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The effects of single and dual coded multimedia instructional methods on Chinese character learning

Abstract: This study investigated the effects of single and dual coded instructional methods using computer-based multimedia on Chinese character learning. 42 college students with no prior knowledge of Chinese language were randomly assigned to a single coded group (text-only and animation-only) and a dual coded group (animation plus text and animation plus narration) to learn 12 concrete (pictograph) Chinese characters and 12 abstract (ideograph) Chinese characters. The results showed there was a significant difference between the single coded and the dual coded instructional methods and there was also a main effect in the character type. In addition, the findings indicated that within the single coded group, there was a significant difference between two character types and a significant difference between two single coded methods with the animation-only method leading to better achievement score than the text-only method. For the dual coded group, the results revealed a significant difference between two character types as well and a significant difference between two dual coded methods with the animation plus narration method outperforming the animation plus text method.

Keywords: dual coding, multimedia learning, animation, foreign language, Chinese

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1 Introduction

College students whose native language is English often find learning Chinese a challenging task due to the significant differences between the two writing systems (Everson and Ke 1997). Words in alphabetic languages like English consist of letters governed by grapheme-phonemic correspondence rules, while words in Chinese, which is a logographic language, consist of one or more characters with strokes having no direct sound-to-spelling connection (DeFrancis 1989). Unlike alphabetic writing systems in which symbols represent speech sounds, Chinese

characters are directly linked to the visual and semantic information (Smith 1985). Reading English requires forming connections between graphemes and phonemes, whereas reading Chinese requires recognition of characters as whole visual units (Ehri 2005). Turnage and McGinnies (1973) suggested that the visual aspects of each Chinese character, which indicate the general meaning of the character, are important to help learners to differentiate and identify a character among others. Characters in logographic languages seem to invoke meaning faster than words in an alphabetic language because they carry meaning directly through the shapes of the characters themselves (Biederman and Taso 1979). Ke (1998) discovered that, given enough graphic details in a character to match mental images, the logographic information seems to provide visual context leading to better recall. Although the Chinese writing system has thousands of different characters, only about 400 syllables represent the pronunciations of these characters (Shen 2010). A study by Wang, Cheng, and Chen (2006) indicated that when reading Chinese characters, children relied on understanding the meaning of the syllable along with its visual-orthographic component. These studies suggest that students may benefit from instructional methods incorporating both verbal and visual information of Chinese characters when learning to read Chinese.

Reading is a cognitive process that involves recognizing and interpreting information in written text or other forms (Baddeley 1992). A widely accepted theory for mental representation and processing of information in cognitive tasks is Paivio's (1971, 1990) dual coding theory, which assumes two independent but interconnected systems: one for representing and processing verbal and language units, and the other for nonverbal objects and events. The theory was built on the assumptions of three levels of information processing in memory (Clark and Paivio 1991, Sadoski and Paivio 2001, Paivio 2007): (1) representational processing involves recognizing objects we are familiar with through direct verbal or nonverbal stimuli; (2) associative processing refers to the representations activated by other representations within the same system, such as the word "pet" can activate the words "dog", "cat", etc., or a picture of a football may activate associated pictures of players and a football field; and 3) referential processing means one-to-many or many-to-many referential correspondence between the systems. For example, the word "pet" may activate multiple mental images of dogs and cats, while a picture of zoo may activate multiple words like "animal", "tiger", "bird", etc.

The dual coding theory suggests that information would be processed more efficiently and stored in long term memory more successfully when presented both verbally and visually (i.e., dual coded) rather than when presented either verbally or visually (i.e., single coded) because if one memory trace is lost the other may still be available. This suggestion is supported by the neuropsycholog-

ical evidence of functional asymmetries between the two hemispheres of the human brain and functions served by different areas in each hemisphere (Ley 1983). In general, the left hemisphere is efficient in verbal tasks, such as speech and comprehension, while the right hemisphere shows advantages in nonverbal tasks like recognition of nonverbal sound and spatial patterns (Paivio 1990).

Studies on how concreteness contributes to word recognition (Sadoski, Goetz and Fritz 1993, Jessen et al. 2000, Wang et al. 2010, Welcome et al. 2011, Gullick, Mitra and Coch 2013) support the dual coding theory as well 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 of 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 and te Linde 1982). Jessen et al. (2000) applied functional magnetic resonance imaging (fMRI) in the detection of brain areas related to word processing. Greater activation was observed 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. Shibahara and Lucero-Wagoner (2002) detected greater priming in the right hemisphere for concrete words but same priming as those in the left hemisphere for abstract words, which suggests that abstract words presented to the right hemisphere may be transferred to the left hemisphere which has processing advantages in verbal coding. The findings of Gullick, et al.'s (2013) event-related potential (ERP) study, which measures brain responses to direct stimuli of a sensory, cognitive, or motor event, were in line with the dual coding theory in terms of concrete words benefit from greater activation in both verbal and nonverbal systems.

Dual coded instructions have shown positive effects in both first language and foreign language vocabulary acquisition (Atkinson and Raugh 1975, Cohen and Johnson 2011, Paivio and Desrochers 1979, Sadoski 2005). Cohen (2009) investigated influence of imagery interventions on student's vocabulary learning. Second grade students were randomly assigned to three groups: word-only, word paired with image, and self-generated image. Feedback from the students revealed that being presented a picture or use images they drew on their own helped them to learn the words. Pan and Pan (2009) investigated whether the presence of pictures in text benefits Taiwanese college students studying English as a foreign language (EFL). The results showed that participants in the text-with-picture condition had significantly higher scores on translation tasks than those in the text-only condition.

As computers have a great capability of presenting information in a variety of formats, such as text, picture, audio, and animation through multiple sensory

modalities, dual coded instructions 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 to teach foreign languages is well documented in educational research (Al-Seghayer 2001, Chung 2008, Davis and Lyman-Hager 1997, Levy 1997, Muyskens 1997, Warschauer and Healey 1998). Several studies have revealed that multimedia annotations and animations have positive effects in foreign language vocabulary acquisition (Chuang and Ku 2011, Kuo and Hooper 2004, Lai 1998, Reed and Beveridge 1990, Rieber 1991).

Extending both the dual coding theory (Paivio 1990) and the generative theory of learning (Wittrock 1974), Mayer (1997, 2001) proposed a generative theory of multimedia learning that during multimedia learning, 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 prior knowledge in the long term memory. The auditory channel processes information of spoken words or background sounds while the visual channel processes printed texts, pictures, and animations as shown in Figure 1 (adapted from Chen 2006). Mayer (1997) suggested that verbal and visual contents should be shown simultaneously because learners can only build the referential connections between the mental representations of texts and images when they both are in the working memory. Because learners can only bring a portion of the words or pictures into the working memory at one time given the limited cognitive capacity of each channel (Baddeley 1992), presenting words as speech rather than on-screen text may reduce modality-specific cognitive load (Sweller 1994).

The generative theory of multimedia learning has been applied to foreign language learning (Plass et al. 1998, 2003, Chen 2006) under the assumption that foreign language learners possess two separate verbal systems but share the

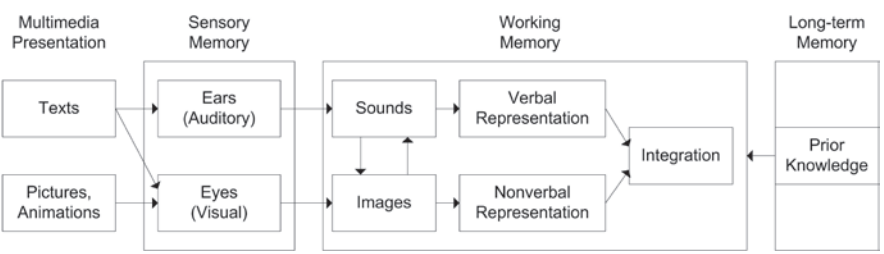

Fig. 1: Information and memory paths in multimedia learning (adapted from Chen, 2006).

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: 26). Plass et al. (2003) studied whether dual-coded instructional multimedia may help English-speaking college students with different verbal and cognitive abilities in a German course. The results showed that participants learned more vocabulary words when both verbal and visual annotations were presented than when only one type of annotation or no annotation was presented. Chen (2006) investigated the effects of multimedia annotations on recall of words by college students learning English as a second language (ESL) who read a text with target words annotated in text-picture or audio-picture and took an immediate recall test. The results indicated that the group with audio-picture annotation performed better than the group with text-picture.

Although a considerable number of studies, as discussed above, have been conducted in learning alphabetic languages, dual coded instructions using multimedia presentations have not been widely developed for vocabulary acquisition of logographic languages like Chinese (Chuang and Ku 2011, Kuo and Hooper 2004, Lai 1998, Sham 2002, Shen 2010). Xie (1997) illustrated the origin and development of six types of Chinese characters: pictographs, ideographs, ideogrammatic compounds, semantic-phonetic compounds, mutual explanatories, and phonetic loans. Pictographs and ideographs are the earliest established types and they often serve as the basic composition of compounds. Pictographs were created by drawing pictures of concrete objects according to their shapes or characteristics, such as 雨 (rain) written as  , representing the rain falling from the sky. Ideographs were originally invented to represent abstract concepts. They can be associated with symbols such as the character 上 (up) which originated from the symbol  , or they can be created by adding an indicating sign to a pictograph, for example, given the pictograph 刀 (knife), the ideograph 刃 was created to represent a knife-edge with the extra stroke to the left indicating the edge. Other types of Chinese characters such as ideogrammatic compounds and semantic-phonetic compounds consist of two or more pictographs or ideographs, together with radicals, the term typically used for a component of a Chinese character (Xie 1997). A radical can be a character or a variation of that character, representing its original meaning in a compound character. For instance, 休 (rest) consists of a radical 亻 derived from 人 (person) and a pictograph 木 (tree), indicating a person resting against a tree.

Given the graphic nature of Chinese characters, researchers have explored the extent to which instructional designs which rely on imagery may offer an advantage in literacy acquisition of Chinese. For example, Chuang and Ku (2011) examined whether dual coded instruction involving animated imagery increased

recognition and retention of Chinese characters by college students. Specifically, the authors presented participants with either animation plus on-screen text or animation plus narration through a computer-based tutorial. No significant differences between the two methods were found using immediate and delayed posttests, a finding which is not in line with the multimedia learning theory (Mayer 2001) that assumes picture and narration should work better than picture and text because both picture and 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. Chuang and Ku (2011) hypothesize that the equal effects of the two methods might be caused by the unitary selection of characters – all the Chinese characters were pictographs that represent concrete physical objects in their study. The study by Kuo and Hooper (2004) investigated the effects of verbal and visual mnemonics on memorizing both concrete and abstract characters by English speakers in a computer-based instructional environment. High school students were randomly assigned to one of five treatment groups: translation, verbal coding, visual coding, dual coding, or self-generated coding, and were given immediate and delayed posttests. The results revealed that the performance of the self-generated coding group was slightly higher than that of the dual coding group, but significantly higher than that of the 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. In Sham's (2002) study, elementary students were randomly assigned into two groups: pictograph characters alone, and pictographs with accompanying pictures. The results indicated that the group without picture achieved better learning outcomes, a finding which is not consistent not consistent with those of other studies (Chuang and Ku 2011, Kuo and Hooper 2004, Shen 2010). Although Sham admitted that the pictographs resembling referential concrete objects should be easier to remember, he argued that the negative effect of pictures could be caused by the modality-specific interference effect (Sweller 1994), that is, "both written Chinese pictographs and pictures share the same modality and are encoded in the imaginal (nonverbal) system in cognition" (Sham 2002: 108). In addition, citing studies on the split-attention effect (Wu and Solman 1993), it was argued that the focus of learning by children might be distracted from the character itself to the accompanying picture.

Besides Chinese characters, Lai (1998) investigated the effectiveness of computer-based static and animated graphics on learning Chinese radicals. Col-

lege students who were native English speakers were randomly assigned to one of the five groups: (1) text with no cue, (2) text with concrete verbal information, (3) text with single static graphic aids, (4) text with gradient static graphic aids, and (5) text with morphing graphic aids. The results from immediate and retention posttests showed significant differences in mean scores between the control group and the four experimental groups. Lai (1998) concluded that concrete verbal information and visual aids facilitated the overall performance of the learner. Meanwhile, the gradient static graphic and morphing through animation conditions helped the learner to achieve better retention.

The effects of verbal and imagery coding in learning Chinese word, which consists of one or more characters, were investigated in Shen's (2010) study. The participants who were college students learning Chinese as a foreign language were randomly assigned to verbal coding group or verbal plus imagery coding group with a concrete word subgroup and an abstract word subgroup in each. The results of immediate and delayed posttests revealed no significant difference between the two instructions in retention of the shape and meaning of concrete words, but found a significant difference for abstract words. Shen (2010) explained that it might due to "the concrete nature of these words, the students recalled mental images of these words that had previously been stored in the students' mental photo albums", which were built from the students' past experiences, and therefore, "during the instruction, when students saw these words, the relevant mental images were activated" (Shen 2010: 496).

In summary, although these studies contributed to the development of instructions for teaching Chinese characters and words, they have some mixed findings and limitations. Both Chuang and Ku's (2011) study and Sham's (2002) study only included concrete characters. They did not include abstract Chinese characters which are more difficult to form mental images. From the perspective of dual coding, concrete words may increase activation of the referential connections between the verbal system and the nonverbal (imagery) system (Jessen et al. 2000). In particular, the split attention effect Sham (2002) discussed may not apply to adult learners. Kuo and Hooper (2004) investigated both concrete and abstract Chinese characters but did not address how to ensure that the selected concrete and abstract Chinese characters were comparable. The number of strokes in their selected abstract characters was larger than those in concrete characters, which may introduce more complexity and a heavier cognitive load. Although the findings by Lai (1998) were consistent with the dual coding theory, the learning time was not controlled in his study since participants in the gradient static graphic group and the morphing graphic group spent much more time than other groups. In addition, Shen (2010) and Sham (2002) did not use computer-based multimedia in their instructional methods.

The present study aims to fill these gaps in the literature by addressing the following research questions using multimedia single coded and dual coded multimedia instructions with both concrete and abstract Chinese characters:

1. Generally, which instructional method works better on Chinese character learning, single coded or dual coded?
2. Does Chinese character learning effect vary with character type (pictographs or ideographs) in different instructional method (single or dual)?
3. Does Chinese character learning effect vary with character type (pictographs or ideographs) in different single coded instructional method (animation only or text only)?
4. Does Chinese character learning effect vary with character type (pictographs or ideographs) in different dual coded instructional method (animation plus text or animation plus narration)?

2 Methodology

2.1 Character selection

The target characters in this study include a total of 24 characters with 12 pictographs and 12 ideographs. As pictographs symbolize concrete objects and ideographs represent abstract ideas, including both fundamental types of characters addresses one concerns listed in previous studies which will allow the development of more generalizable findings that may be applied to the instruction of other logographic languages. Valuable implications for teaching compound Chinese characters based on these two types of fundamental characters may also be achieved. To ensure the cognitive complexity of the selected pictographs and ideographs are comparable to each other and suitable for beginning learners who have no prior knowledge of Chinese, three criteria were specified in the selection: (1) all the pictographs and ideographs must be 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 must be similar, (3) the meanings of all the target characters should be easy to be represented with animated pictures.

2.2 Participants

After receiving approval from the Institutional Review Board, 44 native English-speaking undergraduate students from a southern state of the United States were

recruited. Students completed a screening test that included the following yes-no questions:

1. Have you ever tried to learn Chinese or enrolled in Chinese language classes?
2. Are you at all familiar with the Chinese writing characters?
3. Are you familiar with any Chinese pictographs?
4. Are you familiar with any Chinese ideographs?
5. Are you familiar with the writing system of any of the following languages: Japanese, Korean, or Vietnamese?

Students who answered "yes" to any screening question were excluded from the study due to prior knowledge about Chinese to avoid confounding results. After screening, 42 qualified students volunteered to participate in the study, and consent was obtained.

2.3 Instruments

The instruments used in this study include two computer-based Chinese character learning tutorials, one for the single coded condition and the other for the dual coded condition, and a content-related posttest. The tutorials were developed by a computer science professor.

The single coded condition tutorial displayed 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. Figure 2 and Figure 3 show subgroup examples of the single coded condition.

The dual coded condition tutorial displayed 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 headphone only. The narration was played twice and synchronized with the animation. Figure 4 and Figure 5 show subgroup examples of the dual coded condition.

Each picture was drawn by a Chinese artist who understood the purpose of the study, and was converted to the vector format in Adobe Illustrator. The animation was created by decomposing the picture to multiple layers in Adobe Flash to

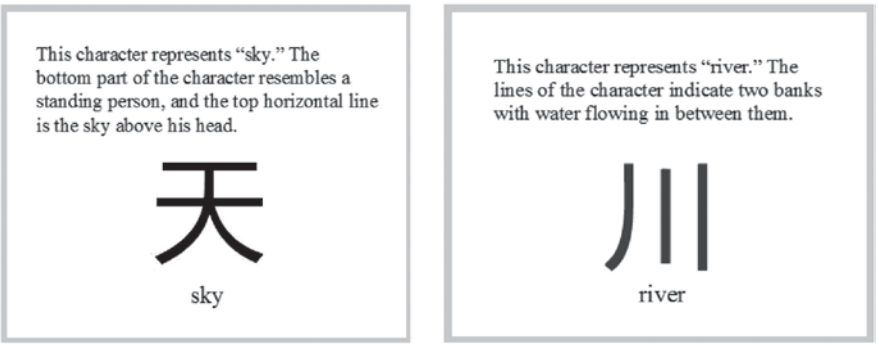

Fig. 2: Text-only instructions in the single coded condition.

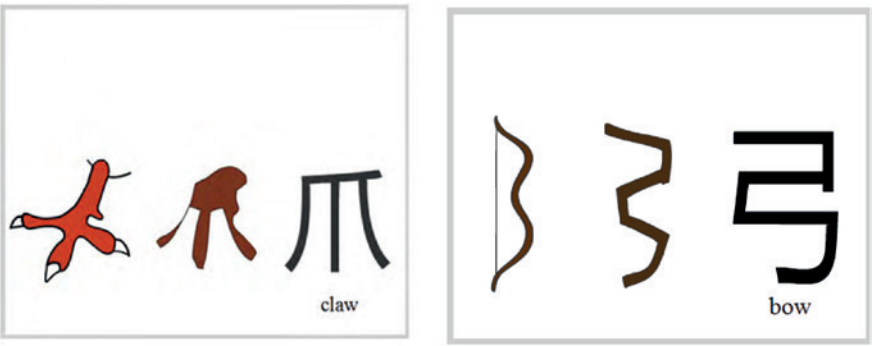

Fig. 3: Animation-only instructions in the single coded condition.

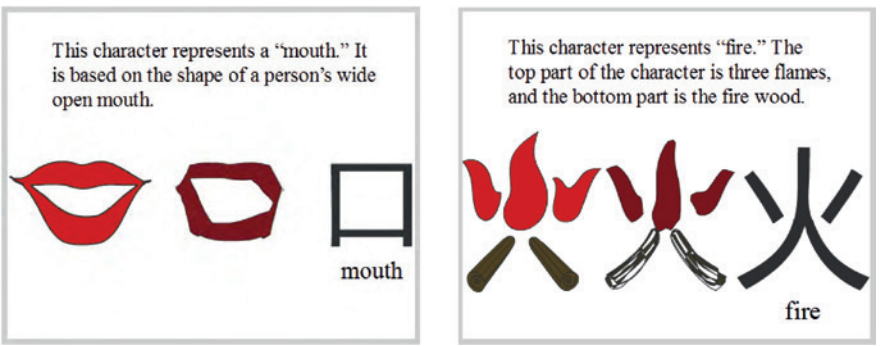

Fig. 4: Animation plus text instructions in the dual coded group.

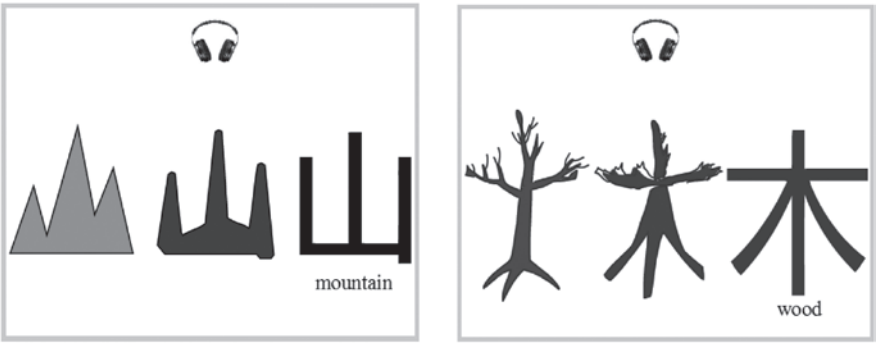

Fig. 5: Animation plus narration instructions in the dual coded group.

match corresponding components in a character. The tutorials were implemented with HTML and JavaScript. The content-based posttest was composed of 24 multiple-choice questions, with one point awarded for each correct answer. The following are some examples:

What does the Chinese character 火 mean in English?
A. fire B. wood C. river D. eye E. sky
What does the Chinese character 川 mean in English?
A. three B. wood C. claw D. center E. river
What does the Chinese character 木 mean in English?
A. root B. cow C. end D. wood E. sky

2.4 Procedures

After the participants signed the consent form, they were randomly assigned to either the single coded group or the dual coded group. Within each group, every participant was assigned a number from 1 to 21. As both groups included two subgroup methods, the orders of the two subgroup methods were counterbalanced to control the order effects. For example, in the single coded group, participants with odd numbers received the text only method first followed by animation only method, while participants with even numbers received the animation only method first followed by the text only method. The participants in the dual coded group were also counterbalanced in this manner.

The participants opened a web browser to load the tutorial directions page of their designated condition. The tutorial began with an example page explaining

the information that would be presented in the instruction of each character under the subgroup method. When the participant was ready, he or she clicked on the "Start" button. The tutorial moved automatically from character to character to ensure each participant spent an equal amount of time in each method. The presentation time for each Chinese character was 15 seconds. When characters displayed in the first subgroup method were finished, an example page of the second subgroup method was displayed. When the participants were ready to begin the next instructional set, they clicked on the "Continue" button. Participants in the dual coded group were prompted to put on headphones before the start of the animation plus narration instruction.

After finishing the tutorial, the participants took the computer-based posttest. They clicked on the "Submit" button in the end, and the test scores were automatically collected and saved in an electronic output file.

3 Data analyses and results

42 participants participated in this study, with 21 in each group learning all 24 characters (12 pictographs and 12 ideographs). An independent groups *t* test was used to analyze the first research question, i.e., whether dual-coded instructional methods led to better Chinese character learning effects than single-coded instructional methods. The instructional method (single or dual) was the independent variable, and posttest scores that represent learning achievement was the dependent variable. The results showed that there was a significant difference between the single coded and the dual coded instructional methods, $t(40) = -4.888$, $p < .002$, with the performance of the dual coded methods better than that of the single coded methods. For the single coded group, the mean score was 19.24 and the standard deviation was 2.256, while for the dual coded group, the mean score was 22.05 and the standard deviation was 1.359. In summary, the result of the *t* test suggested that the participants who received dual coded instruction generally performed significantly better than those who received single coded instruction.

For research question 2, a 2 (between group instructional method) × 2 (character type) repeated measured ANOVA mixed model was conducted to analyze whether learning achievement varies significantly between the two character types (pictographs or ideographs) in the two different instructional methods (single-coded or dual-coded). The instructional method was a between-subject factor as the participants were assigned into either the single coded condition or the dual coded condition. The character type was a within-subject factor as the participants learned both types of characters (pictographs and ideographs). The

Table 1: Descriptive statistics of scores for pictographs vs. ideographs in single coded vs. dual coded conditions

Character Type	Between Group Method	Mean	Std. Deviation	*N*
Pictogragh	Single coded	10.19	1.209	21
	Dual coded	11.38	.669	21
	Total	10.79	1.138	42
Ideograph	Single coded	9.05	1.499	21
	Dual coded	10.67	1.197	21
	Total	9.86	1.571	42

results indicated there was no interaction between instructional method (single coded or dual coded) and character type (pictographs or ideographs), $F(1, 40) = .909$, $p = .346$, but there were main effects in both the instructional method, $F(1, 40) = 23.892$, $p < .001$, and the character type, $F(1, 40) = 17.071$, $p < .001$, which indicated both the factors of the instructional method and the character type significantly influenced the achievement of learning Chinese characters. Table 1 shows descriptive statistics of the achievement scores for pictographs vs. ideographs in single coded vs. dual coded conditions.

Table 1 and the estimated marginal means in Figure 6 revealed that (1) the average scores for pictographs were greater than those for ideographs in both the single coded condition (10.19 > 9.05) and dual coded condition (11.38 > 10.67), and (2) the average scores in the dual coded condition were greater than those in the single coded condition for both pictographs (11.38 > 10.19) and ideographs (10.67 > 9.05).

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.

A2 (single coded instructional method) × 2 (character type) repeated measured ANOVA was conducted for research question 3 which investigated whether learning achievement varies between the character types (pictographs vs. ideographs) in the two different single coded conditions (animation only vs. text only). In the single coded condition, the participants learned 12 characters (6 pictographs and 6 ideographs) with text-only method and the other 12 characters (6 pictographs and 6 ideographs) with animation-only method. Therefore, character type and specific single coded method are within-subject factors. The results indicated a significant difference between the two single coded methods, $F(1, 20) = 16.716$, $p < .001$, indicating the participants' performance depended on

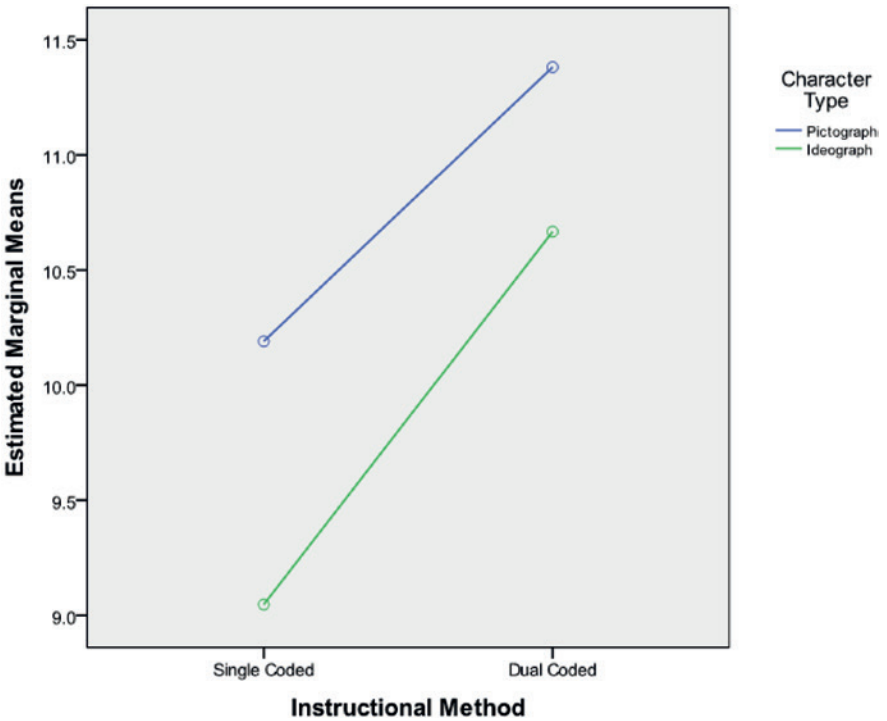

Fig. 6: Estimated marginal means for character types in different conditions.

which specific single coded instructional method was used, and a significant difference between the two character types, $F(1, 20) = 12.308$, $p < .002$, indicating the achievement scores were also affected by which type of character was learned. However, there was no interaction between the single coded instructional methods and the character types, $F(1, 20) = 1.298$, $p = .268$, which suggested the learning effect of a specific single coded method does not depends on which type of character is learned. The descriptive statistics in Table 2 and the estimated marginal means in Figure 7 indicate that (1) the average scores for pictographs were greater than those for ideographs with both text-only method (4.86 > 4.19) and animation-only method (5.33 > 5.05), and (2) the average scores using the animation-only method were greater than those using text-only method for both pictographs (5.33 > 4.86) and ideographs (5.05 > 4.19).

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 does not depend on which type of character is learned.

Table 2: Descriptive statistics of scores for pictographs vs. ideographs in the single coded condition

Within Group Method	Character Type	Mean	Std. Deviation	*N*
Text-only	Pictograph	4.86	.854	21
	Ideograph	4.19	.873	21
Animation-only	Pictograph	5.33	.658	21
	Ideograph	5.05	.865	21

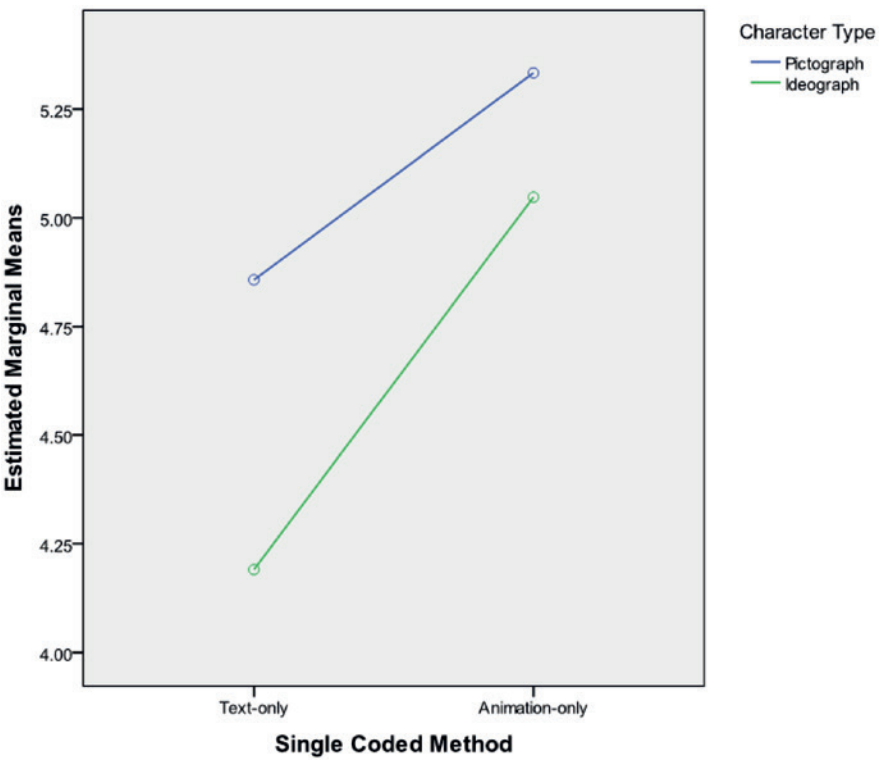

Fig. 7: Estimated marginal means for character types with singled coded methods.

For research question 4, a 2 (dual coded instructional method) × 2 (character type) repeated measured ANOVA was conducted to analyze which dual coded method (animation plus text vs. animation plus narration) is superior for learning different character types (pictographs vs. ideographs). The within-subject factors were character type and specific dual coded method. The results of this

Table 3: Descriptive statistics of scores for pictographs vs. ideographs in the dual coded condition

Within Group Method	Character Type	Mean	Std. Deviation	*N*
Animation plus Text	Pictograph	5.52	.512	21
	Ideograph	5.05	.865	21
Animation plus narration	Pictograph	5.86	.359	21
	Ideograph	5.62	.590	21

analysis also indicated a significant difference between the two dual coded methods, $F(1, 20) = 17.356$, $p < .001$, indicating which specific dual coded instructional method is adopted significantly influences the participants' learning performance, and a significant difference between the two character types, $F(1, 20) = 5.597$, $p < .028$, suggesting the character type is also a factor that can significantly affect the participants' learning achievement scores. No interaction was found between the two dual coded methods and the character types, $F(1, 20) = .298$, $p = .329$. The descriptive statistics in Table 3 and the estimated marginal means in Figure 8 indicate that (1) the average scores for pictographs were greater than those for ideographs using both animation plus text method (5.52 > 5.05) and animation plus narration method (5.86 > 5.62), and (2) the average scores using the animation plus text method were greater than those using animation plus narration method for both pictographs (5.86 > 5.52) and ideographs (5.62 > 5.05).

To summarize, these results suggest that the animation plus narration method worked significantly better than the animation plus text method on both pictograph and ideograph learning, and pictograph learning results were better than ideograph learning results under both dual-coded method conditions.

4 Discussion

4.1 Research findings

The first research question addressed whether the single and dual coded instructional methods have different influences on the acquisition of Chinese characters. The results demonstrated that instructional methods encoded with both verbal (text or narration) and visual information (animation) worked better than single coded instructional methods. 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 pro-

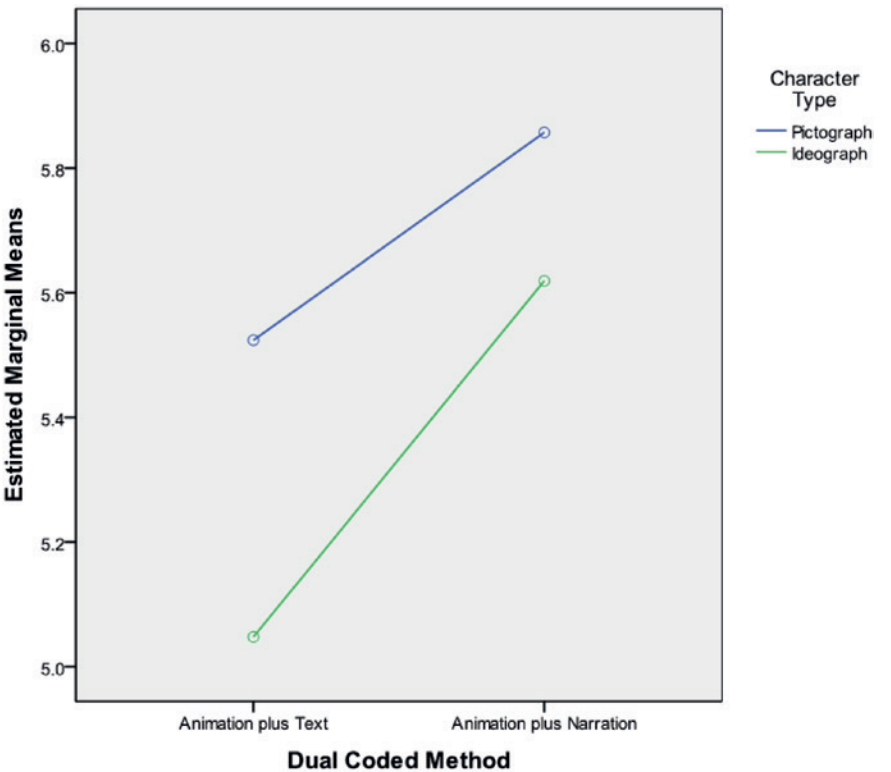

Fig. 8: Estimated marginal means for character types with dual coded methods.

cessed, 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 and Ku 2011, Kuo and Hooper 2004, Plass et al. 2003). The average achievement scores from the dual coded group which were 22.05 out of 24 (92%) were comparable to those reported in a recent study (Chuang and Ku 2011), which were 16.00 out of 19 (84%) for the dual coded groups in the immediate posttest, although their study involved pictographs only.

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. The results revealed that 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 consistent with results from studies on character concreteness (Kuo and Hooper 2004) and word concreteness (Sadoski, Goetz and Fritz 1993, Shen 2010), which suggest that it is easier to establish referential connection between an image and a concrete character or word than an abstract character. An interesting finding in this study was that the average score for ideographs increased by 1.52 from single coded methods (9.05) to dual coded methods (10.67), which was greater than the improvement on the average score for pictographs 1.19 from single coded methods (10.19) to dual coded methods (11.38). This finding suggests that dual coded methods may contribute more to learning ideographs than pictographs.

The third research question was to examine whether different single coded instructional methods (animation-only vs. text-only) influence the learning of the two different types of Chinese characters (pictographs vs. ideographs). The results demonstrated that the learners achieved better scores with the animation-only method than those with the text-only method, which indicated that because of the pictorial property of Chinese characters, 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. In addition, 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 consistent with those from previous studies which have shown that concrete words are more likely to activate a referential association between the images and words compared to abstract words (Sadoski and Paivio 2001).

For dual coded instructional methods studied in the fourth research question, the results showed that participants in the animation plus narration method performed better than participants in the animation plus text method, a finding that is in line with the study by Chen (2006) in which the group with audio-picture annotation performed better than the group with text-picture. In our study, the animation plus narration method played the narration simultaneously with the animation. This approach was supported by the generative theory of multimedia learning (Mayer 1997) which argues that when the verbal information was input through the audio channel (narration) instead of visual channel (printed text), and was presented at the same time with the visual information (image, animation), it should reduce the cognitive load of each channel and may achieve better

learning effects. In addition, the animation plus narration was more effective than animation plus text for both pictographs and ideographs, which was not found in the study that only investigated the effectiveness of the dual coded multimedia instructions on pictographs (Chuang and Ku 2011).

The marginal means within both the single coded group and the dual coded group as shown in Table 2 and Table 3 revealed another interesting pattern. Learning of pictographs improved gradually from one condition to the next, i.e. text only (4.86), animation only (5.33), animation plus text (5.52), and animation plus narration (5.86). By contrast, the participants' performance on ideographs shows no difference in the two middle conditions and improves much more between text only and animation plus narration than is the case for pictographs, i.e. text only (4.19), animation only (5.05), animation plus text (5.05), and animation plus narration (5.62). In addition, the average score for ideographs improved by 0.86 from text-only (4.19) to animation-only (5.05), while the average score for the pictographs improved by 0.47 from text-only (4.86) to animation-only (5.33). This finding suggests that learning ideographs may benefit more from a method involving animation possibly because it contributes to building a referential connection between an image and an abstract character.

In addition, in contrast to Chuang and Ku's (2011) study that employed an approach of overlaying the character on top of the single picture and Lai's (1998) study that created a fade-in fade-out effect with four images to show the evolution from the original picture into the character, the animation implemented in this study had a rate of 15 frames per second, which provided many more details about the transition from the image to the character. In addition, the morphing from the image to the character was created by matching a specific part of the image to the corresponding structure of the character. This approach significantly enhanced the visual effects which might contribute to the effectiveness of the methods involving animation in this study, i.e., animation-only, animation plus text, animation plus narration, compared with the single coded text-only method.

4.2 Instructional implications

This study has important implications in the development of instructional methods for teaching Chinese characters. Since dual coded instructional methods which contain both verbal and visual information generally work better than single coded instructional methods in teaching Chinese characters, either concrete types, like pictographs, or abstract types, such as ideographs, Chinese instructors can guide students to analyze the target Chinese characters from both verbal and nonverbal perspectives. For instance, they may provide an original picture of the

pictograph to accompany the text explanation of the meaning so that the information is dual coded. As using self-generated mnemonics has been reported to be effective on learning concrete Chinese characters (Kuo and Hooper 2004), if a picture is not immediately available, the instructors may also encourage students to observe the target modern concrete Chinese character and free their imagination to create mental images that can represent the original image on which this character is based.

Although it would be more difficult to connect an image to an ideograph, a well-designed dual coded instruction involving animation would help the learner to establish the referential connection between the image and the character. Chinese instructors may consider teaching Chinese characters in a computer-based learning environment so that it is easier for students to access resources related to computer animations. For example, they may develop computer-based animations that reveal the transition between the picture from which a Chinese character was originated and the modern form of the target character and, in addition to the verbal (text) description of the target character, let the students observe the morphing process through a number of transitional images. This way, the dual coded information through both text and animation may help the students' long term retention of the meaning of the character. For example, the abstract ideograph 刃, which means blade, can be taught based on the animation of the character 刀, which mean knife, by transforming the extra stroke to the left to a notch on the edge of the knife to indicate it represents the blade.

In addition, the animation-based dual coded instructional methods have great potential to teach compound Chinese characters which are combination of simple pictographs and ideographs. Because a compound character is usually taught after students have learned each component (pictograph or ideograph) in the character, Chinese instructors may develop or reuse the animations for individual components appeared in a compound character and merge the animation process to help the students capture the semantics in the compound character. For example, if an animation is developed for a associative compound character 明 which means bright and it consists of two pictographs 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."

Furthermore, this study has revealed that, regardless of character type, the instructional method using animation plus narration works better than animation plus text when the animation and narration are appropriately synchronized

as designed in this study. Chinese instructors who have access to multimedia environments should create opportunities for students to process the target information through both visual and auditory channels, such as presenting computer animation as visual information together with the description of the character's etymology in audio 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 may still apply this principle to their daily teaching practice by presenting students the visual information (e.g., pictures) while providing related explanations orally so that both input channels and working memories are activated.

5 Conclusion

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 based on the Dual Coding Theory which suggests that both mental systems, verbal and nonverbal, are involved in processing linguistic units. The results revealed that the dual coded methods (the animation plus text method and the animation plus narration method) were more effective than the single coded methods (the text only method and the animation only method) for both concrete characters (pictographs) and abstract characters (ideographs).

In addition, 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. These findings suggest that well-designed computer animations may significantly enhance the learning of both concrete and abstract Chinese characters, and they may provide more help 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 instructors should consider both linguistic and visual information 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.

The current study measured learning by means of an immediate recall posttest only which is sufficient for measuring character recognition, but it did not include a delayed posttest to investigate the effectiveness on the long-term learning retention. Future studies 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. Another factor to look into is the learners' prior spatial ability to connect a verbal representation to a visual representation of an object, which can be measured by the Purdue Visualization of Rotation Test (Bodner and McMillen 1986). This test has been used in related studies (Lai 1998, Plass et al. 2003). For example, when participants received visual annotations for vocabulary words, low-spatial ability students recalled fewer words than high-spatial ability students because, the authors argued, "do not have sufficient cognitive resources to process the visual information and build referential connections and therefore experience deleterious effects" (Plass et al. 2003: 233).

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Appendix

Twenty four Chinese characters used in this study

Pictographs (3–5 strokes)		Ideographs (3–5 strokes)	
Text only and Text plus Animation			
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)
Animation only and Animation plus Narration			
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)

Bionote

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