THE EFFECTS OF SINGLE AND DUAL CODED MULTIMEDIA INSTRUCTIONAL METHODS ON CHINESE CHARACTER LEARNING

by

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ABSTRACT

Learning Chinese characters is a difficult task for adult English native speakers due to the significant differences between the Chinese and English writing system. The visuospatial properties of Chinese characters have inspired the development of instructional methods using both verbal and visual information based on the Dual Coding Theory. This study investigated the effects of single (verbal or visual) and dual (verbal and visual) coded instructional methods on learning both concrete and abstract Chinese characters using computer-based multimedia while the spatial ability of the learners was statistically controlled. One hundred twenty adults with no prior knowledge of Chinese were randomly assigned to one of four treatment groups: a text-only method group, an animation-only method group, an animation-plus-text method group, an animation-plus-narration method group. All participants learned the same 24 Chinese characters, of which 12 were pictographs representing concrete objects and 12 were ideographs representing abstract concepts. Statistical analyses revealed a significant difference between the single coded and the dual coded instructional methods. The dual coded methods worked better than the single coded methods. Participants performed better on concrete characters than on abstract characters. In addition, under the single coded method, the animation-only method led to better achievement than the text-only method. In contrast, under the dual coded method, the animation-plus-narration method was superior to the animation-plus-text method. These results suggest that dual coded instructional methods involving computer animations with multi-sensory input have a significant positive influence on Chinese character learning. The study also discusses

implications in the areas of not only foreign language instruction of Chinese characters including both integrals and compounds, but also native language acquisition by Chinese dyslexics as well as alphabetic language speakers.

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CHAPTER ONE: INTRODUCTION

Statement of the Problem

College students whose native language is English often find reading Chinese a challenging task due to the significant differences between the two writing systems (Everson & Ke, 1997). When written, words in alphabetic languages like English consist of letters governed by grapheme-phoneme correspondence rules, while words in Chinese consist of one or more characters with strokes having no direct sound-to-spelling connection (DeFrancis, 1989) but direct links to the visual and semantic information (Smith, 1985).

The Chinese language is labeled as a Category IV language by the U.S. government, which means, compared with "learning a cognate language, such as French, it would take three times longer for an American leaner to reach an equivalent proficiency" (Everson and Xiao, 2009). The traditional way of teaching the Chinese writing system is by rote memorization, i.e., to remember a Chinese character, a beginning learner may need to copy it as an arbitrarily assigned symbol numerous times by hand writing. Wang (1989) suggests that learning symbols in this manner is stressful and leads to poor recognition and retention. As a result, learning Chinese characters has been considered the most difficult challenge for L2 learners, a finding which has been reported and confirmed by several studies all over the world (Shen, 2013). Although some studies have shown structural and visual encoding to be an important factor in teaching and learning Chinese characters, the traditional teaching method remains to drill learners in the stroke-by-stroke writing of characters (Li, 1996). Therefore, much of the learner's attention is directed to the individual strokes with the development of structural and visual perception of Chinese characters as a whole left to the learner's own initiative (Wang, 1998).

Chinese characters are not just visual symbols composed of random strokes. The strokes in a character are arranged to represent concrete objects or abstract concepts. Learning a Chinese character, therefore, may involve more visual processing than traditional instructional methods assume (Hoosain, 1991). Studies on the visual properties of Chinese characters (Biederman & Taso, 1979; Ehri, 2005; Ke, 1998; Turnage & McGinnies 1973; Wang, Cheng, & Chen 2006) suggest that students may benefit from instructional methods incorporating both verbal and visual information of Chinese characters when learning to read Chinese.

A widely accepted theory of mental information representation and processing in cognitive tasks is the Dual Coding Theory (Paivio, 1971, 1990, 2007), which assumes two functionally independent but structurally interconnected systems: one for representing and processing verbal units and the other for visual objects. The Dual Coding Theory suggests that information will be processed more efficiently and stored in long term memory more successfully (Baddeley, 1992) when presented both verbally and visually (i.e., dual coded) rather than when presented either verbally or visually (i.e., single coded). The Dual Coding Theory has received converging empirical evidence from the fields of psychology and cognitive neuroscience, including studies on functional asymmetries of the hemispheres (Paivio, 1900; Jones-Gotman & Milner, 1978; Paivio & Ernest, 1971; Whitehouse, 1981), the structures of the verbal and nonverbal systems (Efron, 1963; Mills & Rollman, 1980; Luria, 1976; Paivio & te Linde, 1982), and the referential connections between the systems (Beauvois, 1982; Geschwind, 1965; Kimura, 1982). Furthermore, the Dual Coding Theory has received support from studies on the contributions of concreteness to word recognition (Day, 1979; Funnell et al., 2001; Kounios & Holcomb, 1994; Levine & Banich, 1982; Shibahara & Lucero-Wagoner, 2002; Villardita et al., 1988) and neuroimaging studies on the functional anatomy of the word concreteness effect (Jessen et al., 2000; Friederici et al., 2000; Wang et al., 2010; Welcome et al. 2011; Gullick, Mitra, & Coch, 2013). Dual Coding Theory has been applied to first language acquisition (Begg & Paivio, 1969; Bull & Wittrock, 1973; Denis, 1984; Eddy & Glass, 1981; Glenberg & Langston, 1992; Holmes & Langford, 1976; Jorgensen & Kintsch, 1973; Levin & Berry, 1980; O'Neill & Paivio, 1977; Sadoski, Goetz, & Fritz, 1993; Smith, Stahl, & Neil, 1987) and foreign language acquisition (Pan & Pan, 2009; Paivio & Desrochers, 1979; Plass et al. 1998, 2003; Steffensen et al.; 1999; Taura, 1998).

As computers have a great capability of presenting in a variety of sensory modalities, i.e., text, audio, picture, animation, dual coded instructional methods may benefit from multimedia presentations in which printed text or spoken words are verbally coded and pictures and animations are visually coded. The use of computer-based instruction in foreign language teaching is well documented in educational research (Al-Seghayer, 2001; Chung, 2008; Davis & Lyman-Hager, 1997; Levy, 1997; Muyskens, 1997; Warschauer & Healey, 1998). Several studies have revealed that multimedia annotations and animations have positive effects in foreign language vocabulary acquisition (Chuang & Ku, 2011; Kuo & Hooper, 2004; Lai, 1998; Reed & Beveridge, 1990; Rieber, 1991). Computer-generated graphics have also been used to present the historical transformation of Chinese characters (Ki et al., 1994) and demonstrate the stroke order of characters (Nakajima, 1988; Li, 1996).

To facilitate the design of computer-based instructional methods (Al-Seghayer, 2001; Chun & Plass, 1996; Muyskens, 1997; Warschauer & Healey, 1998) for language acquisition, Mayer (1997) proposed a Generative Theory of Multimedia Learning, which borrows the concept from the Generative Theory of Learning (Wittrock, 1974) that learners are engaged in meaningful learning by selecting relevant information from the presented contents, organizing the selected information into a consistent representation, and integrating it with their prior knowledge. In multimedia learning, this theory predicts that learners will process new information, such as words and pictures, through both auditory and visual sensors, and they will transfer it from the sensory memory to the working memory where the information will be processed and organized into coherent verbal and nonverbal representations connected to the knowledge in the long term memory. The general theory of multimedia learning has been further extended to foreign language acquisition, such as vocabulary learning and text comprehension (Chen, 2006; Plass et al., 1998, 2003).

Although many studies, as mentioned above, have investigated the effects of dual coded teaching methodologies on the acquisition of alphabetic languages, dual coded teaching methodologies using multimedia presentation have not been explored as a teaching tool in the acquisition of logographic languages like Chinese (Chuang & Ku, 2011; Kuo & Hooper, 2004; Lai, 1998; Sham 2002; Shen, 2010). A number of questions remain to be investigated about using both verbal and visual coding strategies and the conditions under which better recall can be achieved when teaching Chinese characters using computer multimedia.

Purpose of the Study

This study aims to answer some of the remaining questions by investigating the effects of computer-based single coded (text-only and animation-only) and dual coded (animation plus text and animation plus narration) instructional methods on learning two basic types of Chinese characters, pictographs and ideographs. It takes the position that students may learn and memorize Chinese characters better by using dual coded strategies than using single coded strategies because of the availability of both mental representations.

Due to the natural picture property of a Chinese character, this study also explores the significance of computer animation in teaching both pictographs, which symbolize concrete objects, and ideographs, which represent abstract ideas. The computer animations in this study were designed to transform an image to a character based on the meaning of the original picture and the structure of the character.

Besides comparing the differences between single coded instructional methods, i.e., text vs. animation, this study examines which dual coded instruction method is more effective, given that information is presented through the same (visual) channel in the animation plus text method, but inputted via both visual channel and auditory channel in the animation plus narration method.

Research Questions

This study addresses the following questions:

1. Do different instructional methods (single vs. dual coded) influence the acquisition of Chinese characters after controlling for learners' spatial ability?

2. Do different instructional methods (single vs. dual coded) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability?

3. Do different single coded instructional methods (animation only vs. text only) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability?

4. Do different dual coded instructional methods (animation with text vs. animation with narration) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability?

Significance of the Study

This study makes original contributions to the field of teaching and learning Chinese characters as a foreign language by examining the effects of using computer-based animations to support both concrete and abstract Chinese character learning. Existing studies have investigated the effects of the use of images or animations in teaching concrete Chinese characters such as pictographs (Chuang & Ku, 2011), but very few of them have explored how animation-based instructional methods can influence learning achievements of Chinese ideographs by concretizing their abstract property through corresponding animated images (Kuo & Hooper, 2004).

This study has important practical implications for the design of effective instructional methods for teaching Chinese characters. Generally speaking, if dual coded instructional methods work better than single coded instructional methods, instructors of Chinese, when delivering instruction on characters and vocabulary, may incorporate nonverbal information, such as computer animations, along with the verbal information, such as text. Since the original pictorial properties of many Chinese characters have been diminished due to the characters' evolution and simplification, the computer animations developed in this study, based on the dual coding theory, may help learners to reconstruct the mental association of the character and the picture from which the character originated and, therefore, enhance long term retention. The effects of animation in practice could be even more significant for teaching ideographs because it has been documented that it is more difficult for learners to establish the referential connection between a picture and an ideograph type character representing abstract concepts (Jessen et al., 2000).

If dual coded presentation proves to be more effective for Chinese character learning, this study could also help practitioners develop more powerful dual coded teaching methods with multi-sensory input for learning character. Finally, as both concrete characters (pictographs) and abstract characters (ideographs) are investigated in this study, the findings may provide valuable implications for teaching compound Chinese characters which are created by combining these two fundamentally different types of characters.

Pilot Study

A pilot study was completed in spring 2013. Forty-two native English-speaking college undergraduates without prior knowledge of Chinese participated. The target Chinese characters were 12 pictographs and 12 ideographs. Three criteria were specified to ensure the cognitive complexity of the selected pictographs and ideographs are comparable to each other and suitable for beginning learners: (1) all the pictographs and ideographs had to be integral one-component characters, rather than compound characters that are combinations of two or more components, (2) the number of strokes (e.g. 3 to 5 strokes) in pictographs and ideographs had to be similar, (3) the meaning of each character had to be easy to be represented with animation.

The instruments included two computer-based tutorials, one for the single coded condition and one for the dual coded condition, and a content-related immediate posttest composed of 24 multiple-choice questions, with one point awarded for each correct answer. The single coded condition tutorial presented 24 characters in two subgroup methods with 12 characters in each method: (1) text-only, in which each Chinese character was presented with its English meaning and a short text description of its etymology, and (2) animation-only, in which each Chinese character was presented with its English translation, a picture and the animation depicting the transformation of the picture into the character. Each animation was played twice. The dual coded condition tutorial presented the same 24 characters using two dual coded subgroup methods: (1) animation plus text, in which each character was presented with animation, a short description of the etymology in text format, and meaning, and (2) animation plus narration, in which each character was also presented with animation, meaning, and etymology; however, the etymological description was presented in audio format through headphones only. The narration was played twice and synchronized with the animation.

Participants were randomly assigned to either the single coded group or the dual coded group. As both groups included two subgroup methods, the orders of the two subgroup methods were counterbalanced to control for the order effects. Participants were given a computerized tutorial which presented the characters in 15-second intervals for both presentation methods. The participants took the computer-based posttest immediately after the tutorial.

The results showed that, in general, the performance of the dual coded group was better than that of the single coded group. With regard to the instructional method (single coded or dual coded) and the character type (pictographs or ideographs), the pilot study revealed that (1) the average scores for pictographs were greater than those for ideographs in both the single coded condition and dual coded condition, and (2) the average scores in the dual coded condition were greater than those in the single coded condition for both pictographs and ideographs. Furthermore, the results suggested a significant difference between the two single coded methods and a significant difference between the two character types, specifically, (1) the average scores for pictographs were greater than those for ideographs with both text-only method and animation only method, and (2) the average scores using the animation-only method were greater than those using text-only method for both pictographs and ideographs. For dual coded methods, the results revealed that (1) the average scores for pictographs were greater than those for ideographs using both the animation with text method and the animation with narration method, and (2) the average scores using the animation with narration method were greater than those using animation with text method for both pictographs and ideographs.

These findings suggest that instructional methods encoded with both verbal (text or narration) and visual information (animation) should work better than single coded instructional methods, a finding in line with the Dual Coding Theory and findings from previous studies (Plass et al., 2003; Kuo & Hooper, 2004). The average scores from the dual coded group (22.05 out of 24 or 92%) were comparable to those reported in a recent study involving pictographs only (16.00 out of 19 or 84%) for the dual coded groups in the immediate posttest (Chuang & Ku, 2011). With respect to character type, the scores for the pictographs were better than those of ideographs, no matter which instructional method was used. On the other hand, the scores using dual coded instructional methods (animation plus text and animation plus narration) were higher than those using single coded methods (text-only and animation-only), for both character types. This finding was in line with results from studies on character concreteness (Kuo & Hooper, 2004) and word concreteness (Shen, 2010), which indicated that it was easier for learners to build a referential connection between an image and a concrete character or word than an abstract character or word.

An interesting finding in the pilot study was that from single coded methods to dual coded methods, the increase of the average score for ideographs was greater than the improvement of the average score for pictographs, a finding which suggests that dual coded methods may contribute more to learning ideographs than pictographs. A similar pattern was observed in the case of all four methods. The average score for pictographs improved gradually from one condition to the next, i.e. text only, animation only, animation with text, and animation with narration. However, the participants' performance on ideographs improved much more between text only and animation plus narration than was the case for pictographs. In addition, with the single coded methods, the average score for ideographs improved more than the average score for the pictographs from text-only to animation-only. This finding suggests that learning ideographs might benefit more from a method involving animation possibly because animation contributes to establish a referential connection between the picture and the corresponding abstract character.

The pilot study results also showed that the two dual coded conditions involving animation led to different effects on learning achievement. Specifically, participants in the animation plus narration method performed better than those in the animation plus text method for both pictographs and ideographs. This finding was consistent with a study in which the group with audio-picture annotation outperformed the group with text-picture (Chen, 2006). This finding is supported by the Generative Theory of Multimedia Learning, which suggests that animation should be synchronized with the narration, because when the verbal information is processed through the auditory channel (narration) instead of the visual channel (printed text), and is presented at the same time as the visual information (image, animation, etc), the cognitive load of the visual channel is reduced and, therefore, this dual coded method may lead to better learning effects (Mayer, 1997).

Summary

The findings of the pilot study suggest that dual coded instructional methods which contain both verbal and visual information generally work better than single coded instructional methods in teaching both concrete and abstract Chinese characters. In addition, the dual-coded instructional method involving animation plus narration seems to work better than the animation plus text method when animation and narration are appropriately synchronized.

The current study increased the sample size from 42 in the pilot study to 120 participants. As the instructional methods investigated in this study involve both verbal information in text and narration formats as well as visual information in animation format, the participants' prior verbal ability and spatial ability (i.e., connecting a verbal representation to a visual representation of an object or restructure the parts of an object) were considered possible confounding factors when completing the learning tasks in this study. The current study manually controlled participants' verbal ability by recruiting only junior and senior college students, and it statistically controlled spatial ability by requesting that participants complete the Purdue Visualization of Rotation Test (PVRT, Guay, 1976; Bodner & Guay, 1997) and using their test scores as a covariate in the data analyses.

Furthermore, as the current study had a much larger sample size, a different research design was adopted, in which the participants were randomly assigned into four different treatment groups, which were text-only, animation-only, animation-plus-text, and animation-plus-narration. Thus, the participants learned the same target characters with only one specific instructional method, instead of the two methods in the pilot study.

CHAPTER TWO: LITERATURE REVIEW

The Chinese Writing System

Writing systems in the world have evolved from pictures to logograms, logograms to syllabaries, and syllabaries to alphabets (Adams, 1990). In general, alphabetic writing systems have advantages over logographic writing systems like Chinese because although "the same text is significantly longer when written in an alphabetic script than in a logography," it is "compensated by the graphical simplicity of letters as compared with logograms" (Adams, 1990, p. 19). The basic units of written Chinese are characters, each representing a morpheme and a phonological syllable. A Chinese character can stand alone as a word or serve as a morpheme in a compound, two-character or multi-character word (DeFrancis, 1989). In fact, Chinese is often viewed as a mixed syllabic and logographic system because most Chinese characters include a phonetic component that represents the pronunciation of the graphic characters as well (Holender, 1987). However, unlike the English writing system in which phonemes are represented by graphemes and assembled into syllables and words, a single Chinese character is unable to involve phonological assembly due to the fact that the graphic units in Chinese map to complete syllables (Perfetti, et al. 2007).

Chinese Character Types

Many Chinese characters were formed through ongoing observation, logical reasoning, and certain rules (Duan & Cuvo, 1996). Although the development of the Chinese writing system over thousands of years has turned the original picture-like characters into abstract dots and lines, "each character is a meaningful piece of art reflecting an interesting story or suggesting an often profoundly logical or philosophical idea" (Li, 1996, p.78). A modern Chinese character consists of prescribed strokes representing various shapes and structures (DeFrancis, 1989). Chinese dictionaries contain more than 60,000 characters, but the total number of characters estimated for daily use is only about 3000 (Hanley, 2005), and a person recognizing 4,300 characters would be considered fully literate in Chinese (Hue, 1992). Chinese characters are categorized into six types (Xie, 1997) based on their composition and structure: *pictographs*, *ideographs*, *ideogrammatic compounds*, *semantic-phonetic compounds*, *mutual explanatories*, and *phonetic loans*. The first four will be discussed in detail whereas the last two will not because few characters fall into those categories.

Pictographs. The earliest Chinese character type is pictographs, which are the iconic symbols that have the etymological origins of shapes and characteristics of concrete objects. For instance, the Chinese character 山 (mountain) was written as , representing *mountain*, and 雨 (rain) was written as , representing *rain falling from the sky*. Other examples include 火 (Fire), 川 (river), 木 (tree), etc. However, these picture-like properties have been weakened due to the evolution and simplification of the traditional characters in different eras. The characters of "bird" 鳥 and "horse" 馬, which were picture-like in ancient times, have been simplified as 鸟 and 马 accordingly, and are examples demonstrating the loss of pictorial properties (Hoosain, 1991). Most of the pictographs can stand alone as words or play the role of a semantic component in a compound character as discussed below. Pictographs are regarded as the most important way of Chinese character composition because they, together with ideographs, serve as the basis of almost all other types.

Ideographs. Ideographs, also named simple ideograms, were originally invented to represent some abstract concepts such as numerals or positions. They can simply be associated with pure abstract symbols, e.g., the character 上 (above) was created from the symbol ⊥ and the character 下 (below) came from the symbol ⊤. An ideograph can also be created by adding an indicating stroke to a pictograph, for example, given the pictograph 刀 (knife), the ideograph 刃 was created to represent knife-edge with the extra stroke to the left indicating the edge. Although abstract concepts can also be represented using compound characters which consist of multiple ideographs and pictographs, and the number of ideographs is much smaller than that of the pictographs, ideographs are frequently used with pictographs as basic components in a the composition of compound characters.

Ideogrammatic Compounds. Ideogrammatic compounds comprise of two or more ideographs of pictographs side by side or one on top of another. The meaning of an ideogrammatic compound representing either a concrete object or an abstract concept, such as a feeling or an action, usually reflects the composition of the meanings of the compounded pictographs or ideographs. For instance, the character 木 means a tree, putting two trees together forms a character 林 which stands for a group of trees or small forest, and adding three trees up creates another character 森 that refers to a big forest. For an abstract action, the character 休 consists of a radical 亻 derived from 人 (person) and a pictograph 木 (tree), indicating a person resting against a tree. When a character or a variation of the character represents its original meaning in a compound character, it is referred to as a radical. Because the same radical may be used in different Chinese characters, a radical is often used as a character index in a Chinese dictionary (Boltz, 1994). Ideogrammatic compounding was a widely used method of composing Chinese characters before the dominance of semantic-phonetic compounds.

Semantic-Phonetic Compounds. Semantic-phonetic compound characters are created by combining two or more pictographs, ideographs, semantic radicals that suggest meaning, or phonetic radicals suggesting pronunciation as shown in Table 1. This fact allows the possibility of the involvement of phonetic information in reading Chinese.

Table 1

Example of Semantic-Phonetic Compound Characters

Character	Pronunciation	Meaning	Semantic Radicals	Phonetic Radicals
沐	Mù	bathe	氵 (means “water”)	木 (pronounced as “mù”)
妈	Mā	mother	女 (means “female”)	马 (pronounced as “mǎ”)
爸	Bà	father	父 (means “father”)	巴 (pronounced as “bā”)

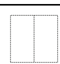
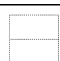
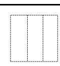
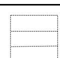
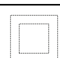
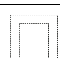
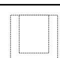
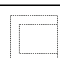
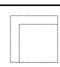
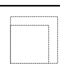
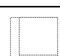
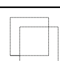
Semantic-phonetic compounding offers a more flexible way of composing characters compared with other types. For example, semantic-phonetic compounds such as 银 (silver), 铜 (copper), 铁 (iron), and 铝 (aluminum) contain the same semantic radical 钅 which represents metal, with the phonetic element indicating it pronunciation. In addition, the phonetic part in some semantic-phonetic compounds may also be semantically significant (Xie, 1997). For example, the phonetic 取 (take) in 娶 (marry) still means *taking* where the semantic 女 means *women*. The majority of modern Chinese characters are semantic-phonetic compound characters and account for more than 90% of modern Chinese characters in use today (Shen, 2010).

Chinese Character Structures

The Chinese writing system consists of different levels of logograms – strokes, radicals, and characters. Radicals are formed by strokes written in a prescribed order, while characters, framed in an imaginary square, are constructed from radicals written with a certain layout, for instance, from outside to inside, top to bottom, and left to right.

Table 2

Structures of Chinese Characters

Structure	Description	Examples
	Left to Right	休, 好
	Above to Below	全, 分
	Left to Middle and Right	粥, 撤
	Above to Middle and Below	享, 兽
	Full Surround	困, 回
	Surround from Above	冈, 风
	Surround from Below	凶, 函
	Surround from Left	区, 医
	Surround from Upper Left	历, 厉
	Surround from Upper Right	可, 包
	Surround from Lower Left	过, 建
	Overlaid	坐, 农

The structure of a Chinese character may provide useful information for beginning Chinese language learners to recognize the composition of characters, especially the compound characters. Table 2 shows some common character structures of simplified Chinese characters, which are from the 12 Ideographic Description Characters (IDCs) defined in the latest Unicode standard (Unicode, 2012).

Chinese Words

Chinese words can contain one to four characters, which are called single-character word, two-character word, three-character and four-character word. Sun et al. (1985) reported that about 55% Chinese words consist of only one character, while words with two characters comprise approximately another 40%, and only 5% are three- and four-character words. In addition, most of the high frequency words in Chinese are represented by single characters as well.

To decipher the meaning of written Chinese words, readers must rely more on context than is the case for English. Chinese has no lexical categories because a given morpheme can play different roles (Aaronson & Ferres, 1986). For example, the same morpheme 悲伤 in Chinese can be a noun (meaning ‘sadness’), an adjective (meaning ‘sad’), or an adverb (meaning ‘sadly’). Meanwhile, Chinese has no grammatical inflections (Li & Thompson, 1981). For instance, the same monosyllabic word 走 in Chinese may translate into *walk*, *walks*, *walking*, and *walked*. The same character 树 in Chinese can indicate a single tree or many trees.

A bi-syllabic Chinese word, or a two-character word, can be formed by putting a morpheme before or after a stem (Chao, 1968). For instance, 老鼠(“mouse”) combines two characters 老("old") and 鼠("mouse") and 香蕉("banana") is formed by adding 香 ("fragrant") to the front of 蕉("banana"), even though the meaning stays the same without the prefix (Sham, 2002). However, using this approach may also generate a specific meaning, such as 男孩 ("boy") and 女孩 ("girl") in which 男 means *male*, 女 means *female*, and 孩 means *child*. As another example, given the personal noun 人 ("person")，or the personal pronouns 我("I" or "me"), 你("you"), 他("he" or "him"), and 她("she" or "her"), the character 们 is used in the plural form of personal noun or pronoun such as 人们("people"), 我们("we"), 你们("you"), 他们("they"), and 她们 ("they").

Bi-syllabic Chinese words can also be created by joining two characters with different meanings (Newman, 1971). For instance, the word *wallet* in Chinese is a word with two morphemes 钱("money")包("bag"). Another example is 黑板("blackboard") that combines 黑("black") and 板("board") similar to how it is constructed in English. Other ways to construct Chinese words include a borrowing from other languages which preserve the semantic and/or phonetic characteristics of the borrowed words (Tzeng & Wang, 1983). For example, the Chinese word 民("people")主("to govern") represents the same concepts that the Greek word *democracy* first lexicalized, while the word *blog* is translated phonetically to 博("broad")客("guest") and bears no connection with the meaning of each character. The translation of *Coca-Cola* to 可口("tasty")-可乐("joy") combines both semantic and phonetic representation (Sham, 2002).

Differences between Chinese and English in Reading

The process of reading Chinese shares some properties with the process of reading alphabetic languages. Graphemic, phonological, and semantic information are all involved in reading Chinese, the same as in reading English (Cheng, 1992; Perfetti, Zhang, & Berent, 1992). However, a major difference between reading English and Chinese is caused by how they match oral language to written symbol – grapheme to phoneme in alphabetic reading and character to syllable in Chinese reading. The Chinese writing system does not reveal any segmental structure which is essential to alphabetic writing systems (Leong, et. al, 2005). For example, in English, the letter *p* in the word "pat" corresponds to the phoneme (/p/) of the pronounced word. In contrast, a Chinese phonetic radical does not have a section of the syllable-morpheme in the character. Instead, the radical corresponds to the entire syllable. Although the Chinese writing system has thousands of different characters, only about 400 syllables represent the pronunciations of these characters (Shen, 2010). It is hard to connect phonology to meaning due to the fact that Chinese contains more homophones compared to other languages (eleven for each single-syllable word on average based on information drawn from Beijing Language and Culture University, 1986). Reading Chinese, therefore, is a process that involves direct lexical access, without intermediate phonological decoding, to the recognition of visual patterns (Baron & Strawson, 1976). In contrast, reading English scripts is a process of analysis based on knowledge of orthographic units and rules governing orthographic-phonological correspondences. Research suggests that graphemic and semantic information has more impact on the Chinese character recognition than it does in recognizing English words (Chen, 1993). Native Chinese speakers tend to make more phonetic errors than graphemic errors while non-native Chinese speakers are likely to make more graphemic errors than phonetic errors (Hayes, 1988). Furthermore, English speakers are good at recalling the auditory representations of a word, while Chinese speakers are good at recalling the visual representations of a character (Travassoli, 2001). In summary, the critical difference between reading Chinese and reading English is that the Chinese reader needs a holistic visual strategy to retain the Chinese characters while the English reader relies more on phonology (Perfetti, et al., 2007).

Visual Properties of Chinese Characters in Reading

Alphabets represent the individual speech sounds in a word, and the reading of alphabetic words maps print to meaning via phonetic transformation. Chinese characters, however, are directly linked to the visual and semantic properties of words (Smith, 1985), and the recognition of the characters in logographic languages maps visual patterns to meaning directly (Susanuma, 1974). As aforementioned, reading English requires forming connections between graphemes and phonemes, whereas reading Chinese requires recognition of characters as whole visual units (Ehri, 2005).

Studies have demonstrated that the visual aspect of Chinese characters is very important in learning Chinese. For example, the visual properties of a Chinese character could help learners to recognize a character among others (Turnage & McGinnies, 1973), and learners tend to remember characters as distinct pictures in the early stage of learning Chinese characters (Chuang, 1975). Furthermore, a high degree of association seems to exist between visual coding strategies in short-term memory and Chinese characters (Chen & Juola, 1982). Characters in logographic languages like Chinese seem to activate meaning quicker than words in alphabetic languages because they carry meaning directly through the shapes of the characters themselves (Biederman & Taso, 1979). Communication is achieved through semantic meaning and visual impact when decoding a Chinese character (Ju & Jackson, 1995). Given enough graphemic details in a character to match mental images, the logographic information seems to provide visual context leading to better recall (Ke, 1998), and when learning to read Chinese, children rote memorize the visual properties of a character and its connection to the meaning (Siok & Fletcher, 2001). In addition, "when reading Chinese characters, children rely on understanding the meaning of the syllable along with its visual-orthographic component" (Wang, Cheng, & Chen, 2006, p.544). Graphic information and visual processing skills seem crucial, as well, in Chinese character reading for both children and adult learners (Wang & Geva, 2003). These findings suggest that instructional methods using both verbal and visual information of Chinese characters may benefit students learning to read Chinese.

Dual Coding Theory

Dual Coding Theory was originally developed by Paivio and his assistants (Paivio, 1971; Paivio & Ernest, 1971) as a theory of human processing, storage, and retrieval of verbal and non-verbal information. This theory can be presented as "a set of assumptions and hypotheses regarding the origins and the structural and functional properties of representational systems". "Human cognition is unique in that it has become specialized for dealing simultaneously with language and with nonverbal objects and events," and "the language is peculiar in that it deals directly with linguistic input and output (in the form of speech and writing) while at the same time serving a symbolic function with respect to nonverbal objects, events and behaviors," therefore, "any representational theory must represent this dual functionality" (Paivio, 1990, p. 52).

The Dual Coding Theory assumes two functionally independent, but interacting symbolic systems in memory, one for processing verbal and language units, and the other for processing nonverbal objects and events. These two systems are expanded to subsystems at the next level in terms of sensory modalities, such as visual, auditory, haptic, etc., linked to motor responses through perception, as shown in Table 3 (Sadoski & Paivio, 2004).

Table 3

Orthogonal Relationship between Mental Systems and Sensory Modalities

Sensory Modalities	Mental Systems	
	Verbal	Nonverbal
Visual	Printed words	Pictures or objects
Auditory	Speech sounds	Environmental sounds
Haptic	Braille	Feel of objects

Representational Units

Paivio (1971) named the components in the verbal system *logogens* and the elements in the non-verbal system *imagens*. Logogens usually represent language units, such as auditory logogens for phonemes and visual logogens for graphemes. Logogens have a sequential structure in which smaller language units are organized into larger units in speech or writing. For instance, phonemes are organized into syllables, and syllables into words, etc. Similarly, graphemes in writing are also in a linear spatial arrangement such as letters combining to form words, and words combining to form sentences.

Imagens may represent objects, parts of objects, and groupings of objects, which are synchronously organized into nested sets or hierarchies. At the perceptual level, our visual system generates the mental images of all the parts of an object simultaneously. Meanwhile, these mental pictures are usually nested in other mental pictures (Paivio, 1990). For example, we can imagine a person in a living room, the living room in a house, and the house in a community. We can also imagine the person playing a piano in the living room while the music was heard through the auditory modality.

System Connections

Besides the representational connections between the sensory systems and the representational systems, two other types of connections exist. The first is the *associative connections* within each system. Logogens are associated with other logogens within the verbal system. For example, we can connect words with other words through synonyms and antonyms. In the nonverbal system, imagens are usually associated with other imagens in an integrated and nested way. For example, a house can be a single imagen, but it consists of other imagens smaller in hierarchy, such as kitchen, bedrooms, and bathrooms, etc.

The second type of connections is the *referential connections* between these two systems, i.e., logogens and imagens are interconnected: the name of an object may generate a representational image of the object in our memory, and similarly, we may recall the name of the object when seeing a familiar object. For instance, hearing the word *tree*, we can recall a picture that represents a tree in mind, and when seeing a picture of a tree, we can name it with the word *tree*. Figure 1 illustrates the general model of the components and processes (Paivio, 1990), with the different cognitive connections between the contents of each system.

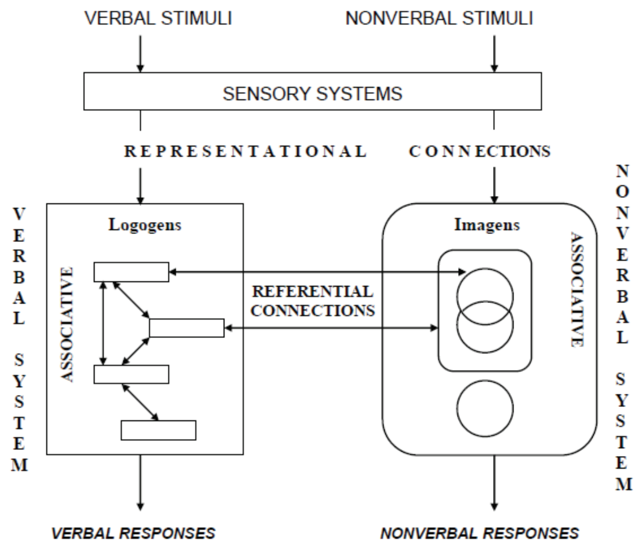


Figure 1. Model of Dual Coding Theory (Paivio, 1990).

Processing Levels

Given the subsystems and the connections among them, Dual Coding Theory (Paivio, 1990, 2007) assumes three corresponding levels of processing: *representational processing*, *associative processing*, and *referential processing*.

Representational processing refers to the process of recognizing objects we are familiar with through direct stimuli, either verbal or nonverbal. For example, either hearing the word *tree* (through the auditory sensor) or seeing the printed word *tree* (through the visual sensor) will activate logogens in the verbal system, while seeing a picture of a tree will activate imagens in the nonverbal system. This processing usually happens very quickly for familiar words or objects and does not involve further comprehension effort.

Associative processing refers to the procedure that representations are activated by other representations within the same system, i.e., logogens activate other logogens while imagens may activate other imagens. For instance, in the verbal system, the word *pet* can activate other words like *dog*, *cat*, etc. In the nonverbal system, a picture of a basketball may activate other associated images of basketball players or a basketball court.

Referential processing refers to the interaction between the two systems, which may involve a one-to-many or many-to-many referential correspondence between logogens and imagens. For example, the word *pet* can activate multiple mental images of dogs and cats, while a picture of a zoo may activate multiple words, such as *animal, tiger, bird*, etc. The latter example also shows that referential processing may be related to associative processing, as the logogen (*animal*) activated by the imagen (a picture of a zoo) may activate other associated logogens like *tiger* and *lion*, which in turn, can activate the nonverbal system to recall the imagens of these animals in memory.

These assumptions of Dual Coding Theory have received supporting evidence from psychological and cognitive neuroscience studies, which are briefly reviewed in the next section.

Neuropsychological Evidence

The independency of the verbal and nonverbal systems has found support from the functional asymmetries between human's hemispheres, as well as evidence of various functions served by different areas in each hemisphere, with verbal inputs being processed in the left hemisphere and nonverbal stimulus being processed in both left and right-hemisphere (Ley, 1983). The functional asymmetries between the two hemispheres have been discovered through the study of normal brains and patients with impaired corpus callosum connecting the two hemispheres (Bryden, 1982). In addition, studies of patients with focal lesions in the hemispheres have revealed the functions of different regions within each hemisphere (Ratcliff et al., 1980).

Functional Asymmetries of the Hemispheres. The left hemisphere is superior and more efficient than the right hemisphere in verbal related tasks, such as speech, comprehension, and perceptual recognition, while the right hemisphere shows advantages in tasks that involve nonverbal processing including nonverbal sound recognition, face identification, and memory for spatial patterns (Paivio, 1990). For example, patients with anterior impaired right hemisphere may perform better in word recognition than naming objects presented in pictures, while patients with left hemisphere damage may do better with pictures rather than words (Whitehouse, 1981).

Furthermore, these conclusions can be generalized across different sensory modalities, such as visual, auditory, and haptic (Paivio, 1990). Dual Coding Theory assumes that symbolic systems and sensory modalities are orthogonal, and it also implies that the cognitive representations corresponding to verbal and nonverbal events are themselves functionally specific and variable with respect to sensory modality. For example, "printed words activate neuronal systems specialized for visual processing of word patterns (visual logogens), whereas spoken words activate systems specialized for auditory processing of word patterns (auditory logogens)" (Paivio, 1990, p. 265).

Although the left hemisphere shows advantages in processing visually coded verbal information, such as letters and words, the functional differences are not divided precisely between the two hemispheres. For example, objects may be recognized equally well regardless of which hemisphere is presented the pictures of these objects, a finding which suggests both hemispheres may contain representational systems for processing images of common objects (Paivio & Ernest, 1971). Patients with either left-temporal or right-temporal lobe damage can respond properly to instructions to construct and describe images of the referents of concrete word-pairs, suggesting that the semantic memory representations and processes necessary for generating nonverbal-visual images may exist in both hemispheres (Jones-Gotman & Milner, 1978).

Support for System Structures and Processing Levels. Neuropsychological research has addressed the sequential structure in the verbal system and the synchronous processing in the nonverbal system. Studies on patients with lesions of regions for speech in the left-hemisphere (e.g., Efron, 1963) and dichotic listening studies (e.g., Mills & Rollman, 1980) suggest that the left hemisphere has more temporal capacity for verbal sequential processing. In addition, investigation of patients with damage to the left-frontal and parietal lobe has revealed that the left-temporal lobe plays an important role in the sequential organization of speech (Kimura, 1982). Therefore, the frontal areas of the left hemisphere might be responsible for processing sequential information, especially "in the case of speech and perceptual and memory processing of verbal stimuli" (Paivio, 1990, p. 270). Although some studies suggest that posterior regions of both hemispheres contribute to the synchronous processing functions in the nonverbal system (Luria, 1976), patients with lesions in the right hemisphere may have difficulty with perceptual recognition, memory, and other cognitive tasks that involve spatial information processing (Paivio & te Linde, 1982), a finding which implies the dominance of the right hemisphere in “dealing with synchronously organized structural information that is simultaneously available for processing” (Paivio 1990, p. 271).

Neuropsychological studies have also found evidence that supports different levels of processing and different types of connections within and between the verbal and nonverbal systems. As aforementioned, representational processing refers to the activation of logogens by verbal input or activation of imagens by nonverbal stimuli. Research on the representational areas in the cortex and the sensory pathways from receptors to these areas has revealed that patients with damaged parieto-occipital areas in the left hemisphere may have difficulty comprehending written language but little trouble recognizing objects (Luria, 1976). Similarly, lesions in the right hemisphere may lead to poor performance in drawing or recognizing faces. Evidence that supports associative processing (via within-system functional connections) and referential processing (via the between-system interconnections) comes mainly from research on functional dissociations (Geschwind, 1965; Luria, 1976; Paivio, 1991; Whitehouse, 1981). In anomic aphasia, for example, patients who have the ability to match names to printed words can recognize an object but cannot name it, and they may perform well in purely verbal or purely visual tests, but very poorly in verbal-visual tests, such as naming colors as characteristics of an object, a finding which suggests that referential processing is disrupted while both verbal associative processing and nonverbal (visual) associative processing are not affected (Beauvois, 1982). Studies on the performance of aphasics with anterior or posterior hemispheric damage in naming pictures have demonstrated that nonverbal associative processing may be interrupted but the referential processing remains intact, which provides evidence for selective associative disturbances (e.g., Whitehouse, 1981).

Evidence from Studies on Word Concreteness. Studies on how concreteness contributes to word recognition (Day, 1979; Funnell et al., 2001; Gullick, Mitra, & Coch, 2013; Jessen et al. 2000; Kounios & Holcomb, 1994; Levine & Banich, 1982; Sadoski, Goetz, & Fritz, 1993; Shibahara & Lucero-Wagoner, 2002; Villardita et al., 1988; Wang et al., 2010; Welcome et al. 2011) also support the Dual Coding Theory although there are alternative theories of semantic representation regarding word concreteness (Kousta et al., 2011). Abstract words, which are usually less imageable, are processed through verbal coding in the left cerebral hemisphere only, while concrete words, in addition to the verbal-based processing in the left hemisphere, may go through a second image-based processing in the right hemisphere (Paivio & te Linde, 1982).

Given separate presentation of words in either visual half-field, the right visual field (left hemisphere) is superior in processing low imagery nouns but not in processing nouns with high imagery in terms of reaction time (Day, 1979). In addition, the right hemisphere contributes more to the recognition of pictographic as compared to phonetic writing systems as well as in the recognition of highly imageable concrete words as compared to less imageable abstract words (Levine & Banich, 1982). Patients with right hemisphere damage may have much worse recall given concrete words but not in the case of abstract words (Villardita et al., 1988). Abstract words presented to the right hemisphere may be sent to the left hemisphere with processing advantages in verbal coding (Shibahara & Lucero-Wagoner, 2002).

Furthermore, Dual Coding Theory has found evidences in studies on the hemisphere activation patterns associated with word concreteness in corpus callosotomy patients (Funnell, et al., 2001). Concreteness effects in semantic processing using Event Related Potentials (ERPs), which are "the stimulus-bound portion of the ongoing electro-encephalogram (EEG) obtained by averaging the measured electrical activity after multiple comparable stimulus events", have also provided evidence for Dual Coding Theory (Kounios & Holcomb, 1994). For example, ERPs examined the response to concrete and abstract concepts when generating word associates or mental images (Welcome et al., 2011). In addition, ERPs' response to direct stimuli of a sensory, cognitive, or motor events, have shown that concrete words benefit from greater activation in both verbal and nonverbal systems (Gullick et al., 2013).

Dual Coding Theory has also received support from recent neuroimaging studies on the functional neuroanatomy of the concreteness effect although the findings are not consistent with the classical assumption of hemispheric asymmetry in some cases. Studies using functional magnetic resonance imaging (fMRI) in the detection of brain areas related to word processing have observed greater activation in the lower left and right parietal lobes as well as in the left inferior frontal lobe during the processing of concrete words compared to abstract words (Jessen et al., 2000). In addition, fMRI in processing concrete and abstract words in lexical decision tasks suggests a subregion of the left inferior frontal gyrus is activated more strongly by abstract words than concrete words, while specific activity for concrete words is observed in the left basal temporal cortex (Friederici et al., 2000). Meta-analysis of neuroimaging studies on neural representation of abstract and concrete concepts have suggested that the verbal system may have greater engagement for processing of abstract concepts while the perceptual system via mental imagery may have greater engagement for processing of concrete concepts (Wang et al., 2010).

In summary, the Dual Coding Theory is well supported by these neuropsychological studies. Its applications have been found in many cognitive tasks including mnemonic techniques, language education, and literacy studies. The next section reviews dual coding in language acquisition, such as vocabulary learning, sentence and text comprehension, and keyword method, etc.

Dual Coding in Language Acquisition

Dual Coding Theory has been applied to design instructional methods for literacy and language acquisition (Clark & Paivio, 1991; Sadoski & Paivio, 2001; Paivio, 2007). This section reviews studies showing the effectiveness of imagery, word and sentence concreteness, and mnemonic techniques based on Dual Coding Theory in teaching first language and foreign language.

Applications in First Language Acquisition

Dual coded instructional methods have shown positive effects in first language acquisition, such as vocabulary learning (Bull & Wittrock, 1973; Cohen, 2009; Cohen & Johnson, 2011; Paivio, 1971; Sadoski, 2005; Smith, Stahl, & Neil, 1987), sentence comprehension (Begg & Paivio, 1969; Eddy & Glass, 1981; Holmes & Langford, 1976; Jorgensen & Kintsch, 1973; O'Neill & Paivio, 1977; Sadoski, Goetz, & Fritz, 1993), and comprehension of larger textual units such as paragraphs and texts (Denis, 1984; Glenberg & Langston, 1992; Levin & Berry, 1980; Purnell & Solman, 1991; Waddill et al., 1988).

Vocabulary Learning. One of the important goals in language acquisition is vocabulary learning, which is directly associated with reading comprehension (Johnson, 2001; Rosenshine, 1980) since a learner should know at least 90% of word meanings in a text so as to comprehend the meaning of the text (Nagy & Scott, 2000).

The significant role of imagery in teaching vocabulary has been well documented. Early studies have reported better vocabulary learning performance by using a “rhyming mnemonic scheme that consists of a series of peg words that rhyme with numerals” that can be used as “stimuli for the recall of new words by imagining the referents of the words in interaction with the rhyming pegs” (Paivio, 1971). Pictures have significant effects on teaching definitions of nouns to children in elementary classes (Bull & Wittrock, 1973) and a mixed pictorial and verbal context is usually more effective than verbal-only context in teaching vocabulary (Smith, Stahl, & Neil, 1987). Furthermore, concrete high-imagery words, illustrations, and self-generated imagery have been shown to have impact on teaching vocabulary to both regular readers and those with reading difficulties (Sadoski, 2005). Imagery interventions have demonstrated positive influence on elementary students' vocabulary learning abilities (Cohen, 2009). In one study, participants were randomly assigned to three groups: word-only, word paired with image, and self-generated image, and words were taught in three categories: musical instruments, science terms, and animals and habitats. The results showed a significant difference between the word-only and self-generated image treatments given science terms. Feedback from the students revealed that being presented a picture or using images they drew on their own helped them to learn the words (Cohen & Johnson, 2011).

Sentence Comprehension. Generally speaking, abstract sentences are stored primarily as verbal units in memory while concrete sentences are stored more likely as nonverbal images, which retain the meaning instead of the wording of the sentence (Begg & Paivio, 1969). Given the same sentence meaning, semantic changes are recognized more often than wording changes for concrete sentences, but wording changes are more noticeable than semantic changes for abstract sentences (Begg & Paivio, 1969).

The effects of sentence concreteness on comprehension and the connection between concrete sentence and imagery have been discussed in numerous studies. The reaction time of sentence evaluation in terms of the rating of how easy to form an image of the sentence has revealed that sentences rated as easy to imagine are evaluated more quickly than sentences rated as difficult to image, indicating imagery may facilitate the comprehension process (Jorgensen & Kintsch, 1973). An extended study on the effects of semantic relatedness and semantic complexity in addition to the effects of rated imagery on reaction time also supports this conclusion (Holyoak, 1974). Furthermore, it has been demonstrated that concrete sentences are classified much faster than abstract sentences in a sentence meaning classification task and more words are recalled from concrete sentences than from abstract sentences in a free recall task (Holmes & Langford, 1976). Findings from sentence rating experiments based on imagery and recall have suggested that concrete sentences receive higher imagery ratings and higher recall scores than abstract sentences (O'Neill & Paivio, 1978), and imagery has played a significant role in sentence understanding in verification and comprehension tasks given high-imagery sentences and low-imagery sentences (Eddy & Glass, 1981). Moreover, results have indicated that using the rating norms as predictors, easy-to-image concrete sentences are recalled twice more than abstract sentences with respect to the comprehensibility, interestingness, and familiarity of concrete and abstract sentences in rating and recall tasks (Sadoski, Goetz, & Fritz, 1993).

Text Comprehension. Comprehension may benefit from self-generated pictures or provided images as discussed in a review of psychological research on the role of imagery processes in prose comprehension by both children and adults (Denis, 1984). Results from experiments designed to investigate the use of images in the comprehension tasks involving technical content by high school students have revealed that technical material may be comprehended better in the form of illustrations than as text, and may be comprehended best if presented in both forms (Purnell & Solman, 1991). In addition, Glenberg and Langston (1992) conducted experiments to test how pictures may help adults in a text comprehension task that involved sequential steps. Participants were given a text about a four-step procedure in which they middle two steps occurred simultaneously. They found participants who were given the text accompanied by appropriate pictures tended to mentally represent the procedures, while they tended to remember the text itself if it was presented alone.

Images may also help on memory for information presented orally in classrooms. For instance, experiments were conducted with elementary students on recall of stories from information recorded on the tape (Levin & Berry, 1980). The researchers designed both single pictures to illustrate only the main idea of newspaper articles, and a group of pictures, each illustrating a sentence in the passage. The results showed that students who only heard the stories on tape recalled less than students how heard the story on tape and viewed related images at the same time.

Dual Coding in Foreign Language Acquisition

Besides applications in first language acquisition, the Dual Coding Theory has been extended to facilitate foreign language acquisition. Many instructional techniques, such as the keyword method (Atkinson & Raugh, 1975), which is a mnemonic technique widely used for learning foreign language vocabulary, have been developed based on the relations between the two systems assumed by the dual coding theory. A bilingual dual coding model has been developed by Paivio and Desrochers (1980) and applied to reading by Japanese-English bilinguals (Taura, 1998) and Chinese-English bilinguals (Steffensen et al., 1999). In addition, the dual coding model has been extended to general foreign language acquisition (Matsumi, 1994; Sham, 2002; Pan & Pan, 2009).

Keyword Method. The keyword method for foreign language vocabulary acquisition was first proposed by Atkinson and Raugh (1975). The basic idea is to use a familiar native word which is phonologically similar to the foreign target word to build an auditory and semantic relationship between the target word in the foreign language and its native language translation equivalent. For example, to learn the Spanish word *carta*, which means 'letter', we may use the English word *cart* because the acoustic link is easily established by the similarity in sound between these two words. To establish the semantic link, we may create an image of the referents of the words such as a large letter-size envelope in a shopping cart (Paivio, 1990). Thus, the acoustic link reminds us of the related word while the imagery connection gives us a trace to what the word means. It has been reported that the keyword method used by native English speakers learning Russian words is more effective than translation-based methods (Atkinson & Raugh, 1975).

More research has been done on the keyword technique in foreign language vocabulary learning. Cohen (1987) provided a critical review of the use of imagery or verbal mnemonics and their succeeding retrieval in vocabulary learning of a second-language. In particular, an imagery-based hook mnemonic method based on the associative processing of the Dual Coding Theory in has been applied to teach college students French as a foreign language (Paivio & Desrochers, 1979). The hook method is similar to the keyword method but promotes "practice in the active recall of appropriate vocabulary items in contexts where other words from the second language itself serve as associative retrieval cues presented in the second language itself, without necessarily relying on translation" (p. 1). The hook method employs a prearranged sequence of mnemonic words to which target words are "hooked" by means of images. These peg words are highly imageable which "translate into numbers by means of a consonant-number code based on visual or acoustic similarity," and in this way, "the pegs and related images can be generated mentally from the numbers to serve as retrieval cues for the new words" (p. 2). The results suggested that the word recall rate using the imagery method was about three times higher than rote, and students using the imagery-based method made twice correct translations as much than those using rote in the translation tasks. Using new concrete English nouns, a study compared a method that was a combination of context analysis and keyword with rote memory, context-only, and keyword-only methods in a class of ninth-grade Spanish-speaking students (Rodriguez & Sadoski, 2000). The immediate post test revealed that the performance of the keyword-context group was the same as that of the other groups, while the keyword-context group performed much better than all the other groups in the delayed posttest one week later.

These findings are in line with the Dual Coding Theory which proposes that verbal and imagery processes are additive on their effects on memory given appropriately designed instructions.

Bilingual Dual Coding Model. For foreign language acquisition by bilinguals, Paivio and Desrochers (1980) proposed a bilingual dual coding model which includes two functionally independent but interacting verbal systems (V_1 and V_2) corresponding to the first language (L_1) and second language (L_2), both associated with the same nonverbal (image) system (I) as shown in Figure 2. This independence assumption implies that bilingual learners may access only the verbal contents without input from the nonverbal system, and they may perceive or recognize events and objects without the involvement of either verbal system.

The connections (V_1 - V_2) between bilingual verbal systems are one-to-one, usually represented by translation equivalents. However, the connections within each system remain one-to-many. For example, an English-Chinese bilingual will translate *dad* into 爸爸, while there are many links between *dad* and other concepts in each language, e.g., dad-father, dad-mom, dad-man in English and 爸爸(dad)-父亲(father), 爸爸(dad)-妈妈(mom), 爸爸(dad)-男人(man) in Chinese. The verbal systems and the nonverbal system are connected at the referential level (V_1 - I, V_2 - I). These connections are partially shared and partially independent because "the verbal translation equivalents in L_1 and L_2 may or may not activate the same nonverbal representational information, depending on the way the two languages have been acquired" (Paivio, 1990, p241-242).

This assumption implies that translation equivalents do not necessarily have identical referential meanings.

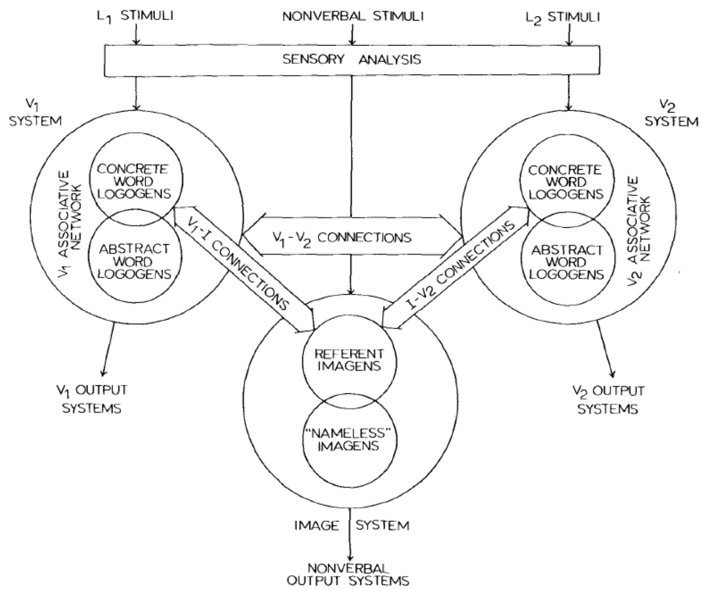


Figure 2. Scheme of the bilingual dual coding model (Paivio & Desrochers, 1980).

Studies have demonstrated the applications of the bilingual dual coding model in instructional methods (Taura, 1998; Steffensen et al., 1999). For example, the participants in Taura (1998)'s study were Japanese-English bilingual high school students. The findings showed that the bilingual dual coding effect in vocabulary acquisition was the same in Japanese-English bilinguals as in alphabetic language speakers who learn another alphabetic language as an L_2. Steffensen et al. (1999) studied the nonverbal aspects, such as images and emotions, during the reading by bilinguals. Participants who were Chinese students studying in an American university were randomly assigned to read an article about travelling on a train in China, written either in English or Chinese. They were tested individually by drawing pictures they possibly created in mind during the reading, and responding to questions about their emotions. The results indicated by strength ratings of the imagery and emotion from articles written in English were almost the same as those written in Chinese. However, the time spent by these second language learners was nearly doubled compared to the native speakers, a finding which is consistent with the observations in ESL classrooms that reading in a second language usually takes much longer than reading in a first language.

Extension to Foreign Language Acquisition. Although the bilingual dual coding model was first introduced to account for the mental representation of information in the memory of bilinguals, it has been extended to general foreign language learning. However, the learner, with associative connections in the established L_1 verbal representations, needs to develop a verbal representational system corresponding to L_2 as well as referential interconnections between those verbal representations and nonverbal representations in the image system (Paivio, 1983).

Sham (2002), who cited work by Matsumi (1994) on the extension of the bilingual dual coding model using participants of both Japanese-English bilinguals and native Japanese speakers learning English, reported that the bilingual dual coding model was supported by the results from the bilingual group, but was not in line with the results from beginning English L2 learners "because their associations between two verbal systems and the imaginal system have not been sufficiently developed" (Sham, 2002, p. 71). Instead, an alternative dual coding model was proposed to investigate the effects of dual coded instructional methods in foreign language acquisition, for example, English speakers learning Chinese words (Sham, 2002).

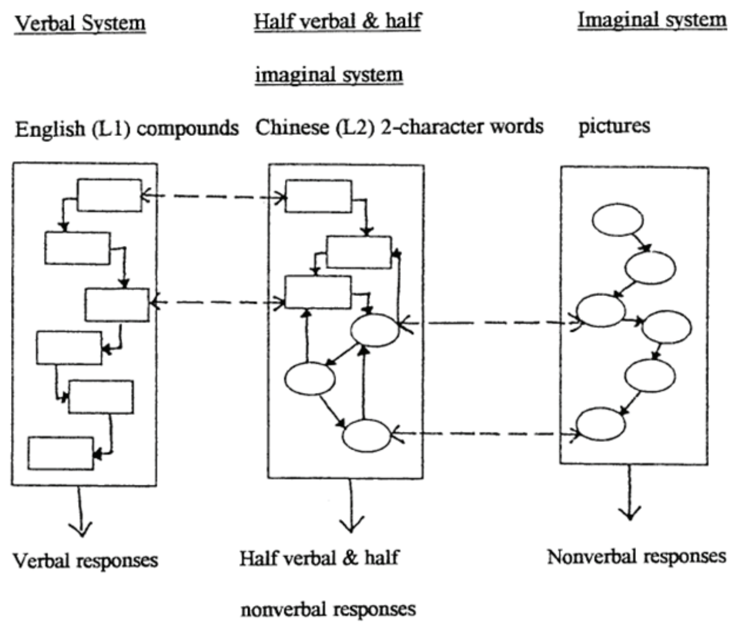


Figure 3. A dual coding model for learning Chinese words (Sham, 2002, p. 170).

A major assumption of this model, as shown in Figure 3, is that coding Chinese words involves dual routes of half verbal and half nonverbal system with referential connections, i.e., English (L_1) words activate logogens in the verbal system with associated imagens processed in the nonverbal system, but Chinese (L_2) words activate both logogens and associated imagens in the mixed verbal and nonverbal system at the same time.

In a study that investigated whether the presence of pictures in text facilitates low-proficiency college students in Taiwan who learned English as a foreign language (EFL) (Pan & Pan, 2009), a low-level (shorter and simple) text was given to two groups: the text-only group and the text-with-pictures group. Similarly, a high-level (longer with more complicated grammar and more difficult vocabulary) text was given to the other two groups: the text-only group and the text-with-pictures group. The results revealed that text-picture groups had significantly higher scores on translation tasks than text-only groups. In addition, participants in the high-level text-with -pictures group had lower scores than those in the low-level text-with-pictures group, a finding which might due to the fact that "pictures have a more beneficial effect only when they closely mirror the structure and complexity of the text" (p. 193), and "when low-proficiency EFL college students are provided with texts that exceed their proficiency level, the accompanying pictures should be as elaborative as possible" (p. 194).

In summary, dual coded instructions have been applied to both first language and foreign language acquisition. The next section reviews theories and studies that involve multimedia learning for foreign language acquisition based on the extension of the dual coding theory.

Dual Coding and Multimedia Learning

Computers have great capability of organizing and displaying information through multi sensory, such as picture, audio, text, and animation. Based on the dual coding theory, printed text or auditory narration in multimedia presentations are verbally coded while images and animations are visually coded. Applications of instructional technologies that involve computer multimedia have become popular in foreign language teaching in recent years (Cheng, 1995; Chuang & Ku, 2011; Kuo & Hooper, 2004; Levy, 1997; Muyskens, 1997; Warschauer & Healey, 1998). Multimedia annotations have shown positive effects in learning foreign language vocabulary (Al-Seghayer, 2001; Davis & Lyman-Hager, 1997, Kuo & Hooper, 2004; Reed & Beveridge, 1990), and computer animations have provided foreign language learners an effective way for obtaining information visually (Chuang & Ku, 2011; Ki et al., 1994; Lai, 1998; Lam et al., 1993; Li, 1996; Nakajima, 1988; Rieber, 1991).

In particular, computer-assisted Chinese language applications have used animations to connect the modern presentation of Chinese characters to their pictorial origins (Cheng, 1995). The visual coding strategy based on computer animation may build a better referential association between the meaning and the structure of a Chinese character, which could help students to memorize it. For example, tutorial lessons of Kanji, which are Chinese characters used in Japanese, have been developed to illustrate the stroke sequence of writing a Kanji character and how a modern Kanji character is transformed from its original picture (Nakajima, 1988). Similar computer programs have been designed to show an animated stroke sequence of writing Chinese characters (Lam et al., 1993). A more helpful computer animation usually begins with a realistic picture related to the origin of a Chinese character, gradually changing to a skeleton preserving the structure of the character, and eventually transforming to the modern written form of the character (Ki et al., 1994).

Dual coded multimedia instructional methods have also been developed for foreign language acquisition (Chen, 2006; Chuang & Ku, 2011; Kuo & Hooper, 2004; Mayer & Sims, 1994; Mayer, 1997, 2001; Plass et al., 1998, 2003). Students with high spatial ability seem to give more cognitive resources to building referential associations between the visual presentation and verbal demonstration of the multimedia content, while students with low spatial ability seem to allocate extra cognitive resources in building representation connections between information presented visually and its visual representation (Mayer & Sims, 1994). Digital vocabulary cards, which are computer-based flashcards using voiced-pronunciation and stroke-sequence animation, have been developed to assist beginning Chinese learners in memorizing Chinese characters (Zhu &

Hong, 2005). The findings revealed that the group given voiced-pronunciation only performed better than the group given characters presented with both voice and animation; however, further examination on the effect of stroke sequence animation is needed to determine whether this medium may help beginning Chinese learners master the proper stroke sequence in Chinese characters (Zhu, 2010).

In order to lay a foundation for investigating how a language learner may integrate verbal and visual information given a multimedia presentation that may involve multiple sensory, Mayer (1997, 2001) developed a Generative Theory of Multimedia Learning which borrows ideas from both the Generative Theory of Learning (Sternberg, 1985; Wittrock, 1974, 1989) and dual-coding theory (Paivio, 1990), and the Generative Theory of Multimedia Learning was further extended and applied to foreign language learning (Chen, 2006; Plass et al., 1998, 2003).

Generative Theory of Learning

The Generative Theory of Learning suggests that human learning is “a function of the abstract and distinctive, concrete associations which the learner generates between his prior experience, as it is stored in long-term memory, and the stimuli” (Wittrock, 1974, p. 89). Meaningful learning can be achieved through a variety of learning strategies, such as recall, integration, organization, and elaboration (Wittrock, 1989). For example, in the recall process, learners may use techniques, such as mnemonics, repetition, rehearsal, or review to obtain information stored in their long-term memory. To connect new information to prior knowledge in an organized way, they commonly apply strategies like paraphrasing, summarizing, outlining, or clustering. With an established connection between the new and prior knowledge, the new information is synthesized and elaborated through writing, mental images, or visual displays, etc. (Chen, 2006). Research on mnemonics in paired associate learning has demonstrated that long-term retention is improved if the learner invents his own elaboration or mnemonics (Treat & Reese, 1976; Wall & Routowicz, 1987). This suggestion corroborates the proposal made by the Generative Theory of Learning that instructional methods which help the learners to create a unique connection between memory and input may benefit long-term retention.

Generative Theory of Multimedia Learning

The Generative Theory of Multimedia Learning integrates ideas from the Generative Theory of Learning and assumptions from the Dual Coding Theory (Mayer, 1997). The Generative Theory of Learning suggests that learners are engaged in meaningful learning by choosing related information from the presented contents, categorizing the selected information into a consistent representation, and incorporating it with their prior knowledge. For multimedia learning, this means learners will select the information, such as words and pictures, through both auditory and visual sensors, and transfer it from the sensory memory to the working memory where the information is processed and organized into coherent verbal and nonverbal representations connected to the knowledge in the long term memory.

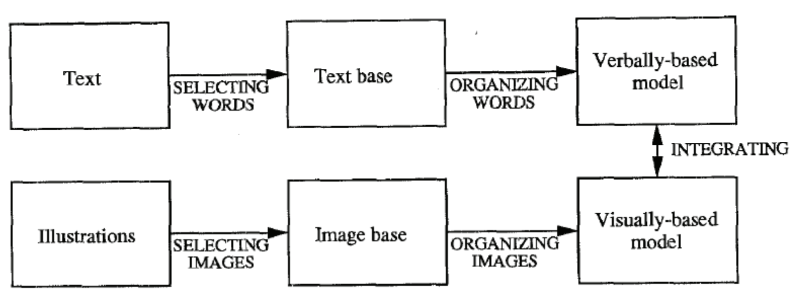


Figure 4. Generative model of multimedia learning (Mayer, 1997, p.5).

The assumption from the Dual Coding Theory indicates that these cognitive processes happen through two systems, i.e., a system handling verbal information and a system for dealing with nonverbal information. As aforementioned, in multimedia presentations, printed text or spoken words are verbally presented information while pictures and animations are nonverbally presented information. With respect to sensory modalities, information, such as spoken words or background sounds, is processed through the auditory channel while information, such as printed texts, pictures, and animations, is processed through the visual channel. As each channel has limited cognitive capacity, learners can only bring a part of the words or pictures into the working memory at one time (Baddeley, 1992), i.e., given new information presented via multimedia, the amount of information that can be processed in the auditory or visual channel is limited at one time. For instance, when listening to a dialog during language learning, learners can only select a portion of the dialogue to be processed in their working memory with possible subsequent integration into their long-term memory (Chen, 2006). The same applies to the visual modality. When learners are shown a sequence of images on a computer screen, they may perceive all the images by the visual modality, but they can only bring a few into their working memory to be processed at one time. Therefore, a practical implication is to present description as narration instead of on-screen text in animations, which may help to minimize modality-specific cognitive load (Sweller, 1988, 1994). The information paths and memory stores in the process of multimedia learning are illustrated in Figure 5 (Chen, 2006).

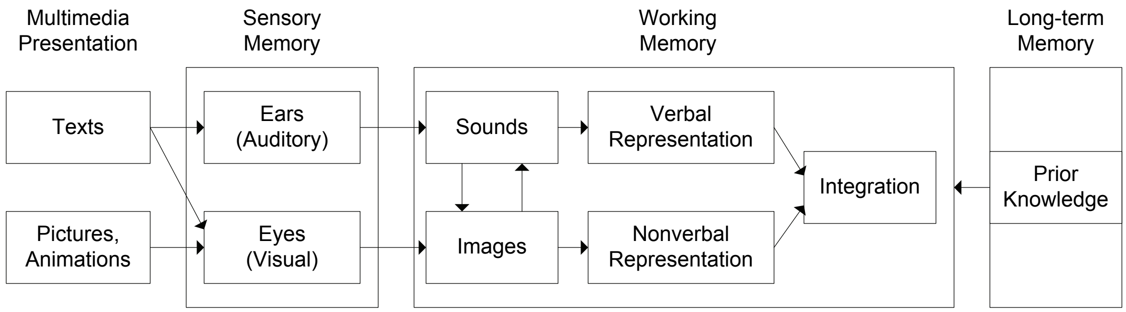


Figure 5 Information and memory paths in multimedia learning (adapted from Chen, 2006)

In addition, verbal and visual content in the multimedia presentation should be shown simultaneously instead of successively because learners can only integrate, i.e., build the referential connections between the mental representations of texts and images when both verbal and nonverbal information are simultaneously available to be processed in the corresponding working memories (Mayer, 2001). For example, students who received either texts with pictures or narration with animation have shown better performance on retention tests than those who were only given access to either text or narration (Mayer, 2001).

Extension of Generative Theory of Multimedia Learning

The Generative Theory of Multimedia Learning has been extended to foreign language learning (Chen, 2006; Plass et al., 1998, 2003) based on the assumption that foreign language learners possess two separate verbal systems that share the same nonverbal system, and they "learn new words when they can establish a direct connection between the words in their native language, the corresponding picture of an object or action, and its foreign equivalent" (Plass et al., 1998, p. 26). For example, Plass et al., (2003) examined whether dual-coded instructional multimedia may help students with diverse verbal and cognitive abilities in foreign language acquisition. After taking a

German vocabulary pretest which measures the baseline of their vocabulary knowledge level, the participants, who were native English adult learners enrolled in a second-year German class, read a story in German presented by a multimedia tutorial, in which target words in the text were annotated both verbally and visually in the form of English translations, pictures, or video clips. Four different treatments were employed in which the control group received no annotations for the target words, one group received verbal annotations only (English translations), one received visual annotations only (pictures) and the fourth group received both verbal and visual annotations (video clips). Following the vocabulary posttests, participants were tested on their spatial ability and verbal ability, because according to cognitive load theory (Sweller, 1994; Mayer, 1997), low-ability students "may not be able to process verbal and visual annotations and build referential connections between them due to the high cognitive load imposed by this processing" (Plass et al., 2003, p. 225). This factor was also considered in Yeung et al. (1998)'s study which compared reading comprehension of low-ability and high-ability ESL students in eighth grade. The results showed that participants learned more vocabulary words when both verbal and visual annotations were presented than when only one kind of annotation or no annotations were given. When participants "received visual annotations for vocabulary words, low-verbal and low-spatial ability students recalled fewer words than high-verbal and high-spatial ability students" because "they do not have sufficient cognitive resources to process the visual information and build referential connections and therefore experience deleterious effects" (Pass et al., 2003, p. 233). These findings were consistent with the Dual Coding Theory in conjunction with the Generative Theory of Multimedia Learning.

Furthermore, dual coded multimedia annotations have shown positive effects on secondary language vocabulary recall (Chen, 2006). The participants who were college students learning English as a second language (ESL) read a text of twenty new words annotated in text-picture or audio-picture and took an immediate vocabulary recall test. The text annotation and audio annotation presented verbal information, while picture annotation presented non-verbal (visual) information. The results indicated that the group with audio-picture annotations performed much better than the group with text-picture annotations on the vocabulary recall test.

The modality effect (Baddeley, 1992; Mayer, 2001) suggests that processors in the working memory are partially independent for auditory information and visual information processing. Text annotation and picture annotation are input through the visual channel, while audio annotation is input through the auditory channel (Chen, 2006, p. 131). In text-picture annotations, the visual channel might be overloaded by the simultaneous register of both text and picture. As a result, the cognitive resources available in the visual working memory were divided between textual and pictorial information, and only the visual working memory was involved in processing both information. In contrast, the audio in audio-picture annotations was input through the auditory channel and processed in the auditory working memory, while the picture was registered through the visual channel and processed in the visual working memory (Chen, 2006, p. 131). Therefore, cognitive resources in both working memories were utilized for audio-picture annotations, leading to better performance.

Chen (2006) further explained the superior performance of audio-picture annotation on the vocabulary recall test based on the split-attention principle (Mousavi, Low, & Seller, 1995). The learners with access to text-picture annotations had to split their attention in the visual working memory between two visual resources, i.e., written text and picture, while learners given audio-picture annotations approached the audio as an auditory resource through auditory working memory and the picture as a visual resource through visual working memory, which did not lead to an attention split in either of the working memories. Therefore, "audio-picture annotations presenting information in a mixed visual and auditory mode might increase the effective capacity of working memory, resulting in better vocabulary recall" (Chen, 2006, p. 132).

To sum up, these studies have suggested that multimedia presentation can be an effective tool for teaching foreign languages. Based on the Generative Theory of Multimedia Learning, dual coded multimedia instructional methods that integrate text with accompanying pictures or animation may help foreign language learners in the tasks like vocabulary learning or reading comprehension. Many of the empirical studies reviewed in the next section have implemented the dual coded instructional methods in a multimedia learning environment to facilitate the acquisition of Chinese as a foreign language.

Dual Coding in Learning Chinese as a Foreign Language

As discussed in the previous sections, a considerable number of studies based on the Dual Coding Theory and multimedia learning have been conducted in alphabetic language acquisition. However, dual coded instructional methods have not been widely developed for learning Chinese as a foreign language. This section reviews relevant studies that have applied dual coded methods in teaching Chinese characters (Chuang & Ku, 2011; Kuo & Hooper, 2004; Sham 2002), Chinese radicals (Lai, 1998), and Chinese words (Shen, 2010; Sham 2002). Furthermore, it discusses how concreteness may contribute to sentence comprehension (Chen, 2010; Ho & Chen, 1993) with learners of Chinese whose native language employs an alphabetic writing system. In particular, it points out where these studies fall short and what remains to be investigated.

Learning Chinese Characters

Given the graphic nature of Chinese characters, researchers have explored the extent to which imagery-based instructional designs may offer an advantage in the acquisition of Chinese vocabulary. For example, Chuang and Ku (2011) examined whether dual coded instructional methods involving animated images increased recognition and retention of Chinese characters by college students with no exposure to the Chinese language. The participants were randomly assigned to two groups with different dual coding treatments: the text group (animated image-plus-text) and the narration group (animated image-plus-narration). A computer-based tutorial presented twenty Chinese characters using these two different methods with each character being displayed for 15 seconds. An immediate posttest and a one-week-later delayed posttest were given to measure character recognition and retention respectively. No significant difference between the treatments (animated image-plus-text or animated image-plus-narration) and no interaction between the treatments and test occasions (immediate or delayed posttests) were found. These results were not in line with the modality effect theory (Baddeley, 1992; Mayer, 2001) which predicts that picture plus narration should work better than picture plus text because both picture and on-screen text are processed through the visual channel, generating more cognitive load in this channel. With the narration being processed via the auditory channel, the cognitive load may be reduced.

The authors hypothesized that the equal effects of these two methods might have been caused by the unitary selection of the Chinese characters – all the characters were pictographs that represent concrete physical objects in their study.

The effects of verbal and visual mnemonics on memorizing both concrete and abstract Chinese characters were investigated in another study conducted in a computer-based learning environment (Kuo & Hooper, 2004). Participants who were high school native English speakers were assigned to one of the following groups randomly: verbal coding, visual coding, dual coding, translation, or self-generated coding. Following a computer-based tutorial, the participants took a computer-based immediate posttest and a one-week-later delayed posttest. The results revealed that the posttest performance of the self-generated coding group was slightly better than that of the dual coding group but significantly better than those of the translation, verbal coding, and visual coding groups. Besides the achievement scores, the time factor was investigated in this study. No restriction was given on how much time the participants could take to view the tutorial. As a result, participants who created mnemonics of their own took more time on tasks than those in other groups. Regarding word concreteness, they found that "(1) participants in the self-generated mnemonics group created fewer mnemonics for abstract characters than for concrete characters, (2) mnemonics for the abstract characters were less descriptive than the mnemonics for the concrete characters, and (3) more errors were made on abstract characters than on concrete characters in posttests" (Kuo & Hooper, 2004, p.30).

In addition, the effects of using pictures to teach elementary students Chinese characters have been investigated. For example, in a study on learning Chinese characters involving fifth- and sixth-graders whose first language is English (Sham, 2002), participants with no prior knowledge about Chinese characters were randomly assigned into two treatment groups: a group given five Chinese pictograph characters alone, and a group given five pictographs with accompanying pictures. The English translations of these characters were presented orally. The results indicated that the group in the no-picture condition achieved better learning outcomes, a finding which is not in line with findings from other studies and in contradiction with the Dual Coding Theory which would predict a positive effect of imagery in character learning. The author posited that the pictographs resembling referential concrete objects should be easier to remember, but argued that the children's attention on the character might be distracted by the accompanying picture (Wu & Solman, 1993). Furthermore, the cognitive load theory (Sweller, 1994) indicated that the negative effect of pictures could be caused by the modality-specific interference effect that "both written Chinese pictographs and pictures share the same modality and are encoded in the imaginal (nonverbal) system in cognition" (Sham, 2002, p. 108).

Learning Chinese Radicals

Besides learning Chinese characters, Dual Coding Theory was applied to Chinese radical learning. A Chinese radical represents the semantic components of Chinese characters. For example, Lai (1998) investigated the effectiveness of static and animated graphics on learning Chinese radicals in a computer learning environment. The participants were college students who were native English speakers without prior knowledge of Chinese radicals. A visualization of rotations test (Guay, 1976; Bodner & Guay, 1997) was administrated to classify the participants into subgroups in terms of their spatial abilities. Participants were randomly assigned to different treatment groups: "(1) written prose with no cue (the control group), (2) written prose with concrete verbal information to help form mental images, (3) written prose with single static graphic aids, (4) written prose with gradient static graphic aids, and (5) written prose with animated graphic aids" (Lai, 1998, p.50). All five groups received content-related immediate and retention posttests. The results showed that instructional methods with graphic aids helped participants to achieve better recall and retention performance than the text-only method. In addition, the animated graphic aids and the gradient static graphic aids were more effective than the single static graphic aids.

Learning Chinese Words

Recognizing individual characters in a multi-character Chinese word is similar to recognizing morphemes in a multimorphemic English word (Shen, 2008). The effects of verbal and imagery coding in learning Chinese words have been investigated by Shen, 2010. The participants were college students learning Chinese as a foreign language. They were randomly assigned to a verbal coding group or a verbal-plus-imagery coding group with a concrete word subgroup and an abstract word subgroup in each. The equivalence of concrete words and abstract words was controlled in three ways: "equality of word frequency rate, similarity of the part of speech, and equivalent level of concreteness for the concrete-word group and of abstractness for the abstract-word group" (Shen, 2010, p.490). Only two-character words were selected because about 80% of the multi-character words are two-character words in Chinese (Shen, 2010). The vocabulary tutorial was delivered in the traditional regular Chinese class setting without utilizing computers. An immediate posttest was administered right after the tutorial, while the delayed posttest was given twenty-four hours later. The results revealed that, “compared with the verbal coding method, the verbal-plus-imagery coding method did not show a superior effect in retention of the sound, shape, and meaning of concrete words, but statistically significant differences were present in the retention of the shape and meaning of abstract words” (Shen, 2010, p. 485). This finding might be caused by given concrete words, participants may recall “mental images of these words that had previously been stored in the students mental photo albums” (p. 496), which were built from the students' past experiences, and therefore, “during the instruction, when students saw these words, the relevant mental images were activated” (p. 496).

The effects of using picture on learning two-character phonetic compound words were reported in another study (Sham, 2002). The participants were 24 students in sixth grade, assigned to one of the two groups randomly: one was given Chinese-English word pairs, the other was given the word pairs with corresponding pictures. The English translations were presented as printed text instead of the oral form as used in the aforementioned study (Sham, 2002) on characters. However, like the findings on characters, the word-to-word group outperformed the word-picture group, a finding which was not in line with the findings from other studies (Shen, 2010). According to Sham, this might be due to the fact that “the phonetic compounds compete the perceptual strength with pictures in the same modality resulting in the modality-specific interference effect on the picture” (Sham 2002, p. 127).

Chinese Sentence Comprehension

The studies on concrete and abstract sentences in alphabetic languages using Dual Coding Theory suggest that concrete sentences are recalled better and evoke more imagery than abstract sentences. A concrete sentence is encoded verbally but is also transformed into the nonverbal (image) code which organizes the sentence into a single component or a composite image, while an abstract sentence contains information that remains linked to the sequentially organized verbal units. The dual coding of a concrete sentence, therefore, is able to reduce the memory load for meaning and supplies more retrieval routes. Chinese sentences in affirmative or negative sentence structures were used to investigate the concreteness effects and the results suggested that "concrete-affirmative sentences and concrete-negative sentences were better recognized than abstract ones", a finding which is in line with Dual Coding Theory (Ho & Chen, 1993).

In another study that investigated the concreteness effects of recalling Chinese sentences (Chen, 2010), Chinese-English bilingual undergraduate students were selected in terms of their verbal ability using reported scores of Chinese and English on Taiwan's college entrance exam. They were instructed to study and recall both Chinese and English concrete and abstract sentences. Participants were randomly assigned to one of four groups that received the sentences in one the following orders: concrete English and abstract Chinese, abstract English and concrete Chinese, concrete Chinese and abstract English, or abstract Chinese and concrete English. The results showed that "Chinese was recalled significantly better than English, and concrete sentences were recalled significantly better than abstract sentences" (Chen, 2010, p.4). These findings provided evidence of concreteness effects at the sentence level in Chinese, and they were consistent with those of previous studies using dual coded instructional methods to teach alphabetic languages (Holmes & Langford, 1976; O'Neill & Paivio, 1978; Eddy & Glass, 1981; Sadoski, Goetz, & Fritz, 1993).

Summary

This literature review suggests that studies on Chinese acquisition as a foreign language have contributed significantly to the development of instructional methods on teaching Chinese characters, words, and sentence comprehension. However, they have shown some mixed findings and limitations.

First of all, it is important to include a pretest to ensure that participants either have no background knowledge of the Chinese language (Chuang & Ku, 2011; Lai, 1998; Sham, 2002) or are at a similar Chinese language level (Shen, 2010) so that the extraneous variables of the participants' initial differences before the treatments can be excluded. Some studies only included concrete characters and did not include abstract Chinese characters which are more difficult to e associated to mental images to help learning happen (Chuang & Ku, 2011; Sham, 2002). From the perspective of dual coding, concrete words may increase activation of the referential connections between the nonverbal (imagery) system and the verbal system (Jessen et al., 2000). Therefore, dual coded methods involving computer-based animated pictures might be an effective design (Chuang & Ku, 2011), which was previously reported as a superior method compared to static pictures in examination of dual coded instructional methods on learning Chinese radicals with the help of static and animated graphics (Lai, 1998). However, some existing studies did not include computer-based multimedia in their instructional methods (Shen, 2010; Sham, 2002).

In the study that investigated both concrete and abstract characters, which would achieve more generalisable findings, the authors failed to provide a persuasive explanation about how to ensure the two groups of characters are comparable to each other (Kuo & Hooper, 2004). For example, the number of strokes in abstract characters was obviously larger than that in concrete characters, making the selected abstract characters look more complex than concrete characters, and therefore creating more cognitive load to memorize and recognize these characters. This could be an important factor that has influenced the results. In addition, their findings that self-generated mnemonics may work better than given mnemonics in Chinese character retention did not take the time factor into consideration, as students who created mnemonics of their own took more time on tasks than those in other groups, which may raise questions about the instructional efficiency. Therefore, authors' conclusion about learning effects in their study would be more convincing if the time of exposure to the characters was equally manipulated for each treatment. Similarly, the findings of the study on Chinese radicals (Lai, 1998) were consistent with the Dual Coding Theory but the learning time was not controlled because participants in the gradient static graphic group and the participants with morphing graphic treatment used a lot more time on the tasks than other groups.

The animations that depicted transition between a character and its corresponding picture developed and used in previous studies were either too simple because they had no mapping between the different parts of character and their corresponding components of a picture but rather overlaid a character as a whole onto a picture (Chuang & Ku, 2011), or the transition between a character and a corresponding picture was not consecutive (Lai, 1998). Both issues might prevent learners from building referential connections between a character and its corresponding picture. Meanwhile, instructional methods involving images may require learners' visualization skills, but some studies failed to statistically control for it and led to learning achievements in their studies which may be confounded by this factor, i.e. learners' spatial ability.

The current study aims to address these limitations by examining, when learners' spatial ability is statistically controlled, the effects of computer-based multimedia instructional methods involved both verbal and nonverbal information, such as dual coded instructional methods with either animation plus text or animation plus narration on learning both concrete and abstract Chinese characters.

CHAPTER THREE: METHODOLGY

As discussed in Chapter 1, the results of the pilot study suggested that dual coded instructional methods work better than single coded instructional methods and the instructional method using animation-plus-narration works better than animation-plus-text in the Chinese character recall task regardless of character type. The current study adopted a similar experimental design and computer-based tutorial materials with some extensions. First, the current study had a larger sample size by recruiting a total of 120 participants from the same school as the one from which participants were recruited in the pilot study. Second, the instructional method in the current study was a between-groups factor instead of a within-groups factor as was the case in the pilot study, , and the participants were randomly divided into four groups with each group learning the same characters by means of only one instructional method. Third, the current study statistically controlled for the learners' spatial ability, i.e., ability to restructure the visual representation of an object by adding the Purdue Visualization of Rotation Test, and it manually controlled for participants' verbal ability by recruiting only college students with junior or senior standing.

Character Selection

The target characters in this study included a total of 24 Chinese characters, 12 pictographs and 12 ideographs, which were identical to the ones used in the pilot study (see Appendix A). Comparing to early studies (Chuang & Ku, 2011; Sham, 2002), this study included both fundamental types of characters, i.e., pictographs symbolizing concrete objects and ideographs representing abstract ideas, which might lead to more generalisable findings for teaching other logographic languages that use Chinese characters. In addition, valuable implications for teaching compound Chinese characters which are created by combining these two types of fundamental characters might also be achieved. To ensure the selected pictographs and ideographs were comparable with regard to cognitive complexity to each other and suitable for beginning learners who have no prior knowledge of Chinese, the following three criteria were used to choose characters used in this tudy: (1) all the pictographs and ideographs had to be integral characters, i.e. one-component characters, instead of compound characters that are combinations of two or more components, (2) the number of strokes in selected pictographs and ideographs had to be similar, specifically 3 to 5 strokes, and (3) the meanings of all the target characters had to be easy to represent with computer animations.

Participants

One hundred twenty six native English-speaking undergraduate students from the computer science program in a southern state of the United States were recruited after receiving approval from the Institutional Review Board (see Appendix B). To avoid the possible confounding results due to variability in verbal ability, only students with junior standing or above were recruited under the assumption that these students' comprehension skills were sufficient for understanding the verbal coding involved in the current study's instructional methods. All of the participants were recruited from upper division computer science classes with the help of their instructors who advertised this study.

According to the results of the demographic survey, 81 of 120 participants (or 67.5%) were male and 39 were female (or 32.5%). All of them were above 18 years old.

Finally, 33 (or 27.5%) were juniors, 42 (or 35%) were seniors and 45 (or 37.5%) were in their fifth year of the college.

Instruments

The instruments developed in this study were a prior knowledge screening test, a demographic survey, a spatial ability test, four computer-based tutorials, and an immediate content-based recall posttest.

Screening Test

After signing the consent letters, participants were requested to complete a screening test which included six yes-no questions about their prior knowledge of Chinese language or other related logographic writing systems, such as Japanese, Korean, or Vietnamese (see Appendix C). To avoid confounding results, students who answered "yes" to any screening question were excluded from the study due to their prior knowledge about Chinese.

Demographic Survey

A three-question computer-based survey was given to the qualified participants to collect demographic information including gender, age, and years in college (see Appendix D).

Spatial Ability Test

The spatial ability of participants is an important factor in studies involving multimedia-based dual coded instructional methods (Lai, 1998; Plass, 2003). For example, it has been reported that when low-spatial ability students received visual annotations for vocabulary words, they recalled fewer words than high-spatial ability students because , according to the authors, they "do not have sufficient cognitive resources to process the visual information and build referential connections and therefore experience deleterious effects" (Plass et al., 2003, p. 233). Spatial ability in their study was measured by the Card Rotation Test (Educational Testing Service, 1976).

Purdue Visualization of Rotation Test, another popular test to measure the learners' spatial ability (PVRT, Guay, 1976; Bodner & Guay, 1997), was adopted to select participants in a study that investigated the effects of using computer animations to teach Chinese radicals (Lai, 1998). The current study adopted the PVRT as the measurement of the participants' spatial ability because what it measures is relevant to the visualization skills required in learning Chinese characters, i.e., visualizing a mental image through the text description of what each part of the character represents or analyzing and matching the parts of an image with the corresponding parts of a Chinese character. The PVRT consists of 30 multiple choice questions (see Appendix E). In each question, the participants were asked to "observe how a three-dimensional object in the top line of the question was rotated and to analyze what the object shown in the middle line of the question looked like when rotated in exactly the same way, and participant then selected the one that looked like the object rotated in the correct position from the five given drawings in the bottom line of the question" (Guay, 1976, p.2).

Computer-based Tutorials

The current study adopted the modified computer-based Chinese character learning tutorials developed for the pilot study by a computer science professor. In total, four different tutorials which covered the same 24 Chinese characters were created, two for the single coded conditions (text-only method and animation-only method) and the other two for the dual coded conditions (animation plus text method and animation plus narration method) (see Appendix F). The text-only method (TO) tutorial presented each of the 24 Chinese characters with its English meaning and a short text describing its origin for 15 seconds; while the animation-only method (AO) tutorial presented each Chinese character with its English translation, a picture which symbolized the origination of the character and the animation depicting the transformation of the picture into the character. Each animation was played twice with 7.5 seconds each time to make sure the time duration of learning each character was equal to that in the TO tutorial. Figure 6 gives an example of the TO tutorial, and Figure 7 gives an example of the AO tutorial.

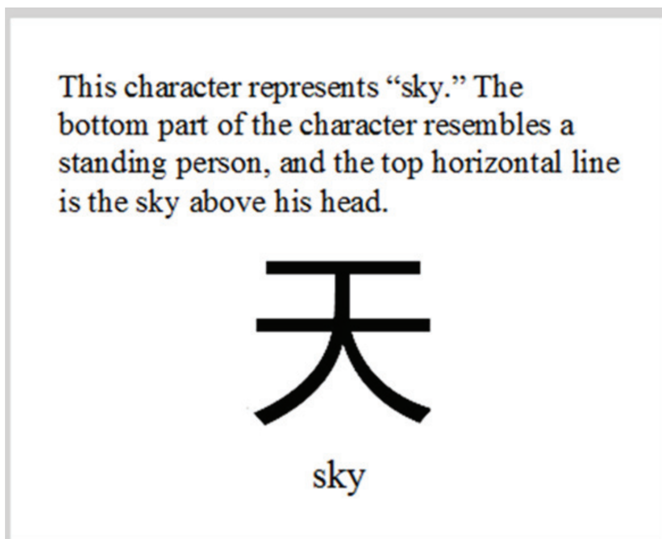


Figure 6. An example of the TO tutorial under the single coded condition

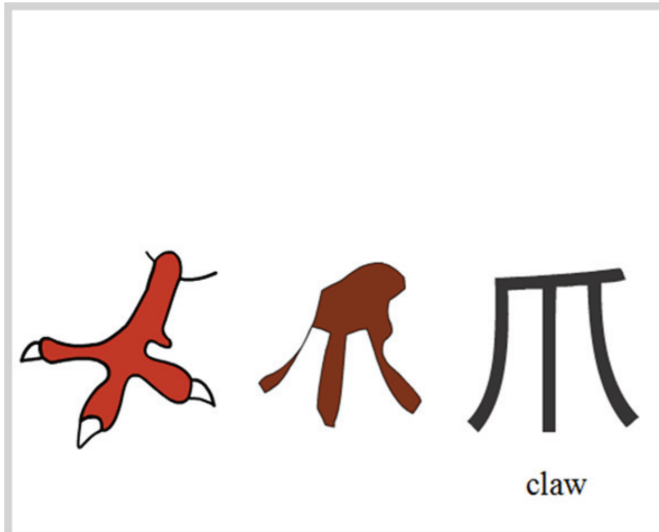


Figure 7. An example of the AO tutorial under the single coded condition

The two dual coded condition tutorials displayed the same 24 characters using two dual coded instructional methods: (1) animation-plus-text method (AT), in which each character was presented with an animation that was the same as that in the AO tutorial, a short description of the etymology in text format that was identical to the one presented in the TO tutorial, and its English meaning, and (2) animation-plus-narration method (AN), in which each character was also presented with the corresponding animation, its English meaning, and its etymology; however, the etymological description was presented in audio format through headphones only. The animation of each character in both the AT and AN tutorials was played twice and the narration in the AN tutorial was synchronized with the animation, with each iteration lasting 7.5 seconds to ensure the same time duration among the four different tutorials (15 seconds per character). Figure 8 and Figure 9 show examples of these two tutorials under the dual coded conditions.

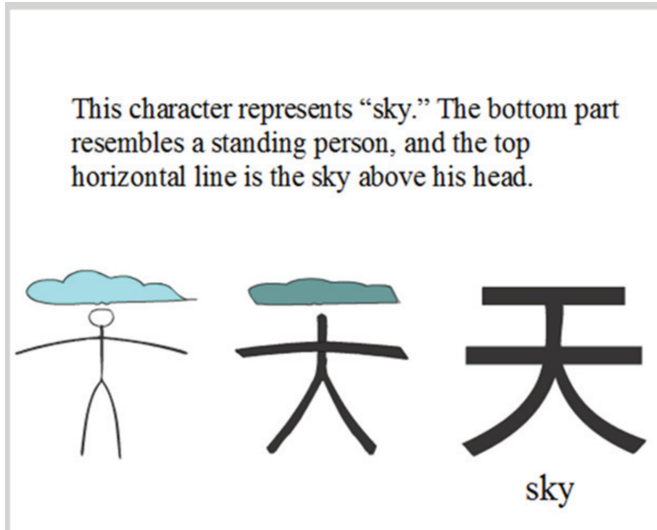


Figure 8. An example of AT tutorial under the dual coded condition

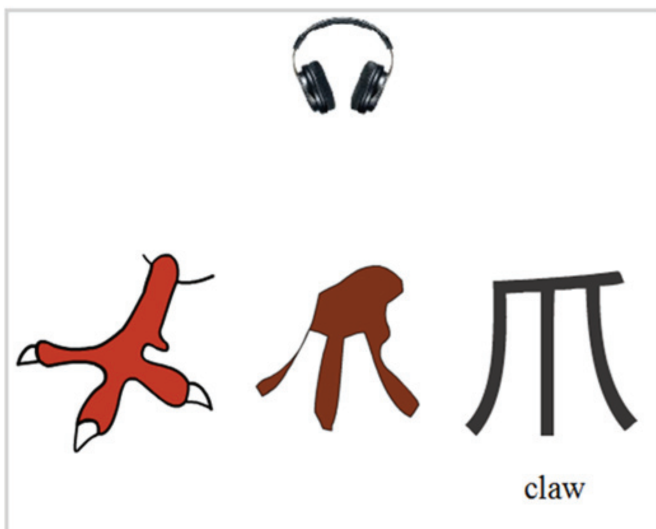


Figure 9. An example of AN tutorial under the dual coded condition

Each image used to create the tutorials was drawn by a Chinese artist who understood the purpose of the study. Individual images were converted into vector art in Adobe Illustrator. For each character, the animation was generated by creating images which gradually, consecutively transformed the initial image with all its details, e.g., a bird as well as its beak, eye, and legs, into the Chinese character and its corresponding graphic elements, e.g., the specific strokes in the character representing the beak, eye, and legs of the bird. The images, or animation frames, were placed on separate illustrator layers and imported into Adobe Flash. The frame rate (or frame frequency), which was defined as unique consecutive images shown per second, was 15 frames per second. In other words, the animation developed in this study displayed 15 unique transition images per second. Because a complete animation from the original picture to the character took 7.5 seconds, the total number of frames (unique transitional images) was about 112, which was significantly larger than the total unique images (one to four drawings) used in existing studies (Chuang & Ku, 2011; Lai, 1998).

The computer-based tutorials were designed and implemented with HTML and JavaScript by the computer science professor to be loaded and played by all the popular web browsers, such as Internet Explorer and FireFox, without requiring installation.

Content-based Recall Posttest

The immediate content-based recall posttest was composed of 24 multiple-choice questions covering all the 24 target characters, each worth one point (see Appendix G). The posttest was administered on the computer immediately following the tutorials. The participant was given a Chinese character they just learned in a multiple-choice question and was required to recall its meaning in English by selecting the correct answer among the five given options. An example of the questions is as follows:

What does the Chinese character “火” mean in English?
A. king B. claw C. fierce D. sky E. fire

The correct answer would be E in this case. To prevent elimination of choices by cross reference of multiple characters, only one question was shown on the screen at one time.

Procedures

A total of 126 students volunteered to participate in the study and signed the consent forms. After that, the participants were randomly assigned to one of the four different groups, i.e., Group A, Group B, Group C and Group D, corresponding to the methods of TO, AO, AT, and AN, with 31or 32 participants in each group. Each participant was assigned a code name which was a combination of their group letter and a number. For example, Participant A1 was the first participant of Group A.

Members of the same group came to the lab at the same time and signed in with their code names for the convenience of the researcher to track the participants' attendance in each group. Two time slots were reserved for each group just in case some participants had unplanned absences in one slot and could make up in the other one.

After their sign-in, each participant was assigned to a computer in the lab. The researcher gave a brief introduction and instruction of their tasks, including completing a screening test which consists of 6 yes-no questions about their prior knowledge about Chinese language, a demographic survey about their age, gender, and years in school, and a spatial ability test including 30 multiple-choice questions, watching a tutorial delivering multimedia presentations of 24 target Chinese characters, and completing an immediate posttest consisting of 24 multiple-choice questions to measure their previous character learning through the tutorial. The participants were required to turn off their cell phones, and not to interact with each other, take notes, or check any online resources during the tasks.

Then the researcher guided the participants to open a web browser to load the task directions page of their designated treatment condition. Among the 126 participants, one from Group A and two from Group C were excluded due to their previous character-based language learning experience based on the results of the screening test, which reduced the number of the participants in both Group A and C into 30. The results of the demographic survey revealed that two students, one in Group B and one in Group D, were sophomores though they were taking upper division courses. Finally, an incomplete data file was found in the spatial ability test for a participant in Group D, so this participant's date were excluded, leaving the total number of the participants in both Group B and D also 30.

After the participants completed the spatial ability test, the tutorial began with an example page explaining how each character would be presented under that instructional condition and how much time each character's presentation would last. The tutorial began when the participants clicked on the "Start" button at the bottom of an example page. The tutorial moved from one character to the next automatically to ensure each participant spent an equal amount of time learning these target characters with each instructional method. With each Chinese character presented for 15 seconds, which was sufficient for the participant to read the text and/or watch and understand the animation, the total presentation time of each tutorial was 6 minutes. The participants in Group D were prompted to put on their headphones before the start of their tutorial as their treatment involved the animation-plus-narration method.

Immediately after the tutorial, the participants took the computer-based recall posttest. They were given 6 minutes to complete the test. Upon completion, they clicked on the “Submit” button at the end of the last page, and test scores were automatically collected and saved in an electronic output file.

CHAPTER FOUR: DATA ANALYSIS AND RESULTS

The current study was to examine how the single-coded (TO and AO) and dual-coded (AT and AN) multimedia instructional methods may affect learning the two basic types of Chinese characters, pictographs and ideographs. Four research questions were formed, which were 1) whether different instructional methods (single vs. dual coded) influence the acquisition of Chinese characters after controlling for learners' spatial ability; 2) whether different instructional methods (single vs. dual coded) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability; 3) whether different single coded instructional methods (TO vs. AO) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability; 4) whether different dual coded instructional methods (AT vs. AN) influence the acquisition of different types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability.

The 120 qualified subjects were randomly assigned to the four different instructional method groups, which consisted of two single coded method groups (TO and AO) and two dual coded method groups (AT and AN). All four groups learned the same 24 characters including comparable 12 pictographs and 12 ideographs.

Normality tests were conducted to check whether the posttest scores were normally distributed for each method and each specific method group. The results from the Shapiro-Wilk Test of Normality were $p = 0.059$ for the single coded methods and $p = .082$ for the dual coded methods, which were not statistically significant, indicating the posttest scores were normally distributed in both the single and dual coded methods.

Figure 10 shows the histogram of the posttest scores for each method. Furthermore, the Shapiro-Wilk Test of Normality showed that the posttest scores were normally distributed for each specific instructional method group as well with $p = 0.125$ for the TO method group, $p = .193$ for the AO method group, $p = 0.199$ for the AT method group, and $p = .177$ for the AN method group. Figure 11 shows the histogram of the posttest scores for each specific method group. The normality test results suggested the normality assumptions of the dependent variable in this study were met, which indicated it is appropriate to conduct the parametric analysis for the research questions in the study.

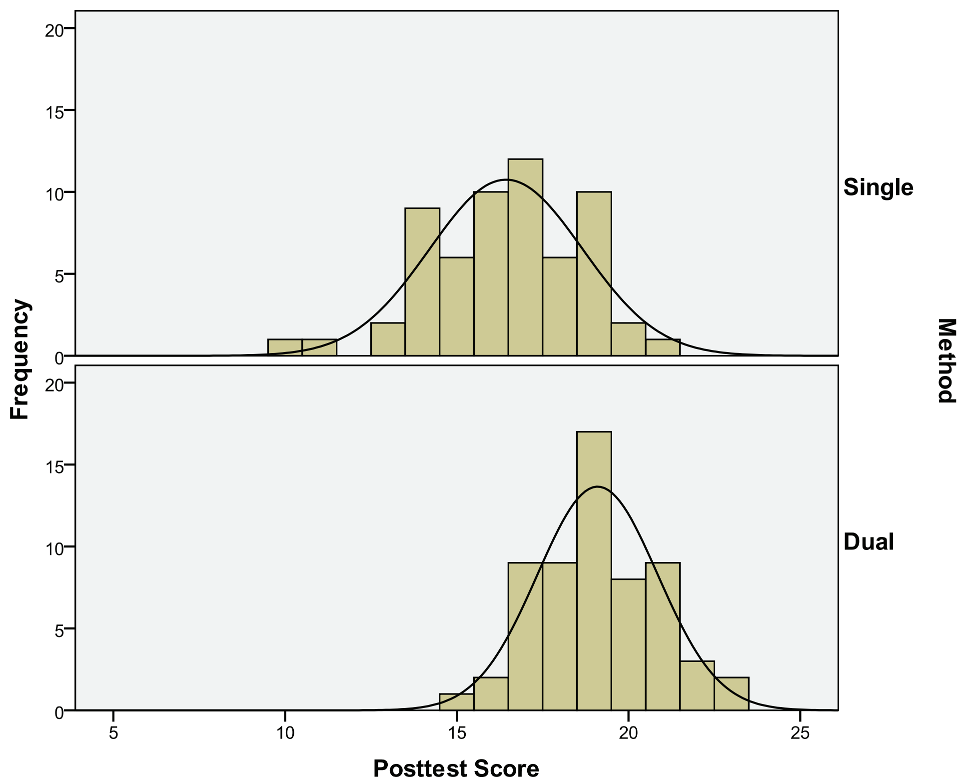


Figure 10. Histogram of posttest scores for each instructional method

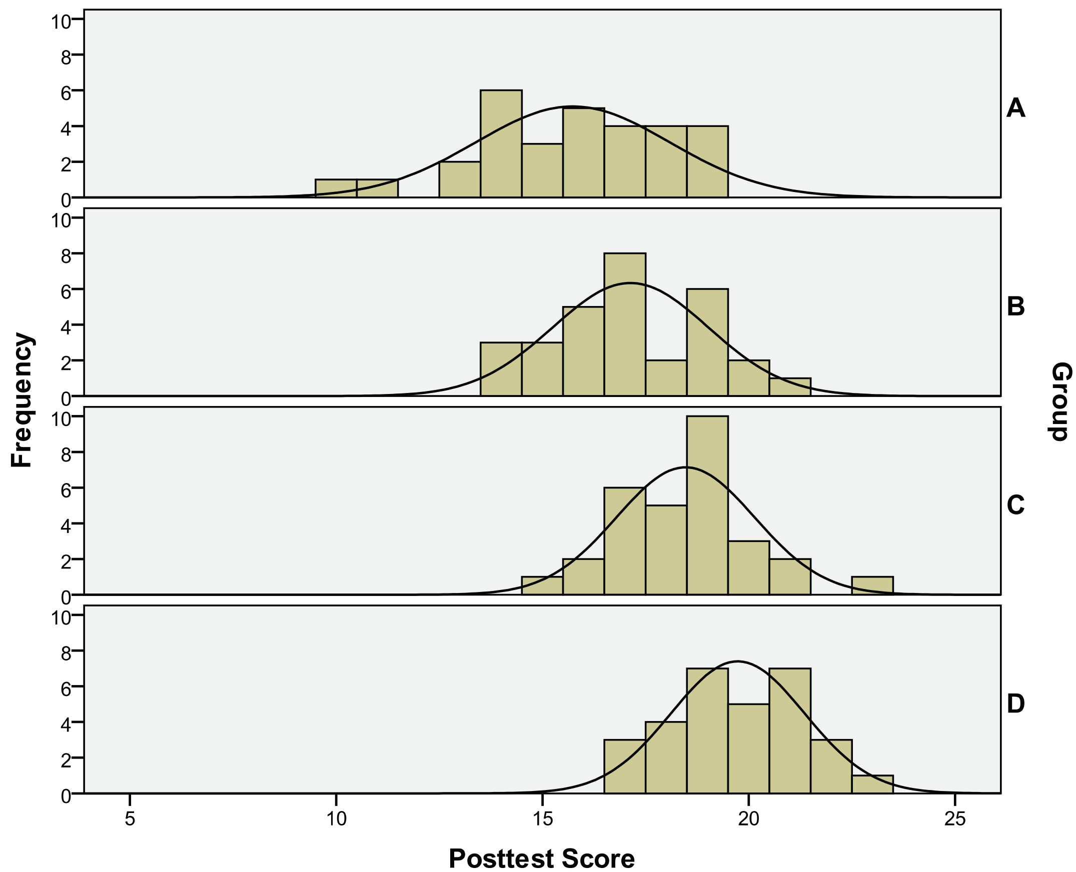


Figure 11. Histogram of posttest scores for specific instructional method group

Research Question 1

A one-way ANCOVA design was used to analyze the first research question, i.e., whether dual-coded instructional methods (Group C and Group D) lead to better Chinese character learning effects than single-coded instructional methods (Group A and Group B). The instructional method, which included two levels: single and dual, was the between-subjects factor, while the participant's spatial ability test score was statistically controlled as a covariate. The dependent variable was the posttest scores that represent learning achievement.

Table 4 shows the descriptive statistics of the achievement scores for the content-based posttest and the spatial ability test scores under the single coded vs. dual coded condition. For the single coded methods, the mean score of the content-based posttest was 16.43 (*SD* = 2.227), while for the dual coded methods, the average score was 19.10 (*SD* = 1.753), which indicated a difference between the single coded method groups and the dual-coded method groups with the performance of the dual coded methods better than that of the single coded methods. Meanwhile, the mean scores of the spatial ability test for different instructional methods, i.e., the single coded methods (*M* = 19.65) and the dual coded methods (*M* = 19.37), were comparable.

Table 4

Descriptive Statistics of Posttest Scores and Spatial Scores in Different Condition

Method		Posttest Score	Spatial Score
Single coded	Mean	16.43	19.65
	Std. Deviation	2.227	4.054
	N	60	60
Dual coded	Mean	19.10	19.37
	Std. Deviation	1.753	3.696
	N	60	60
Total	Mean	17.77	19.51
	Std. Deviation	2.404	3.865
	N	120	120

ANCOVA was first run with a customized model which included the interaction between the independent variable, i.e., the instructional method, and the covariate, i.e., the spatial ability test score in order to test the equal slope assumption for the covariate.

The results revealed that the interaction of instructional methods and the spatial ability test scores was not statistically significant, F (1, 116) = .338, p = .562, and therefore, the homogeneity of regression slopes assumption was met.

The ANCOVA was rerun without the interaction between the instructional methods and the spatial ability test scores. This analysis indicated there was a significant main effect of the instructional method on the posttest score after controlling for the effect of learner's spatial ability, $F(1, 117) = 54.104$, $p < .001$, $\eta_p^2 = .316$. The general rules of thumb for partial eta-squared η_p^2 suggest $\eta_p^2 > 0.01$ is small, $\eta_p^2 > 0.06$ is medium, and $\eta_p^2 > 0.14$ is large for the effective size (Cohen, 1988). Therefore, η_p^2 = .316 in this study indicated that the instructional method had a large effect size on the learning achievement represented by the posttest scores.

Levene's Test of Equality of Error Variances was performed to assess the homogeneity of the error variance for the instructional methods, and the result was not statistically significant, F (1, 118) = 3.074, p = .082, indicating the homogeneity of variance assumption was met. The average learning achievement under the dual coded condition (M = 19.11) was better than that under the single coded condition (M = 16.42) (see Table 5 and Figure 12).

Table 5

Estimated Marginal Means of Posttest Scores for Different Methods

			95% Confidence Interval	
Method	Mean	Std. Error	Lower Bound	Upper Bound
Single Coded	16.424[a]	.258	15.913	16.935
Dual Coded	19.109[a]	.258	18.598	19.620

a. Covariates appearing in the model are evaluated at Spatial Score = 19.51.

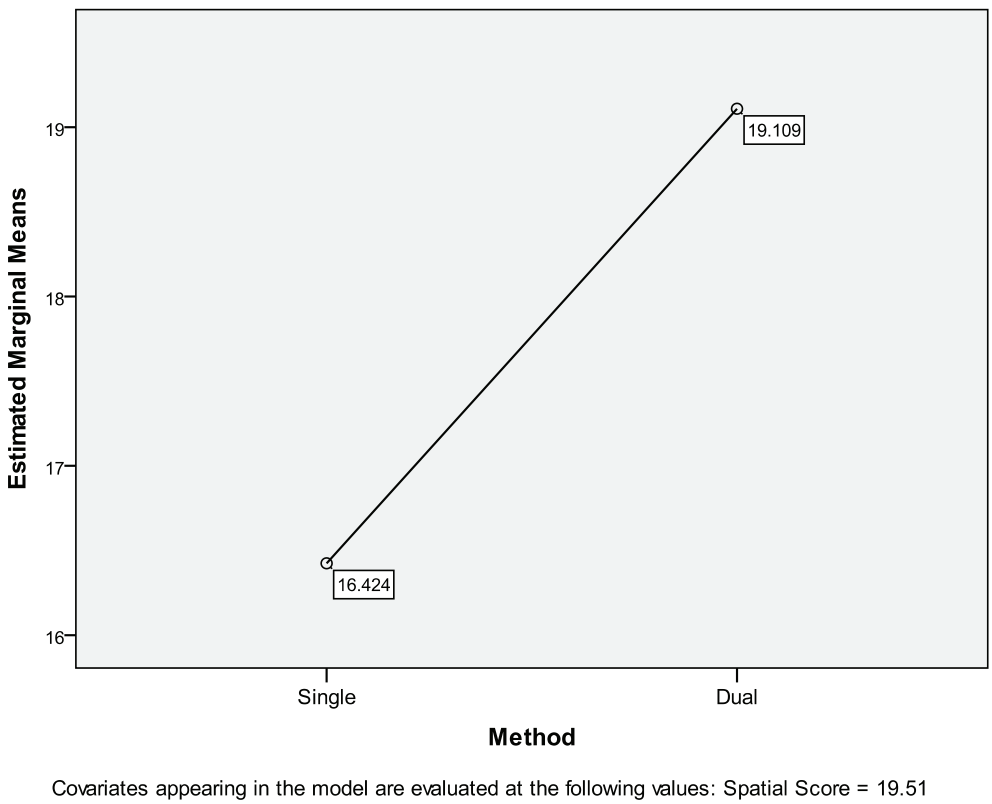


Figure 12. Estimated marginal means of posttest scores for different methods

In summary, the results of these analyses suggested that the participants who received dual coded instruction generally performed significantly better than those who received single coded instruction when controlling for learners' spatial ability.

Research Question 2

A two-way ANCOVA design was adopted to analyze whether learning achievement varies significantly between the two types of Chinese characters (pictographs which are concrete characters or ideographs which are abstract characters) with the two general different instructional methods (single-coded or dual-coded). The general instructional method was included as a between-subjects factor as the participants were assigned into the groups under either the single coded method condition (Group A and B) or the dual coded method condition (Group C and D). The character type was a within-subjects factor as the participants learned both types of the characters (pictographs and ideographs). The participants' spatial ability test score was a covariate and the posttest score was the dependent variable.

Table 6 shows the mean score for pictographs was 8.97 (*SD* = 1.703) under the singled coded conditions and was 10.27 (*SD* = .899) under the dual coded conditions, while the mean score of learning ideographs under the singled coded conditions was 7.47 (*SD* = 1.308) and 8.83 (*SD* = 1.092) under the dual coded conditions.

Table 6

Descriptive Statistics of Scores for Pictographs vs. Ideographs in Different Condition

Character Type	Between Group Method	*M*ean	*S*td. *D*eviation	*N*
Pictogragh	Single coded	8.97	1.703	60
	Dual coded	10.27	.899	60
	Total	9.62	1.182	120
Ideograph	Single coded	7.47	1.308	60
	Dual coded	8.83	1.092	60
	Total	8.15	1.382	120

The results from the Box's test of equality of covariance matrices were statistically non-significant, F (1, 117) = 1.506, p = .211, which suggested the variance–covariance matrices were the same for each method. Meanwhile, the results from the customized ANCOVA model including both of the interactions between the covariate and the two independent variables, respectively, indicated that (1) the interaction between the character type and the spatial ability test score was not statistically significant, F (1, 116) = .195, p = .660, and (2) the interaction between the instructional method and the spatial ability test score was not statistically significant either, F (1, 116) = .312, p = .578, and, therefore, the homogeneity of regression slopes assumption was met. The homogeneity assumption of the error variance was also met as the results of the Levene's test were not statistically significant, F (1, 118) = .776, p = .380 for pictograph scores, and F (1, 118) = 3.748, p = .055 for ideograph scores.

The results of the ANCOVA indicated there was no interaction between the instructional method (single coded or dual coded) and the character type (pictographs or ideographs), F (1, 117) = .145, p = .704. However, significant main effects were found on both the instructional method, F (1, 117) = 53.832, $p < .001$, $\eta_p^2 = .315$ and the character type, F (1, 117) = 8.383, p = .005, $\eta_p^2 = .067$, which indicated both the factors of the instructional method and the character type significantly influenced the achievement of learning Chinese characters after controlling for the effect of the learner's spatial ability. The instructional method had a large effect on posttest scores ($\eta_p^2 = .315$), whereas the character type had a medium effect size on posttest scores ($\eta_p^2 = .067$).

Under the single coded condition, the mean score of learning pictographs (M = 8.96) was greater than that of learning ideographs (M = 7.46), while under the dual coded condition, the mean score of learning pictographs (*M* = 10.27) was also greater than that of learning ideographs (*M* = 8.84). On the other hand, the mean score for learning pictographs under the dual coded condition (*M* = 10.27) was greater than that under the single coded condition (*M* = 8.96), while the mean score for learning ideographs under the dual coded condition (*M* = 8.84) was also greater than that under the single coded condition (*M* = 7.46) (see Table 7, Table 8, and Figure 13).

Table 7

Estimated Marginal Means of Posttest Scores for Different Character Types

			95% Confidence Interval	
Character Type	Mean	Std. Error	Lower Bound	Upper Bound
Pictograph	9.617[a]	.090	9.439	9.795
Ideograph	8.150[a]	.110	7.932	8.368

a. Covariates are evaluated at Spatial Score = 19.51.

Table 8

Estimated Marginal Means of Posttest Scores for Different Methods

			95% Confidence Interval	
Method	Mean	Std. Error	Lower Bound	Upper Bound
Single Coded	8.212[a]	.129	7.956	8.468
Dual Coded	9.554[a]	.129	9.298	9.811

a. Covariates are evaluated at Spatial Score = 19.51.

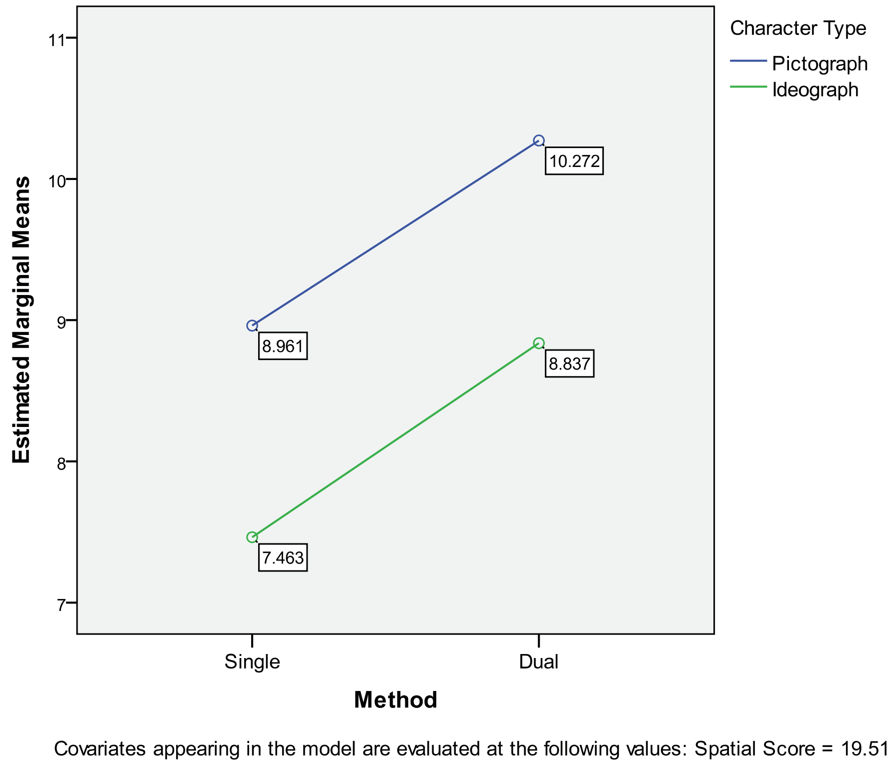


Figure 13. Estimated marginal means of posttest scores for different methods and character types

To sum up, these results suggested that the participants performed better with pictographs than ideographs under both the single and the dual coded conditions, and they achieved significantly better under the dual coded condition than under the single coded condition on both character types when controlling for spatial ability.

Research Question 3

For Research Question 3, a two-way ANCOVA design was adopted to investigate whether learning achievement varies between the Chinese character types (pictographs or ideographs) in the two different specific single coded instructional methods (TO in Group A or AO in Group B). Under the single coded condition, the participants in both Group A and B learned the same 24 characters (12 pictographs and 12 ideographs). Therefore, the specific single coded method was a between-subjects factor and the character type was a within-subjects factor. The participant's spatial ability test score was controlled as a covariate and the posttest scores were dependent variables. The mean scores of the spatial ability test for different single-coded method, i.e., the TO method (M = 19.93) and the AO method (M = 19.37), were comparable.

The mean score of learning pictographs was 8.83 (SD = 1.177) under the TO condition and 9.10 (SD = .960) under the AO condition, while the mean score of learning ideographs was 6.90 (SD = 1.322) under the TO condition and 8.03 (SD = 1.033) under the AO condition (see Table 9).

Table 9

Descriptive Statistics of Scores for Pictographs vs. Ideographs under the Single Coded Condition

Character Type	Single Coded Method	Mean	Std. Deviation	N
Pictograph Score	TO	8.83	1.177	30
	AO	9.10	.960	30
	Total	8.97	1.073	60
Ideograph Score	TO	6.90	1.322	30
	AO	8.03	1.033	30
	Total	7.47	1.308	60

The results from the Box's test suggested the variance–covariance matrices are the same in each single coded group, as they were statistically non-significant, F (1, 57) = 1.048, p = .370. Furthermore, the results from the customized ANCOVA model including interaction terms found no interaction effects between the character type and the spatial ability test score, F (1, 56) = .176, p = .431, and between the single coded instructional method and the spatial ability test score, F (1, 56) = 2.590, p = .113, which suggested that the homogeneity of regression slopes assumption was met. The results of Levene's test were not statistically significant, F (1, 58) = .681, p = .413 for pictograph scores, and F (1, 58) = 2.549, p = .116 for ideograph scores, suggesting the homogeneity assumption of the error variance was met as well.

The ANCOVA revealed a statistically significant difference between the two single coded instructional method groups (TO and AO) when controlling for the spatial ability, F (1, 57) = 7.055, p = .010, η_p^2 = .110, indicating the participants' performance depended on which specific single coded instructional method was used, and (2) a main effect of the character type was also found, F (1, 57) = 5.376, p = .024, η_p^2 = .086, indicating the achievement scores were also affected by which type of character was learned. The single coded instructional method had a large effect on posttest scores (η_p^2 = .110), while the character type had a medium effect size on posttest scores (η_p^2 = .086) as well.

Besides the main effects of the two independent variables, the analyses revealed a significant interaction effect between the single coded instructional method and the character type, F (1, 57) = 19.855, p < .001, η_p^2 = .258, which suggested the learning effect of a specific single coded method depends on which type of character is learned, and this interaction had a large effect size. For pictographs, whether TO or AO is used have a relatively small influence on the learning achievement; while for ideographs, which singled coded method is used make a big difference on learning results with AO works much better than TO.

The average learning score for pictographs under the AO condition (M = 9.12) was higher than that under the TO condition (M = 8.82), while the average learning score for ideographs under the AO condition (*M* = 8.05) was also higher than that under the TO condition (*M* = 6.89). On the other hand, the average score on learning pictographs (*M* = 8.82) were greater than that on learning ideographs (*M* = 6.89) with the TO method, while the average score on learning pictographs (*M* = 9.12) were also greater than that on learning ideographs (*M* = 8.05) with the AO method (see Table 10, Table 11, and Figure 14).

Table 10

Estimated Marginal Means of Posttest Scores for Different Character Types under the Single Coded Condition

			95% Confidence Interval	
Character Type	Mean	Std. Error	Lower Bound	Upper Bound
Pictograph Score	8.967[a]	.136	8.694	9.239
Ideograph Score	7.467[a]	.153	7.160	7.773

a. Covariates are evaluated at Spatial Score = 19.65.

Table 11

Estimated Marginal Means of Posttest Scores for Different Single Coded Methods

			95% Confidence Interval	
Single Coded Method	Mean	Std. Error	Lower Bound	Upper Bound
TO	7.853[a]	.194	7.465	8.240
AO	8.581[a]	.194	8.193	8.968

a. Covariates are evaluated at Spatial Score = 19.65.

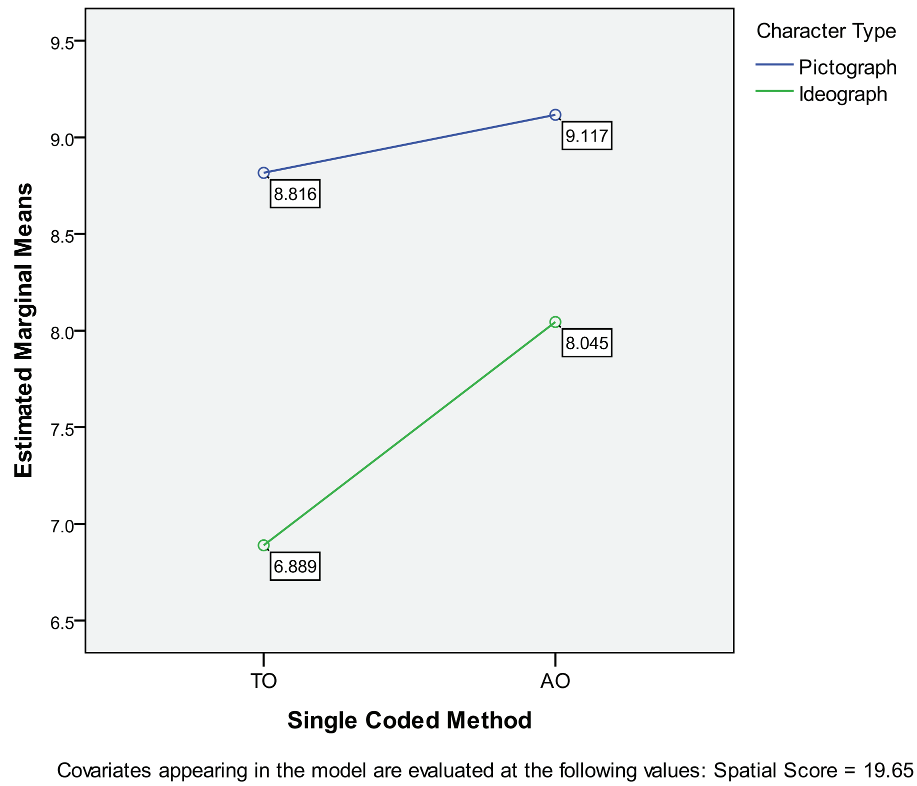


Figure 14. Estimated marginal means of posttest scores for different character types in the single coded condition

In summary, the analyses revealed an effect of single-coded instructional method and character type on learning achievements, and the learning performance under a specific single coded instructional method depends on which type of character is learned, when controlling for learners' spatial ability. In addition, the learning rate of the AO group with ideograph was higher than that with pictograph.

Research Question 4

Similar to Question 3, a two-way ANCOVA design was adopted to analyze Question 4, i.e. whether which specific dual coded method (AT in Group C vs. AN in Group D) is used has different influences on learning effects depending on which type of Chinese characters is learned. The within-subjects factor was the character type, i.e., pictographs or ideographs, and the between-subjects fact was the specific dual coded method, i.e. AT or AN. Again, the participant's spatial ability test score was statistically controlled as a covariate and the posttest score was the dependent variable. The mean scores of the spatial ability test for different dual-coded method, i.e., the AT method (*M* = 19.30) and the AN method (*M* = 19.43), were comparable.

The mean score of learning pictographs was 10.00 (*SD* = .871) under the AT condition and 10.53 (*SD* = .860) under the AN condition, while the mean score of learning ideographs was 8.47 (*SD* = 1.008) under the AT condition and 9.20 (*SD* = 1.064) under the AN condition (see Table 12).

Table 12

Descriptive Statistics of Scores for Pictographs vs. Ideographs under the Dual Coded Condition

Character Type	Dual Coded Method	Mean	Std. Deviation	N
Pictograph Score	AT	10.00	.871	30
	AN	10.53	.860	30
	Total	10.27	.899	60
Ideograph Score	AT	8.47	1.008	30
	AN	9.20	1.064	30
	Total	8.83	1.092	60

The results from the Box's test indicated the variance–covariance matrices are the same in each dual coded group, as they were statistically non-significant, F (1, 57) = .427, p = .734. Furthermore, the customized ANCOVA model including interaction terms revealed that (1) the interaction between the character type and the spatial ability test score was not statistically significant, F (1, 56) = .043, p = .837, and (2) the interaction between the dual coded instructional method and the test score of spatial ability was not significant either, F (1, 56) = .150, p = .700, which suggested that the homogeneity of regression slopes assumption was met. The homogeneity assumption of the error variance was also met as Levene's test results were statistically significant, F (1, 58) = .646, p = .425 for pictograph scores, and F (1, 58) = .040, p = .842 for ideograph scores.

The ANCOVA showed (1) a main effect of the specific dual coded instructional method after controlling for the spatial ability, F (1, 57) = 8.701, p = .005, η_p^2 = .132, indicating which specific dual coded instructional method is adopted significantly influences the participants' learning performance, and (2) a main effect of the character type after controlling for the spatial ability, F (1, 57) = 5.461, p = .023, η_p^2 = .087, suggesting the character type is also a factor that can significantly affect the participants' learning achievement scores. Furthermore, η_p^2 = .132 indicated that the dual coded instructional method had a medium effect size on the achievement scores, and the character type had a medium effect size on the achievement scores as well with η_p^2 = .087. However, there was no significant interaction between the dual coded instructional method and the character type, F (1, 57) = .626, p = .432, η_p^2 = .011.

The estimated marginal means in Table 13, Table 14, and Figure 15 suggested that the average score of learning pictographs (M = 10.00) was greater than that of learning ideographs (M = 8.47) under the AT condition, while the average score of learning pictographs (M = 10.53) was also greater than that of learning ideographs (M = 9.20) under the AN condition. In addition, it can be observed that the average score achieved for pictographs under the AN condition (M = 10.53) was greater than that under the AT method condition (M = 10.00), while the average score achieved for ideographs under the AN condition (*M* = 9.20) was also greater than that under the AT method condition (*M* = 8.47).

Table 13

Estimated Marginal Means of Posttest Scores for Different Character Types under the Dual Coded Condition

			95% Confidence Interval	
Character Type	Mean	Std. Error	Lower Bound	Upper Bound
Pictograph Score	10.267[a]	.113	10.041	10.492
Ideograph Score	8.833[a]	.135	8.564	9.103

a. Covariates are evaluated at Spatial Score = 19.37.

Table 14

Estimated Marginal Means of Posttest Scores for Different Dual Coded Methods

			95% Confidence Interval	
Dual Coded Method	Mean	Std. Error	Lower Bound	Upper Bound
AT	9.234[a]	.151	8.931	9.537
AN	9.866[a]	.151	9.563	10.169

a. Covariates are evaluated at Spatial Score = 19.37.

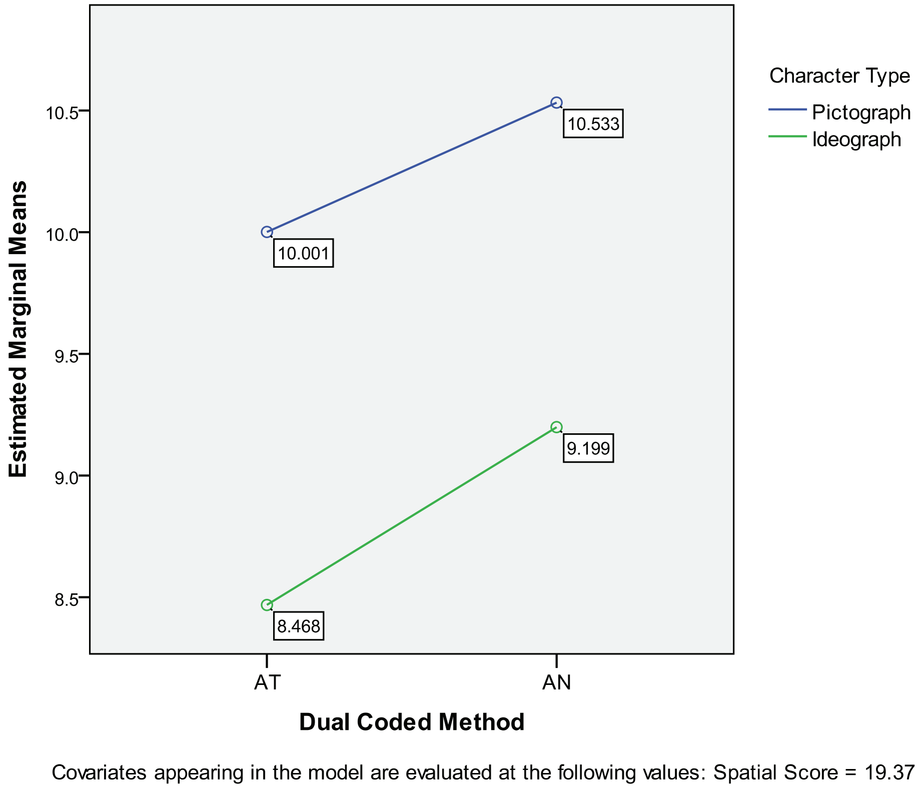


Figure 15. Estimated marginal means of posttest scores for different character types in the dual coded condition

To summarize, the results suggest that the AN method worked significantly better than the AT method on both pictograph and ideograph learning, and pictograph learning results were better than ideograph learning results under both dual-coded method conditions when controlling for the learners' spatial ability.

CHAPTER FIVE: DISCUSSION AND CONCLUSIONS

This final chapter provides a summary and interpretation of the findings, discuss implications for developing instructional methods for teaching adult English native speakers Chinese characters and vocabulary, addresses the limitations of the current study and proposes recommendations for future research in this field.

Research Questions and Findings

Because of the significant differences between the Chinese writing system and the English writing system, learning Chinese vocabulary has been a very difficult task for English native adult learners. The current study investigated how the instructional methods developed based on the Dual Coding Theory and the generative theory of multimedia theory may affect learning different types of Chinese characters, both concrete pictographs and abstract ideographs. In addition, this study developed computer-based animations which gradually transform the picture of origin of a Chinese character to the modern written form the character, and therefore, enhance learning by helping learners build a mental referential connection between the picture and the character.

The first research question addressed whether the single and dual coded instructional methods have different influences on the acquisition of Chinese characters. In addition, the learners' spatial ability was controlled as a covariate to better investigate the independent contributions of the instructional methods to learning. The second research question was to determine whether the single and dual coded instructional methods cause different effects on learning the two different types of characters, such as pictographs and ideographs, after controlling for learners' spatial ability. The third research question was to investigate whether different single coded instructional methods (animation-only or AO vs. text-only or TO) influence the acquisition of the two different types of Chinese characters (pictographs vs. ideographs) when controlling for learners' spatial ability. The final research question investigated specifically whether different dual coded instructional methods (animation-plus-text or AT vs. animation-plus-narration or AN) influence the acquisition of the two types of Chinese characters (pictographs vs. ideographs) after controlling for learners' spatial ability.

Single vs. Dual Coded Methods

In terms of the first research question, the data analyses revealed that the dual-coded instructional methods encoded with both verbal (text or narration) and visual information (animation) worked significantly better than the single coded instructional methods (text-only or animation-only) when learning Chinese characters. This finding supports the Dual Coding Theory since when presented both verbally and visually (i.e., dual coded) rather than either verbally or visually (i.e., single coded), information is expected to be better processed, integrated, and stored in memory because if one hint is lost, the other trace may still exist (Paivio, 1971, 1990). Meanwhile, these findings are in line with those of previous studies in teaching foreign language vocabulary which have shown that dual coded instructional methods involving both text and image information lead to better achievement scores than the single coded text-only method (Chuang & Ku, 2011; Kuo & Hooper, 2004; Plass et al., 2003).

In this study, the performance of the two dual coded groups (19.10 of 24 or 80%) was comparable to the performance reported in a recent study (16 of 19 or 84% correct on the immediate posttest for the dual coded groups) (Chuang & Ku, 2011). The slightly higher mean observed in this study should be considered in light of the fact that their study included only one type, i.e., pictographs representing concrete objects which were easier to be memorized compared with ideographs representing abstract concepts. As suggested by the studies on word concreteness supporting the Dual Coding Theory (Gullick, et al., 2013; Shibahara & Lucero-Wagoner, 2002; Welcome et al. 2011), it should be easier for learners to generate, memorize, and recognize a concrete word than an abstract word because the pictorial property of a concrete word allows for both verbal and non-verbal processing compared to an abstract word that is typically processed as verbal information only. The current study, by contrast, involved both pictographs and ideographs, and while mean achievement scores were slightly lower, the results are applicable to the acquisition of a larger variety of Chinese characters.

Examining these results in relation to the pilot study, it is noteworthy that the mean posttest scores of both the single coded groups (M = 16.43) and the dual coded groups (M = 19.10) were lower than those in the pilot study (see Table 4). This variation might be explained by the different research designs between the current study and the pilot study. The current study had a much larger sample size with 120 qualified participants vs. 42 participants in the pilot study. Because of the small sample size, the pilot study only included the general instructional methods (single coded and dual coded) as a between-subjects factor in which the 42 participants were randomly divided into two general instructional method groups with 21 in each (single vs. dual). Within each group, the participants were taught the same 12 pictographs and 12 ideographs under the two specific instructional method conditions (TO and AO in the single coded group vs. AT and AN in the dual coded group), and therefore the specific method was a within-subjects factor. This approach in the pilot study enabled both of the two sub-groups' participants

(TO and AO) in the single coded group to have the exposure of the AO method, and those in the dual-coded group to have the exposure of the AN method. Results from both the pilot study and the current study support the conclusion that AO was more effective as a single coded method than TO, and AN was superior as a dual coded method to AT. This might be the partial reason why the performance of the participants in the pilot study was better than that in the current study in which each group learned the characters with only one specific method and therefore less potential interference from the within group design was caused and more reliable results were achieved.

Effects Considering Character Types

For the second research question that included the character type as a within-subjects factor, the results were consistent with those in the pilot study. The performance of the participants under the dual coded instructional method conditions (AT and AN) were significantly better than those under the single coded method conditions (TO and AO), for learning both pictographs and ideographs, a finding which demonstrated the effectiveness of the dual coded methods in teaching both concrete and abstract character types. In addition, this finding suggested that the dual coded methods might also be appropriate for teaching compound Chinese characters which are combinations of both pictographs and ideographs.

On the other hand, achievement scores for pictographs were better than those for ideographs, no matter which instructional method was used, which was not surprising as this finding is consistent with not only the findings in the pilot study but also studies on character concreteness (e.g., Kuo & Hooper, 2004) and word concreteness (Sadoski, Goetz, & Fritz, 1993; Shen, 2010). As aforementioned, it was easier for learners to process concrete characters or words because of the involvement of both verbal and nonverbal information and the easier establishment of the referential connection between a meaningful image and its corresponding concrete character or word.

Comparison of the Single Coded Methods

The results of comparing the effects of the two specific single coded methods on Chinese character learning revealed that the learners performed significantly better with the AO method than those with the TO method, which suggested that given only single coded instructional methods, visually coded instructional methods may work better than verbally coded instructional methods in teaching Chinese characters, for both pictographs and ideographs, due to the pictorial property of Chinese characters. Meanwhile, the performance on learning the concrete type of characters like pictographs was greater than that on learning the ideographs which represent abstract concepts, regardless of which specific single coded instructional method was adopted, indicating the concreteness of the character played a significant role with the single coded instructional methods. These findings were in line with those from previous studies which have shown that concrete words are more likely to trigger a referential association between the images and words compared to abstract words (Sadoski & Paivio, 2001). In addition, the concreteness of the pictographs could also help learners create self-generated mnemonics. It has been reported that learners using self-generated mnemonics to learn concrete Chinese characters may perform better than those using visually coded or verbal coded methods, and meanwhile, they may generate more mnemonics for concrete words and make more errors for abstract characters than for concrete characters (Kuo & Hooper, 2004).

Compared with the pilot study, a similar pattern was observed from the estimated marginal means of the pictographs and the ideographs within the single coded groups (TO and AO). Both learning of the pictographs and the ideographs improved from the TO condition to the AO condition, but participants' achievements on learning ideographs made a much more improvement from TO to AO than was the case for pictographs. It was observed that the increase of the average score for ideographs was 1.13 from TO ($M = 6.90$) to AO ($M = 8.03$), while the increase for the pictographs was only 0.27 from TO ($M = 8.83$) to AO ($M = 9.10$) (see Table 9). This finding suggested that learning ideographs could benefit more from a method involving animation possibly because the animation may vividly display the transition between a modern Chinese character and its picture of origin, and therefore, can substantially contribute to concretizing the abstract nature of a character by helping learners easily build the referential connection between this image and the character, especially an abstract character like a Chinese ideograph.

Significance of Animation

Compared with the animations developed in previous studies (e.g., Chuang & Ku, 2011; Lai, 1998), the animation created in the current study provided much more visual information which possibly played a more powerful role in improving the learning effects. Chuang and Ku (2011)'s study employed an approach of overlaying a character on top of a single picture as a whole without decomposing the pictures and characters into different parts to show their correspondences between each other. In Lai (1998)'s study, the animation was created with a fade-in fade-out effect in which only 4 transitional images were developed to show the gradual evolution from the original pictures to the characters. These two animations were, therefore, less vivid and possibly inadequate in providing sufficient visual transitions to help learners build the referential connection between the target verbal and nonverbal information.

To address these issues, the animation developed for the current study had a playback rate of 15 frames per second, which means within one second there are 15 transitional images generated. Since the animation for each character was presented twice within 15 seconds, i.e., a full animation transforming the picture to the character took 7.5 seconds, the total number of the transitional frames generated in one full animation process, therefore, was about 112, which provided the learners much more detail about how the morphing and transition gradually and smoothly generate the character from the picture. More importantly, the morphing from the picture to the character was created by first decomposing both the picture and the character, and then matching a specific part of the picture to the corresponding structure of the character. This approach significantly enhanced the visual properties of the characters which might have contributed to the effectiveness of all the instructional methods that involved animation in this study, including the AO method, the AT method, and the AN method.

Comparison of the Dual Coded Methods

For the dual coded instructional methods, the results revealed that the participants in the AN method group performed better than those in the AT method group, which was consistent with the findings from the pilot study as well as the previous study in which the group with the audio-picture annotation had a better learning achievement than the group with the text-picture annotation (Chen, 2006). I In the AN condition in this study, the narration explaining the relationship between the image of origin and the corresponding modern Chinese character was played simultaneously with the animation.

This approach was supported by the Generative Theory of Multimedia Learning which suggests when verbal information is presented in the format of narration that can be processed through the audio channel together with the corresponding visual information (image or animation) through the visual channel, the cognitive load of audio and visual channels may be decreased and both of the working memories will be utilized (Mayer, 1997). This might be the reason that existing studies found that involving multiple sensory modalities in teaching Chinese characters may create maximum sensory stimuli, and this method may improve learning results by generating in depth association between the characters and the sensory modalities (Chung, 2008).Therefore, better learning effects can be achieved because of multi sensory input of dual coded information, compared with the input of both verbal and visual information, such as printed text and image or animation, through only the visual channel. In contrast, a previous study found no significant difference between the animation-plus-text method and the animation-plus-narration method, but the authors reported that the equal effects of these two methods might be caused by the unitary selection of the Chinese characters, i.e., all the characters were pictographs that represent concrete objects (Chuang & Ku, 2011).

An additional noteworthy finding of this study was the superior performance of the AN group compared to the AT group for both types of Chinese characters. Even though the learning results of the ideographs in the two dual-coded method groups were not as good as those of the pictographs (see Table 12), the performance improvement of learning the ideographs (0.73) from AT ($M = 8.47$) to AN ($M = 9.20$) was mildly greater than that of learning the pictographs (0.53) from AT ($M = 10.00$) to AN ($M = 10.53$), compared with the much larger difference between the performance improvement of learning ideographs (1.13) and that of learning pictographs (0.27) from the TO method to the AO method in the single coded groups. This was possibly due to the fact that both the dual coded instructional methods included the powerful animation as the visually coded information.

Implications for Instructional Methods

The findings of the current study provided many important implications for the development and the application of effective dual coded instructional methods with multi sensory input in teaching and learning the Chinese writing system.

First of all, this study confirms that dual coded instructional methods which contain both verbal information and visual information generally work better than single coded instructional methods in teaching one-component Chinese characters like pictographs and ideographs. In addition, it shows that both concrete Chinese characters, such as pictographs, and abstract characters, such as ideographs, can be effectively taught using well designed dual coded instructional methods. Therefore, Chinese instructors, when teaching Chinese characters, can guide students to analyze the target characters from both verbal and nonverbal perspectives. For instance, they may encourage students to observe the target modern Chinese character as a picture and free their imagination to create mental images that can represent the original image on which this character is based. As some modern Chinese characters have lost their original pictorial properties due to their evolution over time, their current visual structures may look much different from the images of origin. In this case, Chinese instructors may also encourage students to utilize visual coding, such as inspiring them to create their own mnemonics for target characters, besides the verbal information to help them memorize these characters. The self-generated mnemonics could be as effective as the supplied images (Kuo & Hooper, 2004). For example, the modern Chinese character 肉 means *meat*. The reason it symbolizes *meat* is that the ancient way in China to store meat is to hang it with a string (the top short vertical line of the character) to air-dry it. But students who are native English speakers may not be familiar with this ancient Chinese culture. However, based on their own experience with meat, students may imagine the middle part inside the character as two *T-bones*. Even though it is not completely consistent with this character's etymology, this self-generated mnemonic has a value because it makes memorizing this character so much easier with a referential connection between the character and the mental image they have created. Therefore, any helpful imagination from students that can provide effective visual clues for their learning deserves credit from the instructor.

Secondly, this study has made original contributions to teaching and learning Chinese characters by using computer-based animations to enhance the recognition of both concrete and abstract Chinese characters. When Chinese characters can be taught in a computer-based environment, Chinese instructors should utilize these recourses to design and plan their teaching. Whether having knowledge of animation development or not, Chinese instructors should keep in mind the principles of effective animation when creating or selecting ready-made animations. This study suggests that foremost principle is to make sure the animation can smoothly depict the transition between the original image on which the character was based and the modern character by creating a sufficient number of transitional images in addition to providing the related verbal information simultaneously. Given that the original pictorial properties of many Chinese characters have been diminished due to the characters' evolution and simplification, the smooth transition provided by well-designed computer animation will help to reconstruct the mental association of the character and its original picture property and, therefore, enhance learners' the long term retention.

Next, as very few existing studies have explored how animation-based instructional methods can influence learning achievement of Chinese characters (Chuang & Ku, 2011) whereas most of them only investigated the effects of images or primitive animations in teaching concrete Chinese characters such as pictographs (Lai, 1998), the current study addressed this issue and provides supporting evidence for the effectiveness of using well-designed animation in improving ideograph learning, which is always a difficult task for Chinese learners. An even more powerful animation can be created by decomposing the target character and its picture of origin into different parts so that detailed smooth transitions can display how each part of a character matches the corresponding part in its original picture, besides presenting the corresponding verbal information simultaneously. This way, learners of the Chinese writing system may find it much easier to establish the referential connection between the target character and the picture representing its abstract concept because the abstract property of an ideograph has been concretized by this animation-based visual information.

Also, some Chinese characters have very similar shapes and structures, and especially beginning learners of the Chinese writing system, who tend to be insensitive to these subtle differences and not used to perceiving strokes-based written forms, find it difficult to differentiate similar characters and are, therefore, less accurate in recognizing them (Shen, 2013). Therefore, well-designed animations need to carefully select or design the images of origin to vividly illustrate and symbolize the etymology of the target character in detail. For example, 木 (tree), 本 (base or root), and 末 (end) have similar shapes and structures, but the last two are ideographs which are created based on the first pictograph *tree* by adding a horizontal stroke either at bottom, which is the *root* of a tree, or at the top, which is the *end* of a tree's branch. In order to differentiate 木 and 本, the etymology picture of 本 should have more obvious roots at the bottom which will be transformed into the short stroke at the corresponding bottom part of the character. In order to differentiate 木 and 末, the etymology picture of 末 should include more obvious branches at the top which will be transformed into the long stroke at the top of the character 末. Similarly, when teaching 鸟 (bird) and 乌 (crow/black bird) which are only different in whether there is a dot inside of the top part of the characters, the animation of 鸟 can be developed by including a picture of a bird facing left with an eye, and matching the eye of the bird in the picture with the dot in the character 鸟. Compared with 鸟, 乌 is a special kind of bird that is black and, therefore, its eye can hardly be seen.

Furthermore, this study has revealed that, regardless of Chinese character type, the dual-coded instructional method using animation plus narration works better than the animation-plus-text method when the animation and narration are appropriately synchronized as designed in this study. This can be another important principle for Chinese instructors when developing or selecting well-designed animations for teaching Chinese characters. Classroom practitioners who work in a multimedia environment should create opportunities for students to process the target information through both visual and auditory channels, such as playing animations similar to what was included in the dual-coded AN method group of the current study, i.e. presenting animation as visual information together with the description of the character's etymology in narration. This design enables students to receive stimuli from both the visual channel (animation) and the auditory channel (narration), which is more effective than input from the visual channel only, i.e., animation with text, because the cognitive load of each channel is reduced and both working memories are utilized. Chinese instructors who have no multimedia available in their teaching environments can still apply this principle to their daily teaching practice by showing students the visual information (i.e., pictures) while providing related explanations orally so that both input channels and working memories are activated.

In addition, existing studies have observed that adult Chinese L2 learners can quickly develop a mental structure of compound Chinese characters without their orthographic structures after limited exposure to integral characters that are components of these compound Chinese characters (Wang, Liu, & Perfetti, 2004). Findings of the current study can also provide valuable implications for teaching compound Chinese characters which account for the majority of modern Chinese characters (Shen, 2010). Compound characters were created later in the evolution of the Chinese writing system than pictographs and ideographs by combining them either side by side or one on top of another. A compound character can represent a concrete object or an abstract concept. As both concrete characters (pictographs) and abstract characters (ideographs) have been investigated in the current study and the animations developed for this study have been proven to be effective in teaching both concrete and abstract characters, compound characters can be taught by using animations with similar design which decomposes a compound character into its smaller components, such as its pictograph radical or ideograph radical. Meanwhile the instructor may provide the description of what the compound character means, what each of its radicals mean, and how they are joined together to create the new related meaning of this associative compound character. For example, if an animation is developed for a associative compound character 明 which means bright and it consists of two pictograph radicals side by side, 日 which means sun and 月 which means moon, the animation can decompose this compound character into two parts (日 and 月), start the morphing from the pictures of sun and moon side by side and smoothly transform them into the corresponding radicals of the character. The narrative verbal description can be transcribed as “This character means bright. The left part is the sun, and the right part is the moon. Both look bright.”

Moreover, when teaching phonetic-semantic compound characters with a phonetic element suggesting pronunciation and a semantic component suggesting meaning, both of which come from either a pictograph or an ideograph, Chinese instructors can also guide students to observe the semantic component of the target characters and present its visual information which will serve as a related visual cue to help learners recognize and memorize characters. For example, if students have learned the pictograph 山 (mountain) with dual coded methods which provide the picture of origin and explanation of this character, they can easily recognize the semantic component that comes from this pictograph of compound characters, such as 岳 (high mountain) and 峦 (hill) which include 山 at the bottom, 岭 (mountain range) and 峰 (mountain peak) which have this radical on the left, or 岗 (ridge of hill) and 崖 (cliff) which have it on the top, that will be helpful for them to learn the full meanings of these compound characters. With the firm knowledge of these semantic radicals gained with the help of animation-based dual coded methods, some substitution errors, such as miswriting 清洁 as 请洁, in which the first compound character in this word 清 and miswritten character 请 share the same phonetic radicals on the right but have different semantic radicals on the left, can be avoided. This two-character word means *clean*, and the right part of the character, 氵, consisting of three dots, is a pictographic semantic radical meaning *water*, which can be presented by animation that transforms three watch drops into the three dots of this radical. Because it is easy to find the connection between the meaning of the word *clean* and the meaning of the radical *water* (People need water to do cleaning), students will be able to differentiate 清 and 请 quite easily due to their different semantic radicals. This way those substitution errors can be avoided.

Finally, a dual coded instructional method using animations could be expanded to teaching multi-character Chinese words in which the included characters or their components can be represented by pictures, and therefore, applied to Chinese vocabulary learning in general. For example, 刀 ('knife') is a pictograph, and 刃 ('blade') is an ideograph. The multi-character word 刀刃, which means *the blade of a knife*, can be taught by presenting the animations that transform their etymology pictures into their corresponding characters while providing narrative explanations of what different parts of each character represent, such as the hilt of a knife, the back of a knife, etc., which will help learners to easily figure out the meaning of this word and memorize it.

Although the current study was conducted with English native speakers learning Chinese characters as a foreign language, its finding of the strong positive effects of dual-coded instructional methods, especially the animation-based visual coding, may also have implications for teaching native Chinese children who exhibit visuospatial deficits in their reading acquisition. As Chinese characters are symbolic visual representations of either concrete or abstract concepts, which visually map onto meanings but are not directly connected to their pronunciations, when reading Chinese, a visuospatial analysis must be performed in readers' brains to activate each character's meaning and phonology (Siok, et al., 2009). In fact, an fMRI study revealed that the reading performance of native Chinese dyslexia children may be affected by a visuospatial deficit because "neural processing of visually-guided spatial properties is interrupted" in addition to a phonological disorder which seems to occur independently (Siok, et al., 2009, p.891). Also, a meaning spelling theory of Chinese characters proposed by Zhang (2011) argues that Chinese script is a meaning spelling script which constructs new concepts by combining basic meaning-indicating units (characters), and this theory, therefore, predicts that visual processing is most significantly involved in its neural implementation during word recognition in Chinese than in recognition of words written in alphabetic languages. Based on this theory, Zhang and his colleagues conducted an ERP study (2012) on Chinese word recognition and found the orthographic processing engages an early stage of widespread and advanced visual processing which is specific to Chinese word recognition. Therefore, animation involved in dual-coded instructional methods may facilitate visual processing of native Chinese dyslexics struggling with associating written characters with their meanings at the early stage of orthographic processing.

Besides logographic languages like Chinese, dual-coded multi-sensory teaching and learning methods may also be beneficial for the acquisition of other writing systems, such as alphabetic languages. Existing studies have identified that object perception and recognition in daily life involve multi-sensory processing of information, in which the information from different modalities is integrated into a coherent representation in the brain (Ghazanfar & Schroeder, 2006). As learning to read English or other alphabetic languages starts with establishing mappings between speech sounds and corresponding letters (Frith, 1985), this learning process might happen as a result of the emergence of letter-sound integrated pairs as a specific type of audiovisual object perception (Bloment & Froyen, 2010), which suggests the possible effects of multi-sensory input methods on learning alphabetic words. Moreover, in a neuro-imaging study which compared visual word recognition of both Chinese and French readers, a large-scale network that involved not only the universal components of reading in known brain regions but also some brain areas corresponding to the components specific to culture in reading logographs, was observed (Nakamura, et al., 2012). This finding suggests that these distributed areas stand for a rapid and constant underlying system for recognizing word shapes in brain systems across different languages. Therefore, dual-coded multi-sensory instructional methods investigated in this study have the potential to be adapted for other aspects of language acquisition.

Limitations and Suggestions

As the Chinese proficiency test developed by National Chinese Testing Center for non-native speakers requires vocabulary knowledge of 2905 high-frequency characters for the purpose of daily communication (Liu and Song, 1992), easing the challenging task of teaching and learning Chinese characters can be accomplished by joint efforts of linguists, researchers, educators and instructors. This study can serve as an initial attempt to address the visual recognition of Chinese characters, which is just one type of input processing rather than any output processing like pronunciation and writing or auditory input processing like listening, and therefore has its limitations on application of the investigated teaching methods and generalization of its findings. These limitations are summarized below, and suggestions and recommendations are provided for Chinese instructors and researchers.

First, as the dual coded methods investigated in this study involve visual coding which is presented by it etymology picture and animation, they can only be applied to teach pictographs which symbolize the shapes and structures of concrete objects, ideographs which represent abstract ideas, associative compound characters which consist of two semantic components that join together suggesting the meaning of compound characters, and the semantic radicals of phonetic-semantic compound characters which suggest relevant meanings of characters. For those characters, such as phonetic loan characters like 北, which originally meant 'back' (two people sitting together back to back) but borrowed a new meaning 'north' from other character, and therefore has no connection with its original etymology, or mutually explanatory characters 考 and 老, which use each other as a reference of meaning (Liu and Yao, 2008), dual coded methods may not be very helpful in teaching them, so instructors may have to use traditional teaching strategies, such as rote memorization or stroke by stroke drills, to teach them.

Meanwhile, as the visual coding of dual coded methods only addresses semantic components of phonetic-semantic compound characters, and therefore is only helpful for learners to differentiate characters with same phonetic radicals but different though similar semantic radicals, these methods may not be beneficial for differentiating characters with the same semantic radicals but different phonetic radicals. For example, both 招 ('to beckon') and 抬 ('to carry or uplift') consists of a semantic radical 扌 meaning 'hand' on the left but have different phonetic radicals with similar structures on the right. In this situation, dual coded methods can only help them recognize the semantic radical and have to be combined with other methods related to phonology, such as explicitly explaining the pronunciations of those phonetic radicals by instructors prior to differentiating the characters. Besides that, some similar characters with extremely subtle differences that can hardly be presented with visual coding like pictures, such as 己 ('self') and 已 ('to cease'),will also need instructors' explicit explanation and multiple exposures to help learners differentiate them.

In the research design of the current study, as the treatments involved both verbal information and nonverbal information, i.e., description of each target character's etymology and computer-based multimedia animation for each character that transformed an etymology picture into the corresponding character, both verbal ability and spatial ability were considered. In order to control for the influence of participants' spatial ability, the Purdue Visualization of Rotation Test (PVRT, Guay, 1976) was adopted and the test score was included as a covariate when conducting the data analyses. To avoid the confounding effect from the factor of the participants' verbal ability, this study recruited only junior and senior college students and assumed they had sufficient verbal ability after two years' successful college learning experience to read, listen and comprehend the text description of a character within very limited time, i.e., 15 seconds. This might affect the generalizability of the findings of the study. Future studies can involve a more diverse population of participants, such as college freshmen and sophomores, and control the verbal ability by including their SAT scores, or other verbal test scores to measure learners' oral and reading comprehension, as a covariate, to increase the generalizability of research findings.

Another limitation lies in the number and the type of the target Chinese characters included in this study. As the participants needed to finish the demographic survey and the spatial ability test, which consists of 30 multiple choice questions, before receiving the treatment by watching the tutorial and completing the posttest, it was possible they may have felt tired and could not concentrate if too many learning contents were required. Therefore, the researcher limited the tasks to 30 minutes, and only selected two types of 24 Chinese characters as the learning targets. Meanwhile, in order to make sure the two types of the characters were comparable, both the pictographs and ideographs selected for this study were only single-component simple characters. Even though the simple pictographs and ideographs are basic building blocks of compound Chinese characters, which might provide some implications for compound character learning, the evidence from the studies that can directly investigate compound character learning would be even more relevant and persuasive. Therefore, future studies may consider including a larger number of compound characters, both concrete and abstract, to verify the findings of the current study.

Moreover, this study only measured learning achievement by means of an immediate content-based recall posttest, which is sufficient for character recognition, but it did not include a delayed posttest to investigate the effectiveness on the long-term learning retention, considering the participants' availability of attending this study and the difficulty of controlling them for not receiving any exposures related to Chinese characters during their spare time between the immediate and delayed posttests. Future studies, if these confounding factors can be successfully controlled, may involve both an immediate posttest and an identical delayed posttest to explore whether the learning achievement observed immediately following instruction translated into long-term knowledge.

As this study was conducted at a university in a small, rural town in the Middle Tennessee, the last area for future work to extend this study is to replicate it in more diversified locations where the population may be substantially different from this sample, including bilinguals with either alphabetic or character-based second language learning experiences, to verify whether they can provide additional support of the effects of these dual coded teaching methods with multi sensory input in teaching Chinese characters and vocabulary.

Conclusions

Chinese L2 literacy’s objective is to read and write the Chinese language accurately, fluently, and appropriately. As its prerequisite is the automatic character recognition, the major challenge for Chinese L2 instructors is “how to develop a balanced curriculum to achieve pedagogical goals of character learning within a limited learning period” (Shen, 2013, p. 383). Based on the Dual Coding Theory which suggests that two mental systems, verbal and nonverbal, are involved in processing linguistic units and imagery, this study investigated the effects of the single (verbal or visual) and dual (verbal and visual) coded instructional methods in a computer-based environment on modern Chinese character learning by college students who are adult English native speakers, with an aim of making a contribution to the development of powerful character teaching and learning strategies. The results revealed that the dual coded methods, e.g., the animation-plus-text method and the animation-plus-narration method, were more effective than the single coded methods like the text-only method and the animation-only method, for both concrete characters (pictographs) and abstract characters (ideographs). Meanwhile, participants under both the single or dual coded condition achieved higher scores on the pictograph learning than on the ideograph learning. The comparison of the two single coded methods indicated that the animation-only method was superior to the text-only method on both concrete characters and abstract characters, with more improvement on the ideograph learning than on the pictograph learning. Under the dual coded method condition, the animation-plus-narration method outperformed the animation-plus-text method on both character types given that the animation and the narration were appropriately synchronized. Based on these findings, this study suggests that well-designed computer animations may significantly enhance the learning of both concrete and abstract Chinese characters. In addition, well-designed animations may provide more help for learners on abstract character learning by establishing the mental connection between the abstract concepts the character represents and the original picture associated with the character.

In summary, Chinese educators should consider both linguistic and visual information of the target language due to the Chinese writing system's unique pictorial nature. When addressing the recognition of Chinese characters and vocabulary, instructors should create ample opportunities to incorporate these dual coded teaching and learning methods with multi sensory input in their daily teaching practice so that teaching efficiency can be optimized and maximum learning effects can be achieved.

REFERENCES

Aaronson, D., Ferres, S. (1986). Sentence processing in Chinese-American bilinguals. *Journal of Memory and Language, 25*, 136-162.

Adams, M. (1990). *Beginning to read.* Cambridge, MA: MIT Press.

Al-Seghayer, K. (2001). The effect of multimedia annotation modes on L2 vocabulary acquisition: A comparative study. *Language Learning & Technology, 5*(1), 202-232.

Atkinson, R., & Raugh, M. (1975). An application of the mnemonic keyword method to the acquisition of Russian vocabulary. *Journal of Experimental Psychology: Human Leaning and Memory, 104*(2), 126-133.

Baddeley, A. (1992). Working memory. *Science, 255*(5044), 556-559.

Baron, J. & Strawson, C. (1976). Use of orthographic and word-specific knowledge in reading words aloud. *Journal of Experimental Psychology: Human Perception and Performance*, *2*, 386-393.

Beauvois, M. F. (1982). Optic aphasia: A process of interaction betwen vision and language. *Philosophical Transactions of the Royal Society of London, 298*, 35-47.

Begg, I., & Paivio, A. (1969). Concreteness and imagery in sentence meaning. *Journal of Verbal Learning and Verbal Behavior, 8*, 821-827.

Beijing Language and Culture University. (1986). *Modern Chinese frequency dictionary* [Xiandai Hanyu Pinlu Cidian]. Beijing: Beijing Language Institute Press.

Biederman, I., & Taso, Y-C. (1979). On processing Chinese ideographs and English words: Some implication from Stroop-test results, *Cognitive Psychology*, *11*, 125-132.

Blomert, L., & Froyen, D. (2010). Multi-sensory learning and learning to read. *International Journal of Psychophysiology, 77*(3), 195-204.

Bodner, G. M., & Guay, R. B. (1997). The Purdue visualization of rotations test. *The Chemical Educator*, *2*(4), 1-17.

Boltz, W. G. (1994). *The origin and early development of the Chinese writing system*. (American Oriental Series. 78.) New Haven, CT.

Bryden, M. P. (1982). *Laterality Functional Asymmetry in the Intact Brain*. Access Online via Elsevier.

Bull, B. L., & Wittrock, M. C. (1973). Imagery in the learning of verbal definitions. *British Journal of Educational Psychology*, *43*(3), 289-293.

Chen, M. J. (1993). A comparison of Chinese and English Language Processing. In J. Altarriba (Ed.), *Cognition and Culture: A cross-cultural approach to psychology* (pp. 97-117). Amsterdam: Elsevier.

Chen, T. F. (2010). *Dual coding theory and Chinese: Recall of concrete and abstract sentences in Chinese-English bilinguals*. (Doctoral dissertation). Retrieved from http://hdl.handle.net/1969.1/ETD-TAMU-2010-08-8322.

Chen, Z. (2006). *The effects of multimedia annotations on L2 vocabulary immediate recall and reading comprehension: A comparative study of text-picture and audio-picture annotations under incidental and intentional learning conditions* (Doctoral dissertation, University of South Florida, 2006). DAI-A, 68/01, 170.

Chen, H. & Juola, J. (1982). Dimensions of lexical coding in Chinese and English. *Memory and Cognition, 10*(3), 216-224.

Cheng, C.-M. (1992). Lexical access in Chinese: Evidence from automatic activation of phonological information. In H. C. Chen & O. J. L. Tzeng (Eds.), *Language processing in Chinese* (pp.67-92). Amsterdam: Elsevier.

Chuang, C. J. (1975).The function of imagery in learning of Chinese language. *Acta Psychologica Taiwanica, 1*, 145-150.

Chuang. H. Y., & Ku, H. Y. (2011). The effect of compute-based multimedia instruction with Chinese character recognition. *Educational Media International, 48*(1), 27-41.

Chun, D. M., & Plass, J. L. (1996). Effects of multimedia annotations on vocabulary acquisition. *The Modern Language Journal, 80*(2), 183-198.

Chung, K. K. (2008). What effect do mixed sensory mode instructional formats have on both novice and experienced learners of Chinese characters? *Learning and Instruction*, *18*(1), 96-108.

Clark, J. M., & Paivio, A. (1991). Dual Coding Theory and education. *Educational Psychology Review, 3*(3), 149-210.

Cohen, A. D. (1987). The use of verbal and imagery mnemonics in second language vocabulary learning. *Studies in Second Language Acquisition, 9*, 43-62.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cohen, M. T. (2009). The effectiveness of imagery interventions on the vocabulary learning of second grade students. *NERA Conference Proceedings 2009, Paper 33.* Retrieved from http://digitalcommons.uconn.edu/nera_2009/33.

Cohen, M. T., & Johnson, H. L. (2011). Improving the acquisition of novel vocabulary through the use of imagery interventions. *Early Childhood Education Journal, 38*(5), 357-366.

Davis, N., & Lyman-Hager, M. (1997). Computers and L2 reading: Student performance, student attitudes. *Foreign Language Annals, 30*(1), 58-72.

DeFrancis, J. (1989). *Visible speech: The diverse oneness of writing systems*. Honolulu: University of Hawaii Press.

Day, J. (1979). Visual half-field word recognition as a function of syntactic class and imageability. *Neuropsychologia*, *17*, 515-519.

Denis, M. (1984). Imagery and prose: A critical review of research on adults and children. *Text, 4*(4), 381-401.

Duan, D. & Cuvo, A. J. (I996). Comparison of prototype and rote instruction of English names for Chinese visual Characters. *Journal of Applied Behavior Analysis, 22*(1), 25-27.

Eddy, J., & Glass, A. (1981). Reading and listening to high and low imagery sentences. *Journal of Verbal Learning and Verbal Behavior, 20*(3), 333-345.

Educational Testing Service. (1976). *Manual for kit of factor-referenced cognitive tests*. Princeton, NJ: Educational Testing Service.

Efron, R. (1963). Effects of handedness on the perception of simultaneity and temporal order. *Brain, 86*, 261-284.

Ehri, L. (2005). Learning to read words: Theory, findings, and issues. *Scientific Studies of Reading*, *9*, 167–188.

Everson, M. E. & Ke, C. (1997). An inquiry into the reading strategies of intermediate and advanced learners of Chinese as a foreign language. *Journal of the Chinese Language Teachers Association*, *32*, 1-20.

Everson, M. E. (2009). Literacy development in Chinese as a foreign language. In M. E. Everson & Y. Xiao (Eds.). *Teaching Chinese as a Foreign Language: Theories and Applications* (pp. 97 - 111). Boston: Cheng & Tsui Company.

Friederici, A. D., Meyer, M., & von Cramon, D. Y. (2000). Auditory language comprehension: an event-related fMRI study on the processing of syntactic and lexical information. *Brain and Language*, *74*(2), 289-300.

Frith, U. (1985). Beneath the surface of developmental dyslexia. *Surface Dyslexia*, *32*, 301-330.

Funnell, M. G., Corballis, P. M., & Gazzaniga, M. S. (2001). Hemispheric processing asymmetries: implications for memory. *Brain and Cognition, 46*, 135-139.

Geschwind, N. (1965). Disconnexion syndrome in animals and man. *Brain*, *88*, 237-294, 585-644.

Ghazanfar, A. A., & Schroeder, C. E. (2006). Is neocortex essentially multisensory? *Trends in Cognitive Sciences, 10*(6), 278-285.

Glenberg, A. M., & Langston, W. E. (1992). Comprehension of illustrated text: Pictures help to build mental models. *Journal of Memory and Language, 31*(2), 129-131.

Guay, R. (1976). *Purdue spatial visualization test*. Purdue University.

Gullick, M. M., Mitra, P., & Coch, D. (2013). Imagining the truth and the moon: An electrophysiological study of abstract and concrete word processing. *Psychophysiology*, *50*, 431-440.

Hanley, R. (2005). Learning to read in Chinese. In M. J. Snowling, & C. Hulme (Eds.), *The science of reading: A handbook*. Malden, MA: Blackwell.

Hayes, E. B. (1988). Encoding strategies used by native and non-native readers of Chinese Mandarin. *The Modern Language Journal, 72*(2), 188-195.

Ho, C. S-H., & Chen, H-C. (1993). Effects of syntactic structure in the memory of concrete and abstract Chinese sentences. *Journal of Psycholinguistic Research*, 22, 505-518.

Holender, D. (1987). Synchronic description of present-day writing systems: Some implications for reading research. In J. K. O'Regan and A. Levy-Schoen (eds.), *Eye movements: From physiology to cognition*. Amsterdam: Elsevier North Holland.

Holyoak , K. J. (1974). The role of imagery in the evaluation of sentences: Imagery or semantic factors? *Journal of Verbal Learning and Verbal Behavior, 13*(2), 163-166.

Holmes, V., & Langford, J. (1976). Comprehension and recall of abstract and concrete sentences. *Journal of Verbal Learning and Verbal Behavior, 15*, 559-566.

Hoosain, R. (1991). *Psycholinguistic implications for linguistic relativity: A case study of Chinese.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Hue, C. W. (1992). Recognition processes in character naming. In H. C. Chen, & O. J. L. Tzeng (Eds.). *Language processing in Chinese* (pp. 93-108). Amsterdam: Elsevier.

Jessen, F., Heun, R., Erb, M., Granath, D.-O., Klose, U., Papassotiropoulos A., et al. (2000). The concreteness effect: Evidence for dual coding and context availability. *Brain and Language, 74*, 103–12.

Johnson, D. D. (2001). *Vocabulary in the elementary and middle school*. Boston: Allyn & Bacon.

Jones-Gotman, M., & Milner, B. (1978). Right temporal lobe contribution to image-mediated memory. *Neuropsychologia, 16*, 61-71.

Jorgensen, C., & Kintsch, W. (1973). The role of imagery in the evaluation of sentences. *Cognitive Psychology, 4*(1), 110-116.

Ju, D., & Jackson, N. E. (1995). Graphic and phonological processing in Chinese character identification. *Journal of Reading Behavior, 27*(3), 299-313.

Ke, C. (1998). An empirical study on the relationship between Chinese character recognition and production. *The Modern Language Journal, 80*(3), 340-350.

Ki, W., Tse, S.K., Law, N., Lau, F., & Pun, K.H. (1994). A knowledge-based multimedia system to support the teaching and learning of Chinese characters. *Proceedings of ED-MEDIA 94 World Conference on Educational Multimedia and Hypermedia*, Vancouver, British Columbia, Canada, June 25-30.

Kimura, D. (1982). Left-hemisphere control of oral and brachial movements and their relation to communication. *Philosophical Transactions of the Royal Society of London, 298*(1089), 135-149.

Kounios, J., & Holcomb, P. J. (1994). Concreteness effects in semantic processing: ERP evidence supporting dual-coding theory. *Journal of Experimental Psychology: Learning Memory and Cognition, 20*(4), 804-823.

Kousta, S. T., Vigliocco, G., Vinson, D. P., Andrews, M., & Del Campo, E. (2011). The representation of abstract words: why emotion matters. *Journal of Experimental Psychology General*, *140*, 14.

Kuo, M., & Hooper, S. (2004). The Effects of visual and verbal coding mnemonics on learning Chinese characters in computer-based instruction. *Educational Technology Research and Development, 52*(3), 23-38.

Lai, F. Q. (1998). *Impact of graphic aids in electronic texts on learning Chinese radicals: implications of the dual coding theory*. (Unpublished Unpublished doctoral dissertation). Retrieved from ProQuest Dissertations and Theses.

Lam, H. C., Pun, K. H., Leung, S. T., Tse, S. K., & Ki, W. W. (1993). Computer-assisted-learning for learning Chinese characters. *Communications of COLIPS, an Intl. Journal of the Chinese and Oriental Languages Processing Society*, *3*(1), 31-44.

Leong, C. K.,Tan, L.H., Cheng, P. & Hau,K. T. (2005). Learning to read and spell English words by Chinese students. *Scientific Studies of Reading*, *9*, 63-84.

Levin, J. R., & J. K. Berry (1980). Children's learning of all the news that's fit to picture. *Educational Communication and Technology Journal, 28*(3), 177-185.

Levine, S. C., & Banich, M. T. (1982). Lateral asymmetries in the naming of words and corresponding line drawings. *Brain and Language*, *17*, 34-45.

Levy, M. (1997). *Computer-assisted language learning: context and conceptualization*. Oxford, UK: Oxford University Press.

Ley, R. G. (1983). Cerebral laterality and imagery. In A. A. Sheikh (Ed.), *Imagery: Current theory, research, and application*. New York: Wiley.

Li, C. N. & Thompson, S. A. (1981). *Mandarin Chinese: A functional reference grammar*. Berkeley, CA: University of California Press.

Li, X. (1996). HyperCbaracters: A Pilot study in computerized learning of Chinese characters. *CALICO Journal*, *14*(1), 77-94.

Liu, Y., & Song, S. (1992). *Vocabulary guideline for Chinese proficiency test*. *汉语水平词汇与等级大纲*. Beijing: Beijing Language and Culture University Press.

Liu, Y., Yao, T. C., Bi, N. P., Ge, L., & Shi, Y. (2008). *Integrated Chinese.* (Vol. 1, No. 1, 3rd ed.). Cheng & Tsui Co.

Luria, A. R. (1976). *The working brain: An introduction to neuropsychology*. New York: Penguin.

Matsum, N. (1994). Processes of words memory in second language acquisition: A test of bilingual dual coding theory. *The Japanese Journal of Psychology, 64*(6), 460-468.

Mayer, R. E., & Sims, V. K. (1994). For whom is a picture worth a thousand words? Extensions of a Dual Coding Theory of Multimedia Learning. *Journal of Educational Psychology, 86*(3), 389-401.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1-19.

Mayer, R. E. (2001). *Multimedia learning*. New York: Cambridge University Press.

Mayer, R. E. & Moreno, R. (1998). A split attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*, 312-320.

Mills, L., & Rollman, G. B. (1980). Hemispheric asymmetry for auditory perception of temporal order. *Neuropsychologia, 18*(1), 41-47.

Mousavi, S., Low R. & Sweller, J. (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87*, 319-334.

Muyskens, J. (Ed.). (1997). *New ways of learning and teaching: focus on technology and foreign language education*. Boston: Heinle & Heinle Publishers.

Nagy, W. E., & Scott, J. A. (2000). Vocabulary processes. In M. Kamil, P. B. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research* (Vol. 3, pp. 269-284). Mahwah, NJ: Erlbaum.

Nakajima, K (1988). On developing Hypercard stack for the study of Chinese characters: KanjiCard, *CALICO Journal*. Dec. 75-87.

Nakamura, K., Kuo, W. J., Pegado, F., Cohen, L., Tzeng, O. J., & Dehaene, S. (2012). Universal brain systems for recognizing word shapes and handwriting gestures during reading. *Proceedings of the National Academy of Sciences, 109*(50), 20762-20767.

Newman, R. (1971). *About Chinese*. Middlesex: Penguin Books.

O'Neil, B., & Paivio, A. (1978). Some consequences of violating selection restrictions in concrete and abstract sentences. *Canadian Journal of Psychology, 32*(1), 3-18.

Pan, Y., & Pan, Y. (2009). The effect of pictures on the reading comprehension of low-proficiency Taiwanese English foreign language college students: An action research study. *VUN Journal of Science, Foreign Language, 25*(4), 186-198.

Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, & Winston.

Paivio, A. (1983). Strategies in language learning. In M. Pressley & J. R. Levin (Eds.), *Cognitive strategies research: Educational applications*. New York: Springer-Verlag.

Paivio, A. (1990). *Mental representations: A dual coding approach*. New York: Oxford University Press.

Paivio, A. (1991). Dual Coding Theory: Retrospect and current status. *Canadian Journal of Psychology, 45*(3), 255-287.

Paivio, A. (2007). *Mind and its evolution: A dual coding theoretical approach*. Mahwah, NJ: Erlbaum.

Paivio, A., & Ernest, C. (1971). Imagery ability and visual perception of verbal and nonverbal stimuli. *Perception & Psychophysics, 10*(6), 429-432.

Paivio, A., & Desrochers, A. (1979). Effects of an imagery mnemonic on second language recall and comprehension. *Canadian Journal of Psychology, 33*(1), 17-28.

Paivio, A., & Desrochers, A. (1980). A dual-coding approach to bilingual memory. *Canadian Journal of Psychology, 34*(4), 388-399.

Paivio, A., & te Linde, J. (1982). Imagery, memory, and the brain. *Canadian Journal of Psychology, 36*(2), 243-272.

Perfetti, C. A., Zhang, S., & Berent, I. (1992). Reading in English and Chinese: Evidence for a "universal" phonological principle. In R. Frost & L. Katz (Eds.), *Orthography, phonology, morphology, and meaning* (pp. 227-248). Amsterdam: Elsevier.

Perfetti, C. A., Liu, Y., Fiez, J. Nelson, J., Bolger, D. J., & Tan, L-H. (2007). Reading in two writing systems: Accommodation and assimilation in the brain's reading network. *Bilingualism: Language and Cognition*, *10*(2), 131-146.

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (1998). Supporting visual and verbal learning preferences in a second-language multimedia learning environment. *Journal of Educational Psychology, 90*(1), 25-36.

Plass, J. L., Chun, D. M., Mayer, R. E., & Leutner, D. (2003). Cognitive load in reading a foreign language text with multimedia aids and the influence of verbal and spatial abilities. *Computers in Human Behavior. 19*(2), 221-243.

Purnell, K. N., & Solman, R. T. (1991). The influence of technical illustrations on students' comprehension in geography. *Reading Research Quarterly, 26*(3), 277-299.

Ratcliff, G., Dila, C., Taylor, L., & Milner, B. (1980). The morphological asymmetry of the hemispheres and cerebral dominance for speech: a possible relationship. *Brain and Language*, *11*(1), 87-98.

Reed, D. J., & Beveridge, M. (1990). Reading illustrated science texts: A microcomputer based investigation of children's strategies. *British Journal of Educational Psychology, 60*(1), 76-87.

Rieber, L. P. (1991). Computer animation, incidental learning, and continuing motivation. *Journal of Educational Psychology, 83*(3), 318-328.

Rosenshine, B. (1980). Skill hierarchies in reading comprehension. In R. J. Spiro, B. C. Bruce, & W. F. Brewer (Eds.), *Theoretical issues in reading comprehension* (pp. 535-554). Hillsdale, NJ: Lawrence Erlbaum.

Sadoski, M., Goetz, E. & Fritz, J. (1993). Impact of concreteness on comprehensibility, interest, and memory for text: Implications for dual coding theory and text design. *Journal of Educational Psychology, 85*(2), 291-304.

Sadoski, M., & Paivio, A. (2001). *Imagery and Text: A dual coding theory of reading and writing.* Lawrence Erlbaum Associates, Publishers: Mahwah, New Jersey; London.

Sadoski, M., & Paivio, A. (2004). A dual coding theoretical model of reading. In R. B. Ruddell & N. J. Unrau (Eds.), *Theoretical models and processes of reading* (5th ed.) (pp. 1329-1362). Newark, DE: International Reading Association.

Sadoski, M. (2005). A dual coding view of vocabulary learning. *Reading & Writing Quarterly, 21*(3), 221-238.

Sham, D. P. L. (2002). *A dual-coding model of processing Chinese as a second language: A cognitive-load approach*. (Unpublished doctoral dissertation). University of New South Wales, Sydney, Australia.

Shen, H. H. (2008). An analysis of word decision strategies among learners of Chinese. *Foreign Language Annals, 41*, 501-552.

Shen, H. H. (2010). Imagery and verbal coding approaches in Chinese vocabulary instruction. *Language Teaching Research, 14*(4), 485-499.

Shen, H. H. (2013). Chinese L2 literacy development: cognitive characteristics, learning strategies, and pedagogical interventions. *Language and Linguistics Compass, 7*(7), 371-387.

Shibahara, N., & Lucero-Wagoner, B. (2002). Hemispheric asymmetry in accessing word meanings: Concrete and abstract nouns. *Perceptual and Motor Skills, 94*(3), 1292-1300.

Siok, W. T., & Fletcher, P. (2001). The role of phonological awareness and visual-orthographic skills in Chinese reading acquisition. *Developmental Psychology, 37*(6), 886-899.

Siok, W. T., Spinks, J. A., Jin, Z., & Tan, L. H. (2009). Developmental dyslexia is characterized by the co-existence of visuospatial and phonological disorders in Chinese children. *Current Biology, 19*(19), R890-R892.

Smith, F. (1985). *Reading without nonsense* (2nd edition), New York: Teachers College Press.

Smith, B. D., Stahl, N., & Neil, J. (1987). The effect of imagery instruction on vocabulary development. *Journal of College Reading and Learning, 20*, 131-137.

Sorby, S. (2009). Educational Research in Developing 3-D Spatial Skills for Engineering Students. *International Journal of Science Education, 31*(3), 459-480.

Steffensen, M. S., Goetz, E.T., & Cheng, X. (1999). The images and emotions of bilingual Chinese readers: A dual coding analysis. *Reading Psychology, 20*(4), 301-24.

Sun, F., Morita, M., & Stark, L.W. (1985). Comparative patterns of reading eye movement in Chinese and English. *Perception and Psychophysics, 37*, 502-506.

Susanuma, S. (1974). Kanji versus kana processing in alexia via transient agraphia: a case report. *Cortex, 10*(1), 88-97.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(2), 257-285.

Sweller, J. (1994). Cognitive load theory, learning difficulty, and instructional design. *Learning and Instruction, 4*(4), 295-312.

Taura, H. (1998). Bilingual dual coding in Japanese returnee students. *Language, Culture and Curriculum, 11*(1), 47-70.

Travassoli, N. (2001). Color memory and evaluations for alphabetic and logographic brand names. *Journal of Experimental Psychology: Applied, 7*, 104-111.

Treat, N. J., & Reese, H. W. (1976). Age, pacing, and imagery in paired-associate learning. *Developmental Psychology*, *12*(20), 119.

Turnage, T., & McGinnies, E. (1973). A cross-cultural comparison of the effects of presentation mode and meaningfulness on short-term recall, *American Journal of Psychology, 86*(2), 369-381.

Tzeng, O. J. L. & Wang, W. S-Y. (1983). The first two Rs. *American Scientist*, *71*, 238-243.

Villardita, C., Grioli, S., & Quatropanni, M. C. (1988). Concreteness, abstractness of stimulus words and semantic clustering in right brain damaged patients. *Cortex, 24*, 563-571.

Unicode. (2012). Ideographic Description Characters. Retrieved on June 3rd, 2013, from www.unicode.org/charts/PDF/U2FF0.pdf.

Waddill, P. J., McDaniel, M. A., & Einstein, G. O. (1988). Illustrations as adjuncts to prose: A test-appropriate processing approach. *Journal of Educational Psychology, 80*(4), 457-464.

Wall, H. M., & Routowicz, A. (1987). Use of self-generated and others' cues in immediate and delayed recall. *Perceptual and Motor Skills*, *64*(3), 1019-1022.

Wang, G. C. (1989). Research on teaching Chinese in forty-five universities: Analysis of survey results. *Journal of Chinese Language Teaching Association, 24*(3), 101-113.

Wang, S. (1998). A study on the learning and teaching of Hanzi - Chinese characters. *Working Papers in Educational Linguistics, 14*(1), 69-101.

Wang, J., Conder, J. A., Blitzer, D. N., & Shinkareva, S. V. (2010). Neural representation of abstract and concrete concepts: A meta-analysis of neuroimaging studies. *Human brain mapping, 31*, 1459-1468.

Wang, M., Cheng, C., & Chen, S.-W. (2006). Contribution of morphological awareness to Chinese-English biliteracy acquisition. *Journal of Educational Psychology, 98*(3), 542-533.

Wang, M., & Geva, E. (2003). Spelling performance of Chinese children using English as a second language: Lexical and visual-orthographic processes. *Applied Psycholinguistics, 24*(1), 1-25.

Wang, M., Perfetti, C. A., & Liu, Y. (2003). Alphabetic readers quickly acquire orthographic structure in learning to read Chinese. *Scientific Studies of Reading*, *7*(2), 183-208.

Wang, M., Liu, Y., & Perfetti, C. A. (2004). The implicit and explicit learning of orthographic structure and function of a new writing system. *Scientific Studies of Reading*, *8*(4), 357-379.

Warschauer, M., & Healey, D. (1998). Computers and language learning: An overview. *Language Teaching, 31*(2), 57-71.

Welcome, S. E., Paivio, A., McRae, K., & Joanisse, M. F. (2011). An electrophysiological study of task demands on concreteness effects: evidence for dual coding theory. *Experimental Brain Research, 212*, 347-358.

Whitehouse, P. J. (1981). Imagery and verbal encoding in left and right hemisphere damaged patients. *Brain and Language, 14*(2), 315-332.

Wittrock, M. C. (1974). Learning as a generative activity. *Educational Psychologist, 11*(2), 87-95.

Wittrock, M. C. (1989). Generative processes of comprehension. *Educational Psychologist, 24*(4), 345-376.

Wu, H-M, & Solman, R. T. (1993). Effective use of pictures as extra stimulus prompts. *British Journal of Educational Psychology, 63*, 144-160.

Xie, G. H. (1997). *The composition of common Chinese characters: An illustrated account*. Beijing: Peking University Press.

Yeung, A. S., Jin, P., & Sweller, J. (1998). Cognitive load and learner expertise: split-attention and redundancy effects in reading with explanatory notes. *Contemporary Educational Psychology, 23*(1), 1-21.

Zhang, J. X. (2011). The meaning spelling theory of Chinese characters: Insight into the nature of written Chinese from the perspective of cognitive psychology. *Journal of South China Normal University (Social Science Edition), 4*, 5-13.

Zhang, J. X., Fang, Z., Du, Y., Kong, L., Zhang, Q., & Xing, Q. (2012). Centro-parietal N200: An event-related potential component specific to Chinese visual word recognition. *Chinese Science Bulletin, 57*(13), 1516-1532.

Zhu, Y. (2010). Rediscovering the impacts of digital flashcard on Chinese character memorization of beginning US learners. *Chinese Teaching in the World*, 1, 127-137.

Zhu, Y., & Wei, H. (2005). Effects of digital voiced pronunciation and stroke sequence animation on character memorization of CFL learners. *Journal of Chinese Language Teachers Association*, *43*(3), 49-70.

APPENDICES

Appendix A: Chinese Characters Included in This Study

Table 15

Chinese Characters Included in This Study

Pictographs (3-5 strokes)		Ideographs (3-5 strokes)	
川 river (3)	弓 bow (3)	下 down (3)	刃 blade (3)
月 moon (4)	手 hand (4)	王 king (4)	天 sky (4)
牛 cow (4)	鸟 bird (5)	旦 dawn (5)	末 end (5)
口 mouth (3)	山 mountain (3)	三 three (3)	上 up (3)
火 fire (4)	木 wood (4)	中 center (4)	凶 fierce (4)
爪 claw (4)	目 eye (5)	本 root (5)	甘 sweet (5)

Appendix B: IRB Approval Letters

MIDDLE TENNESSEE STATE UNIVERSITY

September 6, 2013

Lisa Wang, Dr. Aleka Blackwell
Department of Literacy Studies
lw2s@mtmail.mtsu.edu, Aleka.Blackwell@mtsu.edu

Protocol Title: "Effectiveness of Dual-Coded Instructions in Learning Chinese Characters"

Protocol Number: 13-209

Dear Investigator(s):

I have reviewed your research proposal identified above and your requested changes. I approve of the following changes and approve the revised consent form:

1. The addition of a question to the Chinese Knowledge Questionnaire.
2. Collection of demographic information.
3. Addition of the Purdue Spatial Visualization Test.
4. Increase in number of participants to 160.

Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615)494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project report to the Office of Compliance upon completion of your research. Complete research means that you have finished collecting data and you are ready to submit your thesis and/or publish your findings. Should you not finish your research by the expiration date, you must submit a Progress Report and request a continuation prior to the expiration date. Please allow time for review and requested revisions. Your study expires February 11, 2016.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to provide a certificate of training to the Office of Compliance. If you add researchers to an approved project, please forward an updated list of researchers and their certificates of training to the Office of Compliance before they begin to work on the project.

Please note: **all research materials must be retained** by the PI or **faculty advisor (if the PI is a student)** for at least **three (3) years after study completion**. Should you have any questions or need additional information, please do not hesitate to contact me.

Sincerely,

Kellie Hilker

Research Compliance Officer
Middle Tennessee State University

AUSTIN PEAY STATE UNIVERSITY
INSTITUTIONAL REVIEW BOARD

Date: 9/9/2013

RE: Amendment to study number 13-013: Effectiveness of dual-coded instructions in learning Chinese characters

Dear Ling Wang,

This is to confirm that the amendments to the participant selection (increase the number to 120) and to the procedures (having students complete the full spatial ability test instead of 15 randomly selected items from the full test) for study # 13-013 have been approved. This approval is subject to APSU Policies and Procedures governing human subject research. The full IRB may still review this protocol and reserves the right to withdraw approval if unresolved issues are raised during the review.

Your study remains subject to continuing review on or before 9/9/2014, unless closed before that date. Please submit the appropriate form (request for continuing review or closed study report) prior to 9/9/2014.

Please note that any further changes to or deviations from the approved study protocol must be promptly reported and approved before continuing the study. Depending on the level of changes; they may be approved by chair, expedited review, or full board review. If you have any questions or require further information, you can contact me by phone (931-221-6106) or email (shepherdo@apsu.edu).

Again, thank you for your cooperation with the APSU IRB and the human research review process. Best wishes for a successful study!

Sincerely,

Omie Shepherd

Omie Shepherd, Chair
Austin Peay Institutional Review Board

cc: Dr. David Guest

Appendix C: Screening Test of Prior Knowledge of Chinese

Please answer the following questions related to Chinese language learning. Thank you!

1. Have you ever tried to learn Chinese or enrolled in Chinese language classes? Yes. No.

2. Are you at all familiar with the Chinese writing characters? Yes. No.

3. Are you familiar with any Chinese pictographs? Yes. No.

4. Are you familiar with any Chinese ideographs? Yes. No.

5. Are you familiar with the writing system of any of the following languages: Japanese, Korean, or Vietnamese? Yes. No.

6. Have you ever attended any studies related to teaching Chinese characters? Yes. No.

Appendix D: Demographic Survey

Please answer the questions in the following demographic survey. Thank you!

1. Gender

    A) Male

    B) Female

2. Age

    A) <18 years old

    B) >= 18 years old

3. Years in College

    A) 1

    B) 2

    C) 3

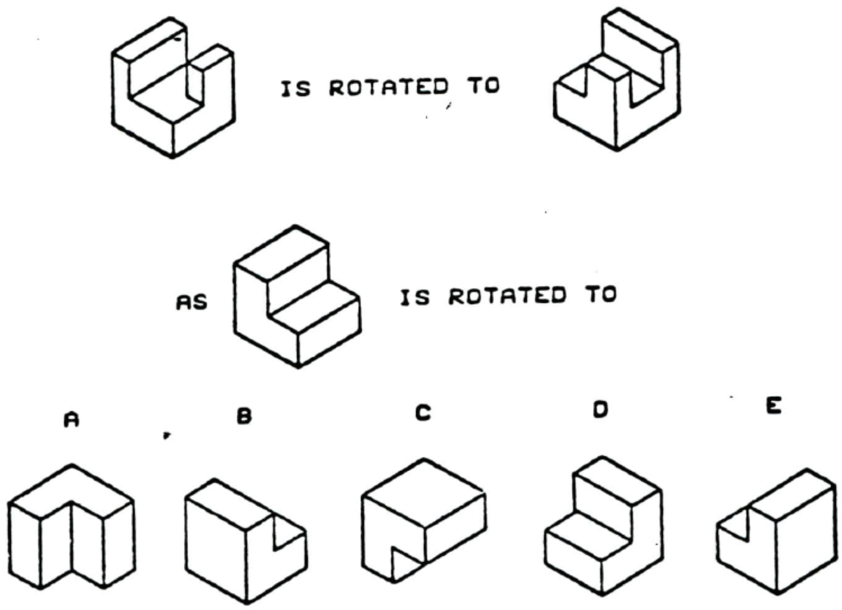
    D) 4

    E) 5 or more

Appendix E: Spatial Ability Test

Guay (1976)

This test consists of 30 questions designed to see how well you can visualize the rotation of three-dimensional objects. Shown below is an example of the type of question.



You are to:

1. study how the object in the top line of the question is rotated;

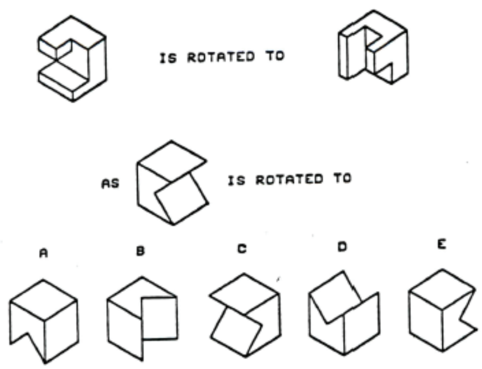
2. picture in your mind what the object shown in the middle line of the question looks like when rotated in exactly the same manner;

3. select from among the five drawings (A, B, C, D, or E) given in the bottom line of the question the one that looks like the object rotated in the correct position.

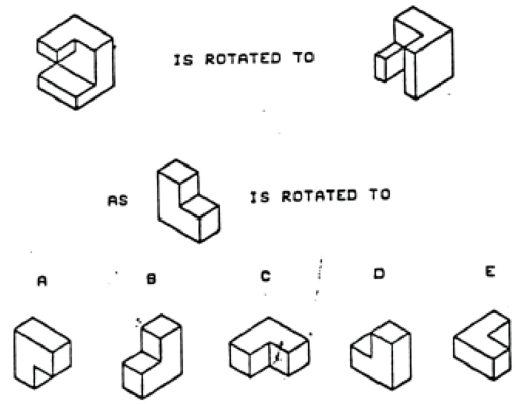
What is the correct answer to the example shown above?

Answer A, B, C, and E are wrong. Only drawing D looks like the object rotated according to the giving rotation. Remember that each question has only one correct answer.

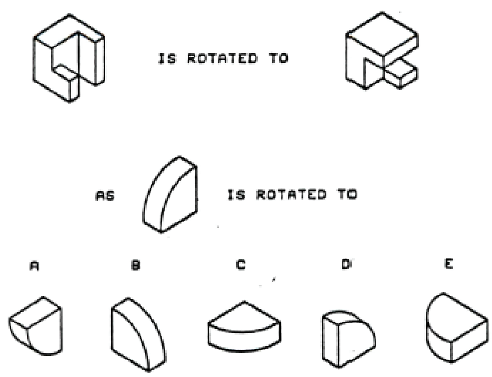
Question 1:



Question 2:



Question 3:



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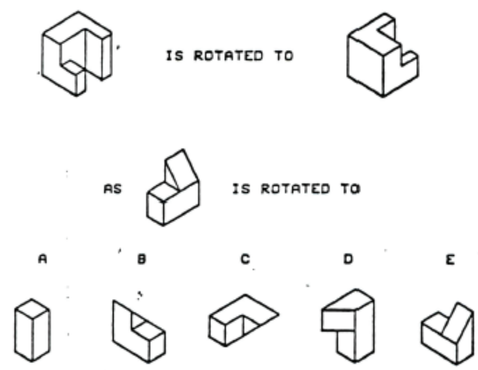

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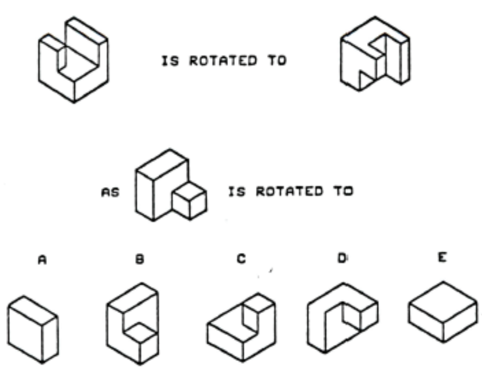

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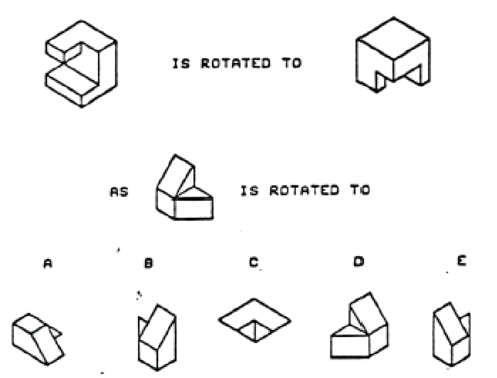

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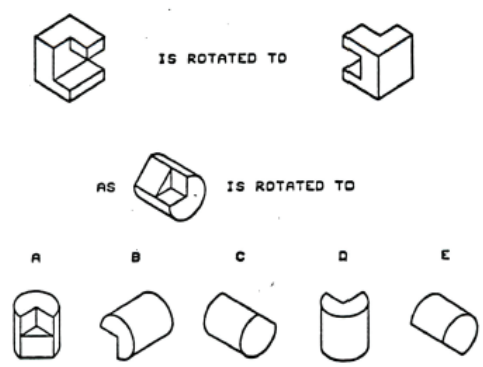

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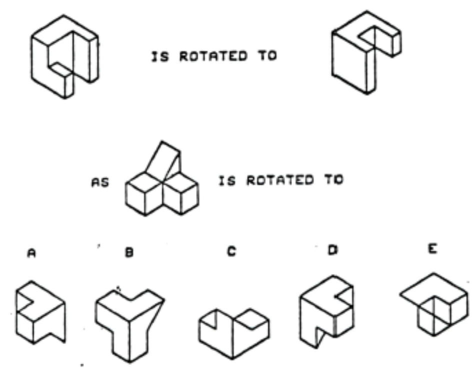

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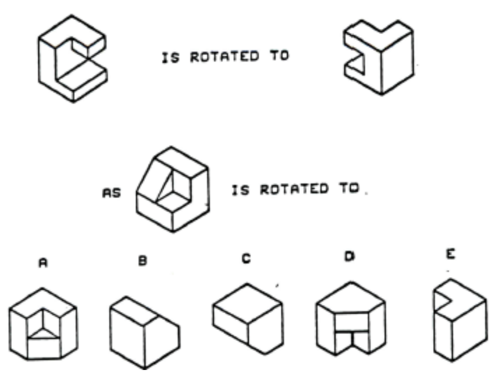

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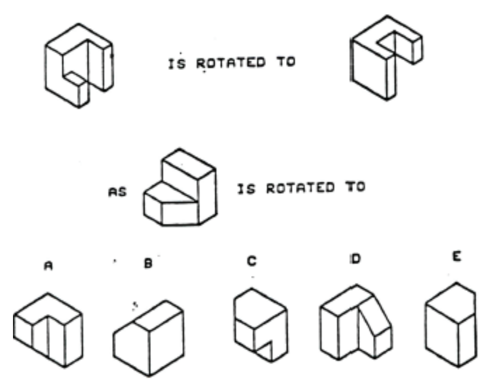

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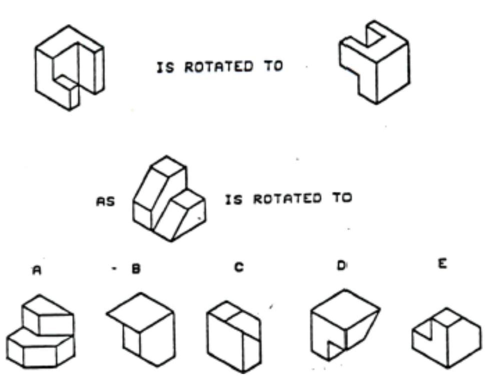

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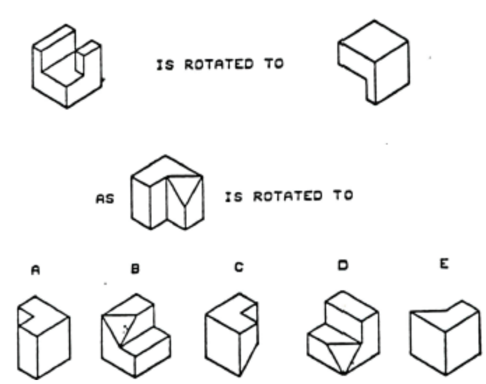

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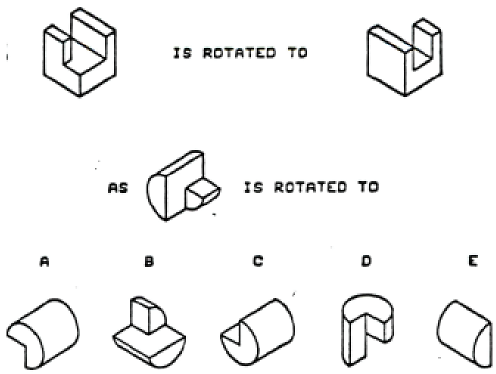

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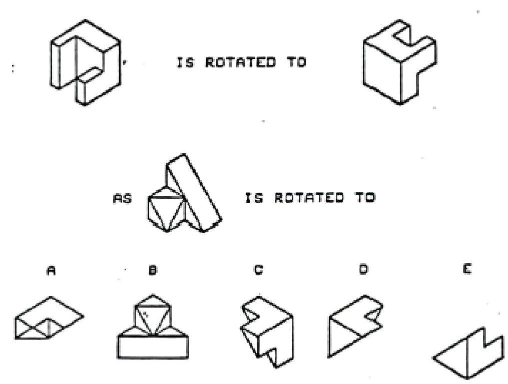

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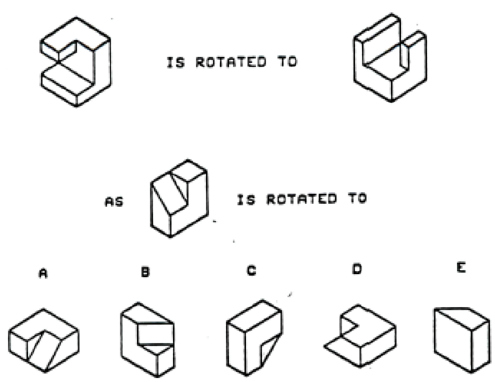

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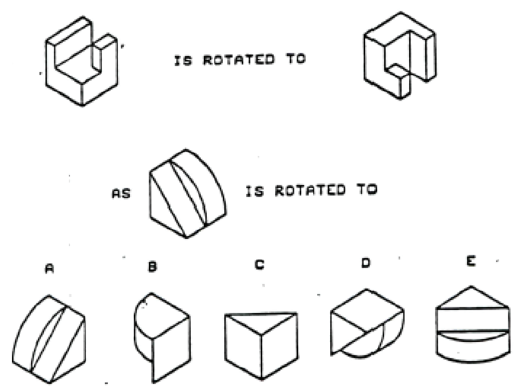

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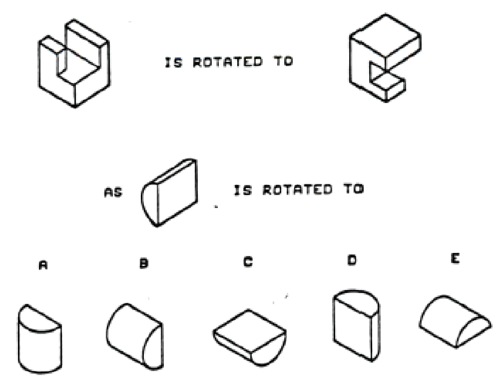

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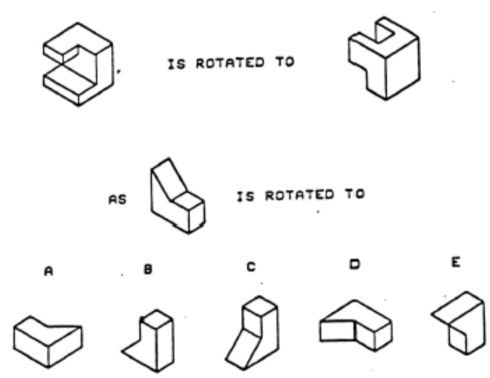

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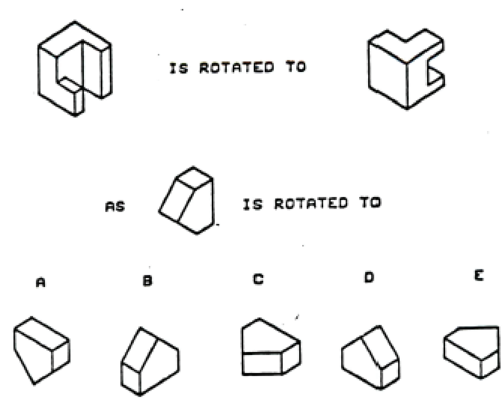

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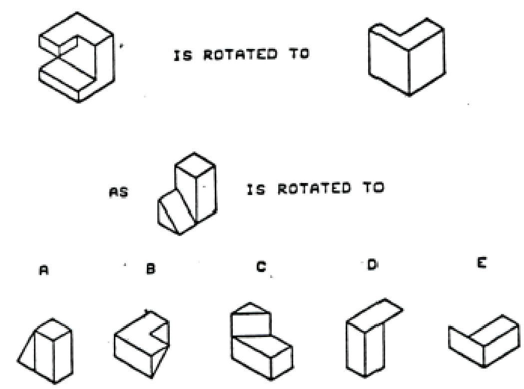

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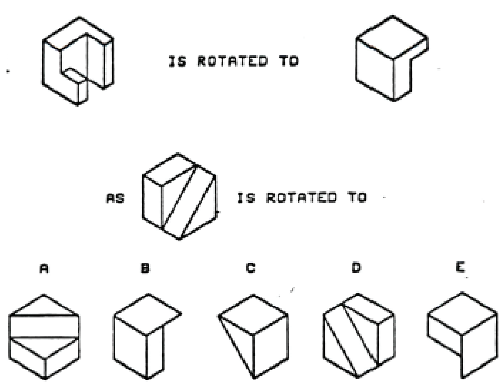

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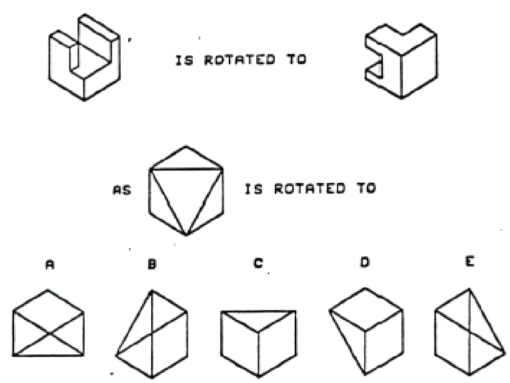

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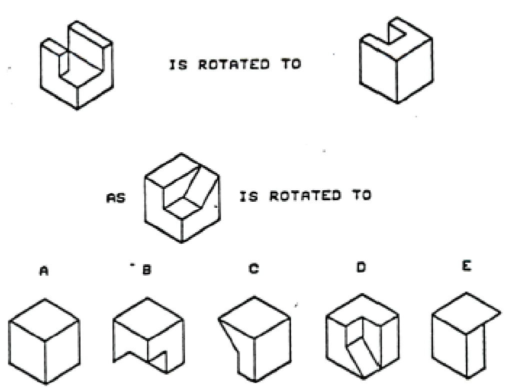

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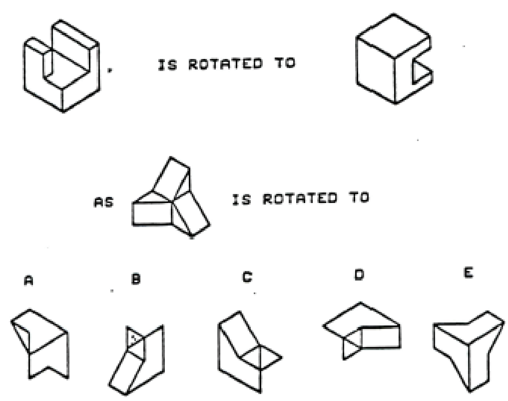

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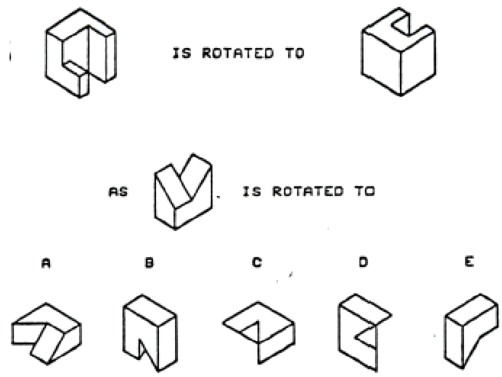
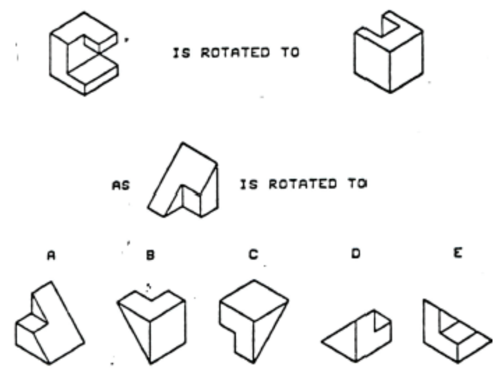
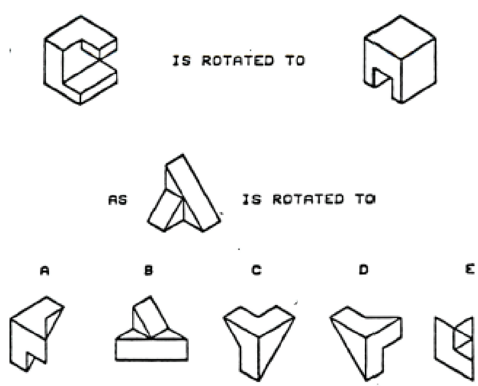


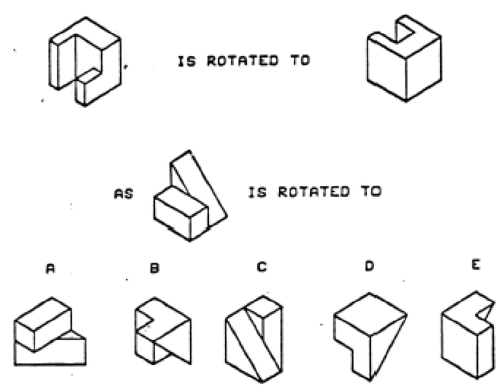
Question 26:



Question 27:



Question 28:



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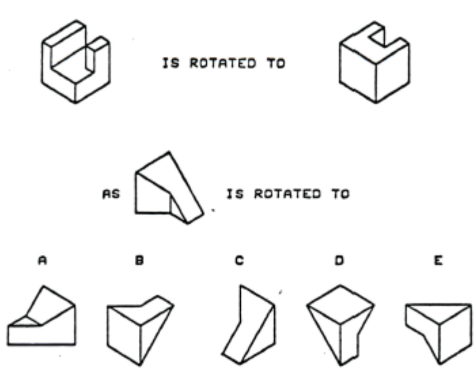
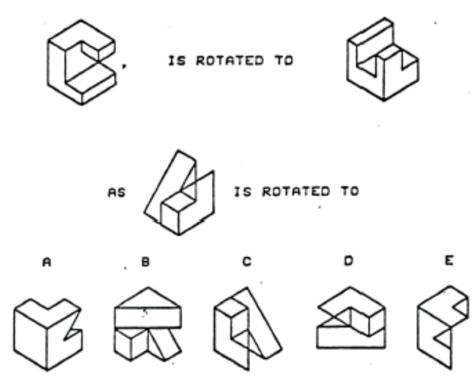
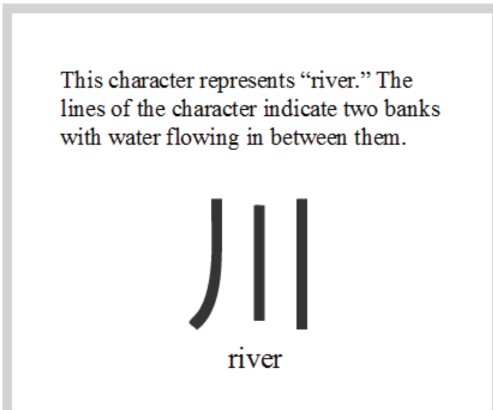


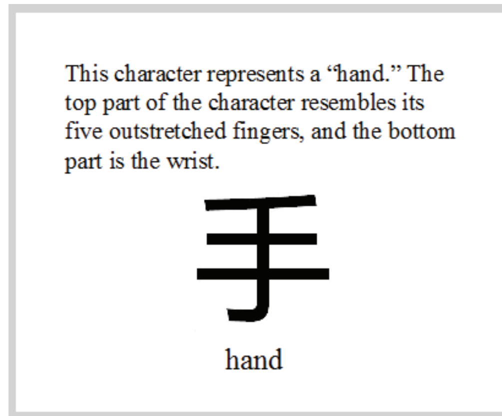
Question 30:

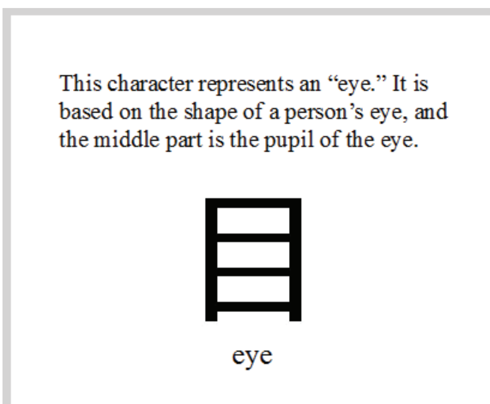


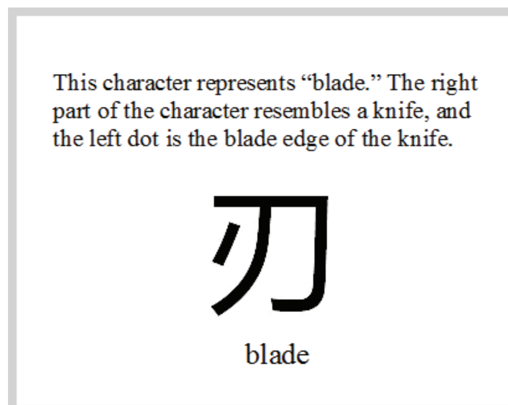
Appendix F: Screenshots of the Computer-Based Tutorial

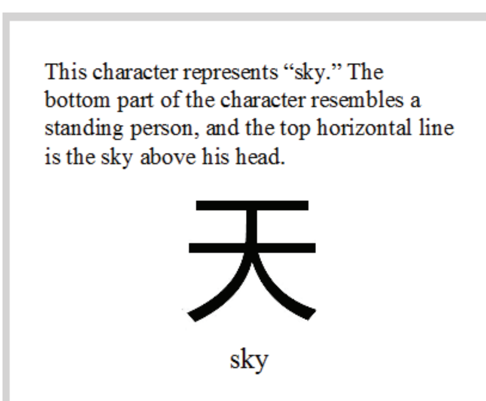
Examples of the Single-coded Text-only Method

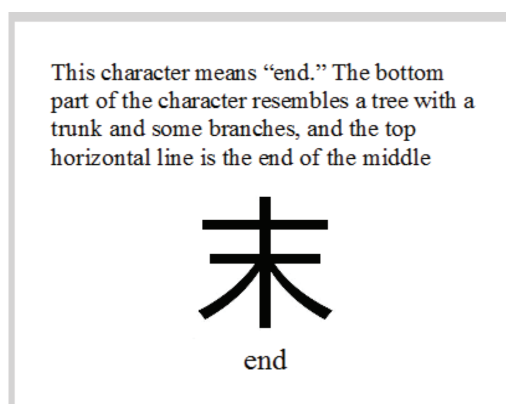




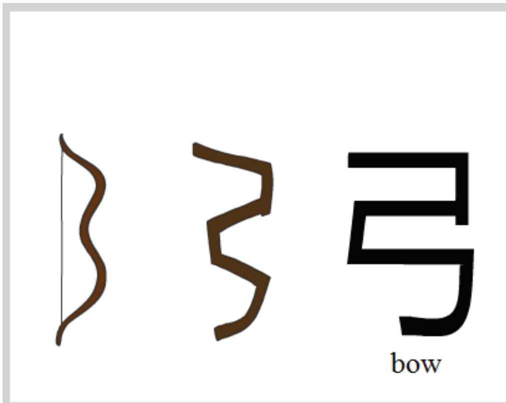


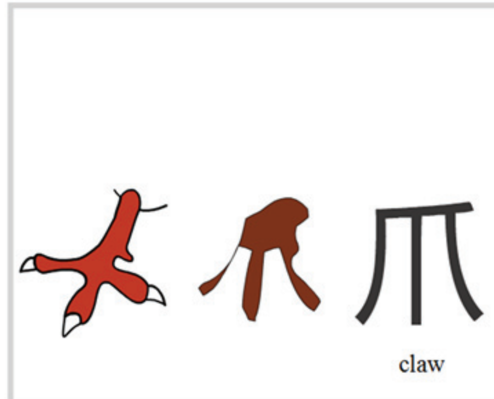


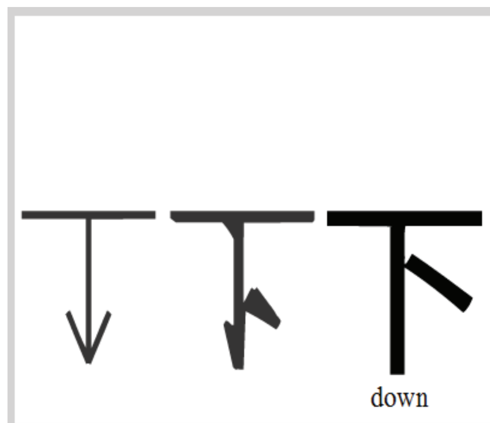




Examples of the Single-coded Animation-only Method

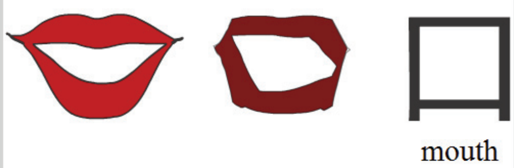




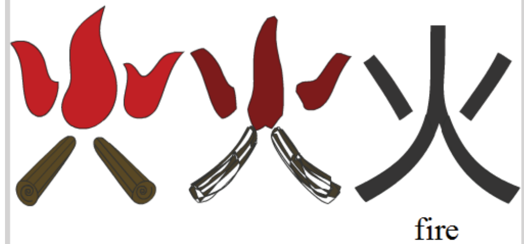


Examples of the Dual-coded Animation plus Text Method

This character represents a "mouth." It is based on the shape of a person's wide open mouth.



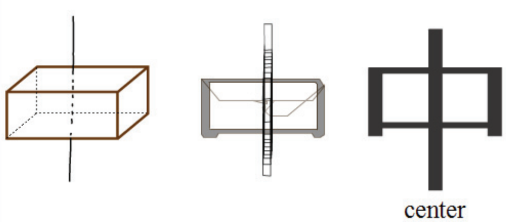
This character represents "fire." The top part of the character is three flames, and the bottom part is the fire wood.



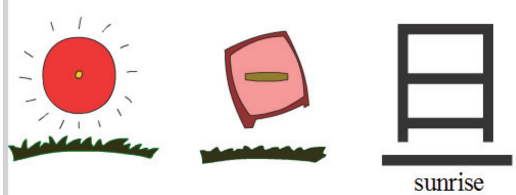
This character represents a "cow." It is based on the face of a cow, the top part is the horns and the lower horizontal line is the stretched ears.

This character represents "three," which is indicated by the three horizontal lines.

This character represents "center," which is indicated by the vertical line passing through the center of the square from top to bottom.

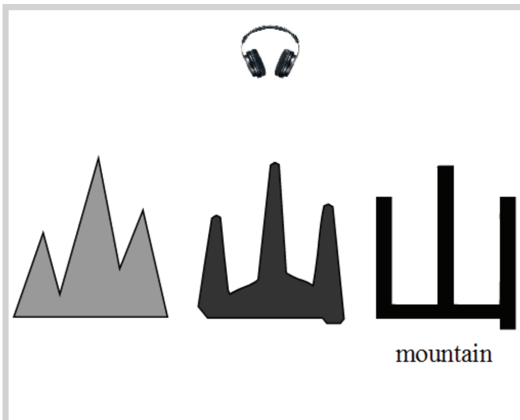


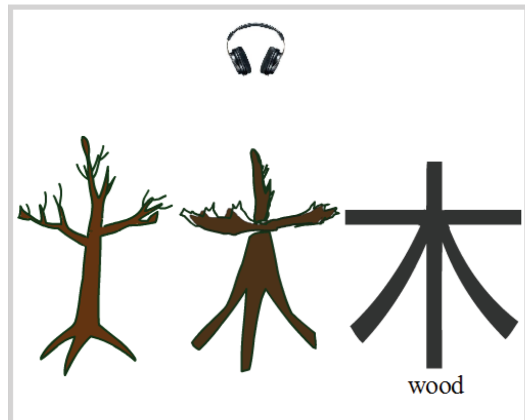
This character represents "sunrise." The top part of the character is the sun, and the bottom horizontal line represents horizon.

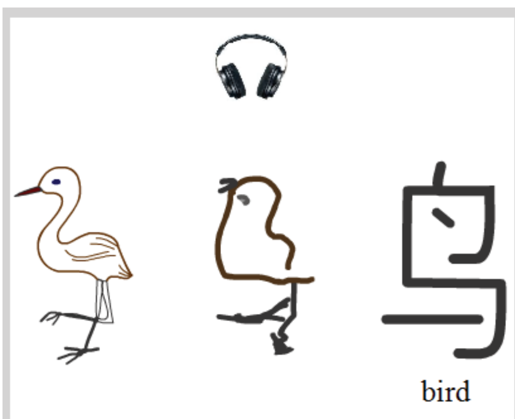


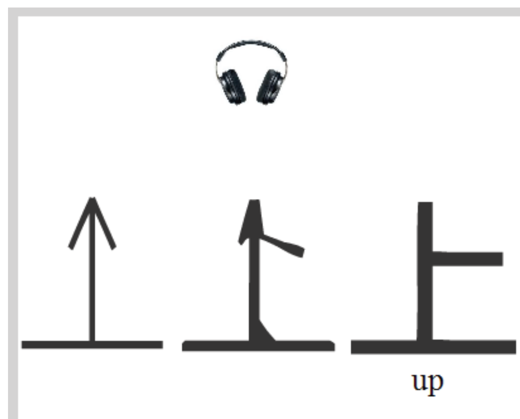
Examples of the Dual-coded Animation plus Narration Method

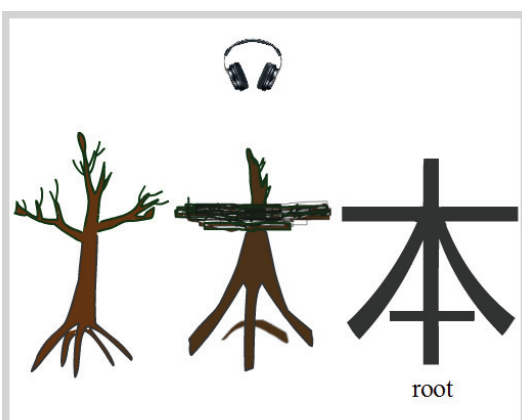
(Audio playback through headphone)

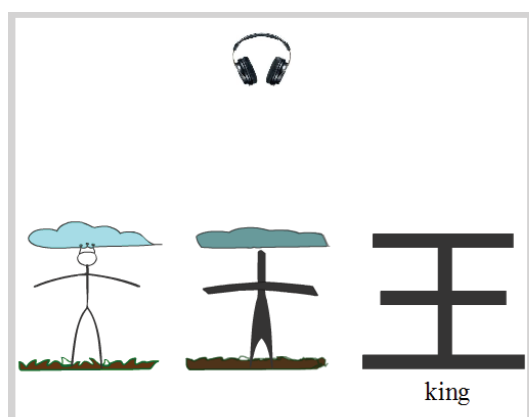












Appendix G: Content-Based Recall Posttest

1. What does the Chinese character "王" mean in English?

A. center B. sky C. up D. king E. hand

2. What does the Chinese character "刃" mean in English?

A. down B. claw C. blade D. hand E. moon

3. What does the Chinese character "川" mean in English?

A. three B. wood C. claw D. center E. river

4. What does the Chinese character "月" mean in English?

A. sunrise B. bow C. moon D. eye E. sweet

5. What does the Chinese character "天" mean in English?

A. wood B. end C. king D. root E. sky

6. What does the Chinese character "上" mean in English?

A. up B. mountain C. sunrise D. down E. three

7. What does the Chinese character "牛" mean in English?

A. blade B. end C. root D. cow E. sky

8. What does the Chinese character "火" mean in English?

A. king B. claw C. fierce D. sky E. fire

9. What does the Chinese character "山" mean in English?

A. fierce B. claw C. up D. mountain E. three

10. What does the Chinese character "旦" mean in English?

A. moon B. eye C. sweet D. up E. sunrise

11. What does the Chinese character "末" mean in English?

A. wood B. root C. sky D. end E. cow

12. What does the Chinese character "目" mean in English?

A. moon B. sunrise C. eye D. sweet E. mouth

13. What does the Chinese character “弓” mean in English?

A. bird B. river C. claw D. bow E. blade

14. What does the Chinese character “木” mean in English?

A. root B. cow C. end D. wood E. sky

15. What does the Chinese character “手” mean in English?

A. claw B. hand C. king D. fierce E. end

16. What does the Chinese character “三” mean in English?

A. river B. king C. center D. blade E. three

17. What does the Chinese character “下” mean in English?

A. root B. up C. blade D. down E. end

18. What does the Chinese character “凶” mean in English?

A. mountain B. claw C. down D. fierce E. up

19. What does the Chinese character “本” mean in English?

A. wood B. root C. end D. sky E. cow

20. What does the Chinese character “甘” mean in English?

A. sunrise B. sweet C. mouth D. eye E. moon

21. What does the Chinese character “鸟” mean in English?

A. bird B. bow C. cow D. blade E. king

22. What does the Chinese character “口” mean in English?

A. end B. sunrise C. sweet D. mouth E. eye

23. What does the Chinese character “中” mean in English?

A. up B. cow C. root D. end E. center

24. What does the Chinese character “爪” mean in English?

A. mountain B. river C. down D. claw E. blade