure 13. Evaluation: web-based quiz, normal quiz phase (condition "remember meaning")

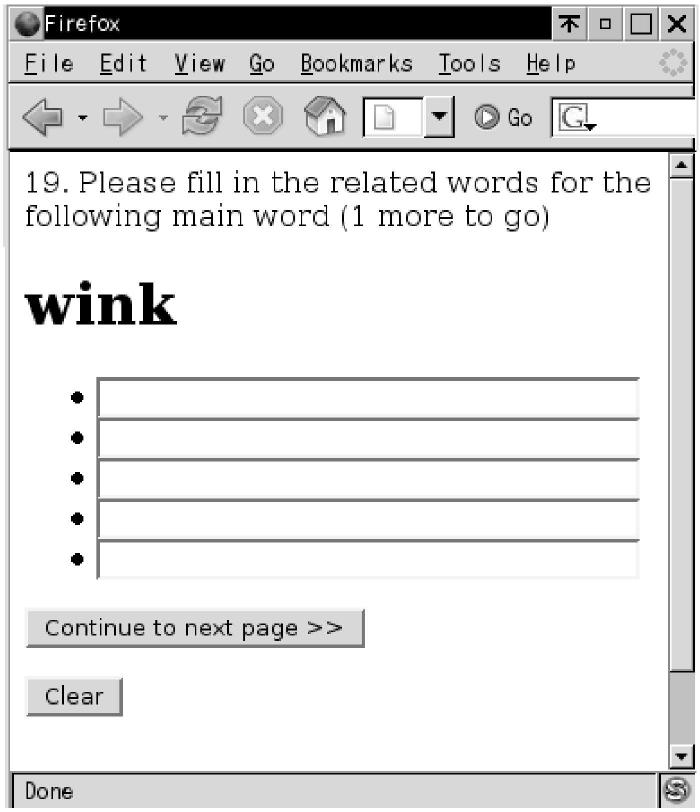

Figure 14. Evaluation: web-based quiz, surprise quiz phase (condition "remember meaning")

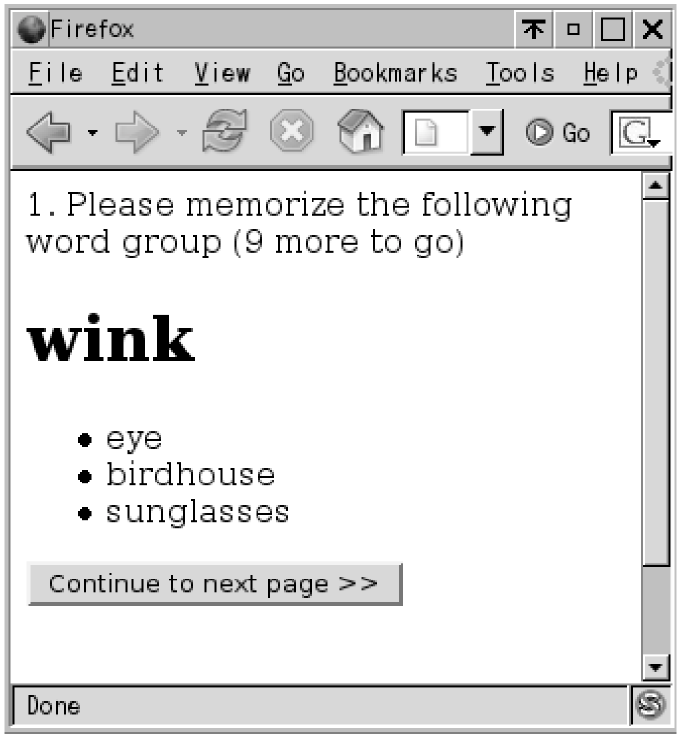

Figure 15. Evaluation: web-based quiz, learning phase (condition "remember parts")

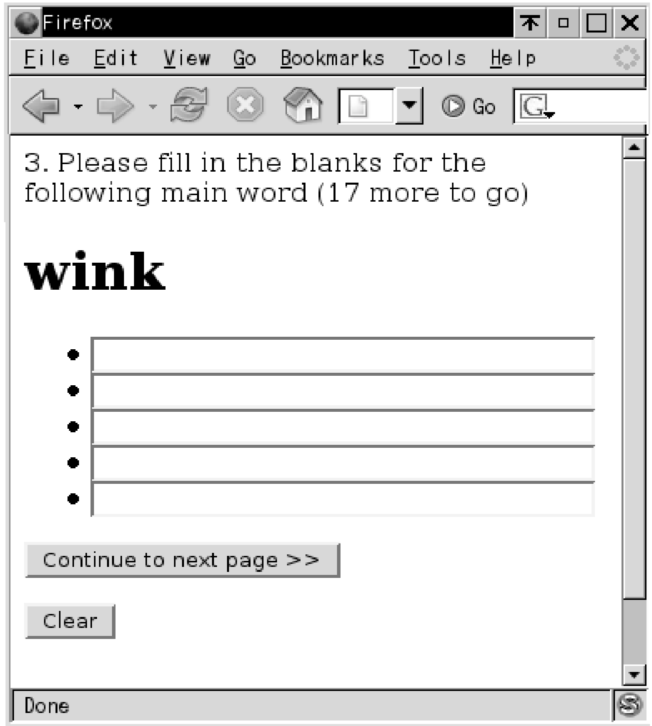

Figure 16. Evaluation: web-based quiz, normal quiz phase (condition “remember parts”)

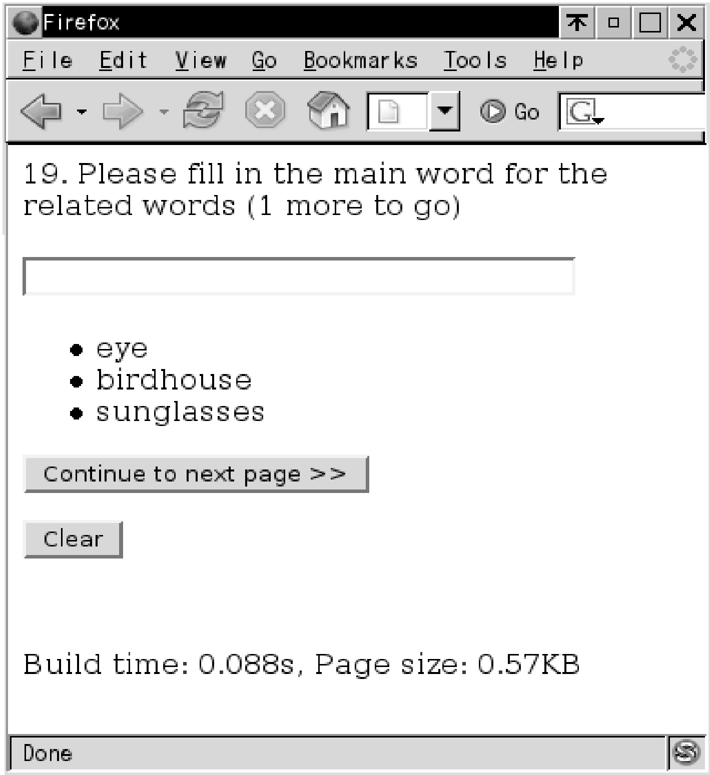

Figure 17. Evaluation: web-based quiz, surprise quiz phase (condition “remember parts”)