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Ellyn L. Arwood

University of Portland, arwood@up.edu

Carol X. Lam

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Using Neuroeducation as a Model to Evaluate the Effect of Imagery on Chinese Character Writing

Carol X. Lam, Ellyn L. Arwood

University of Portland School of Education, Portland, Oregon, USA

Using imagery as a strategy for language learning may be helpful to encode linguistic forms into conceptual networks for long-term memory. Based on Arwood's neuroeducation model of language learning, this research evaluated the effect of imagery in Chinese character writing by English-speaking adolescent students. After comparing imagery effects under three instructional conditions (i.e., English translation, pictorial presentation, and verbal-contextual interpretation), the results showed that the use of imagery predicted significantly better writing results in the immediate and one-week writing tests, but not in the four-week writing test. Cognitive analyses found that imagery was commonly used as a mediational strategy in the pictorial and verbal-contextual methods in the early learning phases. The pictorial method mainly elicited perceptual visual patterns which failed to support sustained memory. For a better character encoding and retrieval, images had to be generated associated with sufficient and relevant contextual information.

Keywords: imagery, neuroeducation, Chinese character writing, memory, mediational strategy

Introduction

The Chinese language uses a logographic writing system with characters and components originated from images of living and non-living things. Therefore, using pictures or physical images to increase students' semantic knowledge of the character, including the underlying meaning of character components and spatial configurations (Lam, 2016; Weekes, YIN, SU, & CHEN, 2006), has been considered a fundamental method in character learning (see GU, 2006; TAN, 1998; WANG & ZHENG, 2005). However, it is unknown whether and in what conditions physical images can be converted into students' mental images (referring only to visual images) aligned with character forms. It is also not clear to what degree mental images of character meaning mapped with character forms can help with character learning. The researchers aimed to investigate the effects of visual imagery in character encoding and retrieval in an instruction-differentiated character writing study on learners of Chinese as a foreign language (CFL).

Previous research in the imagery strategy of character learning hardly analyzed cognitive processes and underlying mechanisms of this mental function (e.g., KUO & Hooper, 2004; WANG & Thomas, 1992). Current psycho-neural studies and theories in imagery have provided insightful data for analyzing the imagery process. However, scholarly attempts to translate psychological and neuroscience findings into classroom practices are rare. Arwood (2014; 2017) suggested a neuroeducation model for the study of language

Carol X. Lam, assistant researcher, Ed. D., University of Portland, Portland, Oregon, USA.

Ellyn L. Arwood, professor, Ed. D., University of Portland School of Education, Portland, Oregon, USA.

acquisition. The model emphasizes triangulation of the literature from relevant findings in cognitive psychology of the mind, neuroscience of the brain, and language theories to study language learning as a cognitive function. The interface of the three areas can be taken as the method of analysis for focused studies on the cognitive process in a language learning task (Lam, 2017). This research features one theory, the Neuro-Semantic Language Learning Theory (NsLLT) (Arwood, 2011), which was developed based on the neuroeducation model to translate scientific findings into language learning classrooms. NsLLT has been extensively used as a method of analysis in language acquisition research beyond language levels and types, including special education (e.g., Duffett, 2016), English literacy (e.g., Robb, 2016), and Chinese as a foreign language (e.g., Lam, 2016).

This research follows the neuroeducation model. Along with relevant findings in the studies of imagery, language, and memory in cognitive psychology and neuroscience, the researchers sought the rationale from the NsLLT for analyzing the cognitive underpinnings of the writing results in the current research. Other writing-related cognitive processes, such as spatial and motor cognition, were not included in this research.

Review of the Literature

Psychological Theories in Visual Imagery and Perception

Visual imagery can be easily confused with visual perception (see Belardinelli, Palmiero, & Di Matteo, 2011; Kosslyn & Thomson, 2003). As this research involved both visual perception and imagery, it is pertinent hereto differentiate the two processes. To put it simply, perceiving an object is to physically see it, while visual imagery is the mental visualization of previously memorized patterns (Enns, 2004; Kosslyn, 1994; Mazard, Laou, Joliot, & Mellet, 2005). As evidenced in a number of studies, while there is considerable overlap between the two processes, distinct activity patterns have been found at various levels in the brain (see Behrmann, 2000; Belardinelli, Palmiero, & Di Matteo, 2011). There is ongoing debate over the format of visual imagery in relationship to perception. The debate is around two prominent theories: the perceptual theory and propositional theory.

The perceptual theory postulates that imagery representations preserve key aspects of pictures perceived (e.g., Kosslyn, 1980). Some research results in the early visual areas are consistent with this theory. Imaging studies showed that the visual perceptual regions of the brain were active when participants were engaged in mental imagery (Anderson, 2010; Enns, 2004; O' Craven & Kanwisher, 2000). The imagery systems can reproduce many of the detailed visual contents as perceived by the eyes (e.g., Chambers & Reisberg, 1985; Finke, 1989; Wimmer, Maras, Robinson, & Thomas, 2016). Kosslyn and Thomapson (2003) argued that it is because early visual areas specialized for high-resolution details were involved in the imagery process, supporting the pictorial representation of visual imagery. Comparative studies of the perceptual and imagery processes revealed that activities in the early visual areas were much stronger during perception than during imagery (see Ganis, Thomson, & Kosslyn, 2004; Mazard et. al, 2005). The results of these studies are likely to reflect that visual perception produces higher visual resolution and detailed contents than visual imagery.

The propositional theory posits that visual representations are by no means pictorial, but rather rely on abstract symbols or codes used in language (e.g., Pylyshyn, 1973; 2002; 2003). According to this theory, to generate visual images, higher-level processing is required to recruit brain areas overlapping with the language circuitry (Kosslyn & Thomapson, 2003). Evidence was shown in several neuroimaging studies, indicating that semantic representations, or at least some verbal components, are implicated in the imagery process (Mazard et

al., 2005; Olivetti Belardinelli et al., 2009). For example, Mazard et al. (2005) found that imagery elicited significantly stronger activation in the left inferior frontal (important for verbal comprehension and production) and left inferior temporal gyrus (responsible for visual object recognition) than perceptual processes. It might be that visual imagery produced semantic representations, or vice versa, which access visual information (including faces or words) stored in long-term memory (Kosslyn, 1994). The propositional theory is consistent with the report that mental manipulation of an object is harder than processing physical pictures of an identical object, presumably due to cognitive load from extensive brain areas that require more top-down projections (see Klemen & Chambers, 2012; Olivetti Belardinelli et al., 2009; Wimmer et al., 2016).

While the debate over the format of visual imagery continues, the imagery function has long been studied in an array of psychological and language research, such as in memory tasks (e.g., Berger & Gaunitz, 1979; Lam, 2016; WANG & Thomas, 1992). The research on the mediational role of imagery in associative learning and memory can be traced back to earlier psychological studies (e.g., Bower, 1970; Paivio, 1969). In an imagery mediation study in English-Russian word association, Atkinson and Raugh (1975) found that English-speaking participants learned significantly more meaning-word associations via mental images, with the memory sustaining up to six weeks later. This study suggests that visual imagery may help with long-term memory for information retention. However, previous research showed that the ability in making visual images varied among individuals (see Arwood, 2011). Not everyone, but good imagers, can use imagery as a strategy for memory tasks (Keogh & Pearson, 2011). Using images as a mnemonic technique also has yielded different results in Chinese character learning. For example, in one study, picture mnemonics yielded superior effects in character learning (see Luk & Bialystok, 2005). Nevertheless, WANG and Thomas's (1992) research on Chinese character learning found that mnemonic images must be learner-generated. Perceived images only showed immediate benefits.

Altogether, the perceptual and propositional theories of imagery, though still controversial, can both find evidence from neuroimaging research. These findings support a distributive model of imagery function which appears to represent at multilevel brain regions, depending on individual imagers, image tasks, and methods of experiment (see D'Esposito et al., 1997). The overlap of visual imagery with the language and visual perceptual systems has drawn sustained interests from educational and psychological researchers in the mediational function of imagery for language learning and memory. The results have not reached a consensus.

Neuroscience Findings in the Mechanisms of Imagery

Recent neurophysiological and imaging research in imagery has started to shed light on underlying mechanisms of this function. Some findings in neuronal object generation and maintenance are likely to share the same mechanisms of student-interpreted character meanings and structures represented in the format of visual images.

Among the limited data on the neuronal object generation and maintenance (e.g., D'Esposito et al., 1997; Kosslyn, 1994; Mazard et al., 2005; Olivetti Belardinelli et al., 2009), research from the brain lesion studies has generally supported the coexistence of two pathways for imagery processing. These are the parietal pathway (known as the dorsal pathway) for spatial representation (e.g., Driver & Mattingley, 1998) and the temporal pathway (known as the ventral pathway) for processing visual properties of objects, such as size, shape, color, etc., (see Anderson, 2010; Goodale, Milner, Jakobson, & Carey, 1991). These two pathways converge with Chinese character learning for recognizing character components and their spatial arrangements, as many of the

components and their configurations represent the objects or scenes experienced in daily life. Both the pathways contribute to visual image generation and maintenance.

In line with the perceptual theory mentioned earlier, visual images are believed to be generated from the stored visual sensory information of objects or scenes loaded onto a short-term memory to produce percept-like images (Farah, 1995; Zull, 2011). In neurophysiological studies, the process is studied together with the mechanisms of visual working memory (VWM). Keogh and Pearson (2011) argued that visual imagery is a component of VWM. Their research found that the performance of VWM can be predicted by the strength of visual imagery. As to the neural substrates responsible for image generation, scores of neurophysiological and imaging studies pointed to the temporal-occipital visual association cortex, asymmetrically localized to the left hemisphere in a majority of study cases (e.g., D'Esposito et al., 1997; Farah, 1995; Farah, Weisberg, Monheit, & Peronnet, 1989). This is also consistent with the propositional theory mentioned above as the localization of imagery generation overlaps with the verbal language systems.

For sensory information to be maintained for cognitive operations in the VWM system, a distributed cortical network was found from frontal, parietal, occipital, to temporal areas (Ganis et al., 2004; J. M. Palva, Monto, Kulashekhar, & S. Palva, 2010; Pessoa, Gutierrez, Bandettini, & Ungerleider, 2002), depending on specific tasks and individual diversities. Research results suggested that an inter-areal phase synchrony in the α -, β -, and γ - frequency bands may be a mechanism for the maintenance of VWM (Palva et al., 2010), including the maintenance of object representations (Curtis & D'Esposito, 2003). Synchronization modulates neuronal interaction and regulates network communication (Singer, 2009; Womelsdorf, 2007). It was found that synchronous activities were strengthened with increasing memory load among the frontal-parietal regions which underlie executive and attentional functions during memory maintenance (Ganis et al., 2004; Palva et al., 2010). However, VWM may not require more cognitive resources to process larger units of information. Luck and Vogel's (1997) research showed that VWM processes integrated objects rather than individual features. In other words, to integrate individual features (e.g., stroke images) into coherent objects (e.g., component images) can lead to potentially less cognitive load and improved memory as the objects are encoded in long-term memory systems (see Belardinelli et al., 2011; Kosslyn, 1994).

The major concern of the present research was on the process of visual images of objects (i.e., referents) to relate to language structures for functional use (i.e., character writing in this research). To gain insights into the relationships between images and language learning, the researchers, as previously mentioned, anchored in the NsLLT to use it as the rationale of the current research.

The Neuro-Semantic Language Learning Theory

The Neuro-Semantic Language Learning Theory (NsLLT) emphasizes language functions for use of the language in communication, which means to place the acquisition of meanings or concepts before language structures (Lam, 2016; 2017). The theory proposes a neurobiological hierarchy of four levels in the acquisition process: sensory inputs (Level 1), perceptual patterns (Level 2), conceptual circuits (Level 3), and neuro-semantic networks (i.e., language, Level 4; Arwood, 2011). There are increasing meaning levels along the hierarchy. This aligns with the neurophysiological and imaging findings in a progressive-and-bidirectional view of meaning representation (e.g., Clarke & Tyler, 2014; Gainotti, Ciaraffa, Silveri, & Marra, 2009; Poldrack et al., 1999). This view recognizes a feed-forward projection of signals from primary sensory cortexes to higher-level integration regions for information processing, but for conceptual activities (e.g., NsLLT, Level

3) to take place, there must be abundant top-down projections (see Klemen & Chambers, 2012). In other words, conceptual learning involves synchronous activities among neurons in the early and higher-level cortices to form semantic circuits and networks that recognize new inputs to be encoded within the system. It is these network-wide connections among neurons that create accessible long-term semantic memory (Squire, 1987).

Arwood (2011) maintained that images are concepts or signs in relationship to the referents. Conceptual meanings are created through layers of perceptual patterns (i.e., NsLLT, Level 2), such as auditory or visual patterns, within cerebral circuits that form images (i.e., NsLLT, Level 3). Images then integrate across multi-modal networks for language use (i.e., NsLLT, Level 4). Language structures ought to be encoded into conceptual networks for meaningful encoding and retrieval. When new inputs are recognized by the existing networks, the learner's conceptual systems are refined and adapted to the new messages; and thus, creating linkages for later recall (Zull, 2011). It is at the fourth level that concepts or images can be flexibly displaced, transformed, and used in various contexts (Arwood, 1991; 2011).

However, as mentioned previously, integrating sensory inputs into images or concepts varies across individuals, circumstances, and cultures. The process can be difficult especially when new messages are incongruent to the learner's acquired semantic systems (see Gainotti et al., 2009; Heikkila, Alho, Hyvonen, & Tiippana, 2015); for example, when many Chinese characters do not correspond to the learner's knowledge of the world. Neuroimaging research showed that incongruent meaning between visual and auditory signals resulted in the failure of signal integration (see Doehrmann & Naumer, 2008). This evidence can further justify the assumption that the incongruence between existing knowledge and new messages affects the success of meaning-structure integration. For a successful image integration in language learning, Arwood, Kaulitz, and Brown (2009) argued that images need to be supported by language to provide contexts and access points for increased meaning, memory access, and higher-level thinking (i.e., NsLLT, Levels 3 & 4), thereby enhancing the ability in the use of the language.

The Present Study

In view of the mediational function of imagery and its possible limitations, the researchers investigated the effects of visual imagery strategy in the encoding and retrieval of Chinese characters. Quantitative and qualitative data, collected from image making questionnaires and handwriting of new characters, were compared among three instructional methods across three phases. The three instructional methods were: (1) characters presented with English translation (i.e., English); (2) characters presented with pictorial presentation (i.e., pictorial); and (3) characters explained via verbal-contextual instruction (i.e., verbal).

The primary hypothesis for this study was that the CFL learner's ability to use the imagery strategy to learn character-denoted meanings should predict better performance in character writing. Based on the hypothesis, the researchers sought to answer two research questions: (1) Did the pictorial method produce better writing performance than the other two instructional methods? (2) Did the participants' imagery strategy affect writing performance?

Methods

Participants. The participants were recruited from a northwest public high school in America. All the participants were native English speakers, taking Mandarin as an elective class in the 1st, 2nd, or 3rd year. The study was conducted as an in-class project. The participants completed a demographic and Chinese background

questionnaire. Those whose heritage language was Chinese were excluded. At the end, 51 participants took part in the study upon signed consent; 48 participants (ages = 14-17; female = 22; male = 26) completed three phases, so only the data from these participants were analyzed. All the participants received project credits.

Materials. Thirty new characters which did not appear in the participants' curriculum book were selected from five Chinese character picture books (GU, 2006; A. Matthews & L. Matthews, 2007; TAN, 1998; WANG & ZHENG, 2005; ZHANG, 2005). The characters were either integral ideographs or left-right compounds. All the selected characters met two conditions: (1) stroke numbers ranged from four to eight, matching the participants' reading level of Chinese (LU, 2011); and (2) English translation was at a medium frequency range from 1,000 to 10,000 frequency count (Brysbaert & New, 2009; CHANG, Stafura, Rickles, CHEN, & Perfetti, 2014). A database of the 30 characters, including their English translation, verbal interpretation, and pictorial illustration, was created.

Instruments. The Image Making by Teaching Method (IMTM) questionnaire was designed based on Wyra, Lawson, and Hungi's (2007) Ability to Make Images Questionnaire. It measured overall performances of image making on memorizing the characters and the components as well as on the writing recall in the main study. The questionnaire consisted of three sections with a total of nine questions rated on a 5-point scale.

The Image Making by Character (IMC) questionnaire was a character-by-character questionnaire. It included a 5-point scale to measure the participants' image making experiences for learning each individual character. It also consisted of an open-ended question about the participants' preferred instructional methods and their reasons of using the methods to learn each character.

Procedures. The study ran over a period of four weeks, consisting of three phases, including the main study and two follow-up tests. The main study was conducted in 90 minutes in a computer lab. All thirty characters were randomly grouped three in a block and were given 32 learning period for each character. After learning three characters, the immediate writing tests were administered in paper-and-pen format with no time restrictions. After a practice session of six characters, the participants first completed a learning session of 18 characters in the instructional methods previously selected by the researchers (i.e., teacher-select session). At the end of this session, the participants completed the IMTM questionnaire. Then, the participants completed another six characters in their self-chosen methods (i.e., student-select session). The IMC questionnaire was administered after each immediate writing test. In the main study, character presentation and task instructions were carried out on Google PowerPoint 2010. The first and second follow-up tests were administered one week and four weeks, respectively, after the main study in paper-and-pen format with no time restrictions. The participants completed a writing recall of the 18 characters prompted in the same way as in the researcher-select session in both follow-up tests.

Research design. This research used a within-subject experiment design. Quantitative data including writing scores and questionnaire rates, together with supplementary qualitative data from survey responses, were collected. The writing scores were evaluated by three independent raters. The software tool, SPSS 18.0, was used to compute the statistical data.

A within-subject one-way ANOVA was run to test the impacts of the methods on writing performances across phases. A statistical correlation test was conducted to determine the significance level of the relationships between participants' self-perceived image making and writing performances. Content analysis was used to analyze the survey responses in the student-select session.

Results

Writing performances by method. Instructional methods significantly impacted the participants' writing performances at all three phases, $F(2, 48) = 5.93, 94.65, 79.38, p < .01$ (see Figure 1). In the immediate writing, the pictorial method produced significantly better results than the English method, $p \leq .01$, but the difference was not significant between the English and verbal methods, $p = .63$. There was no significant difference between the pictorial and verbal methods in the immediate writing, $p = 1.00$. It should be noted that, in contrast to the immediate writing, writing performances in the pictorial method showed the greatest decline in the follow-up tests, an average of 74% decrease. The verbal method, conversely, produced significantly better performance than the other two methods in the two follow-up tests, $p < .01$. However, the participants had the greatest variability in using the verbal method in character recall, $SE_1 = .82, SE_2 = .76$.

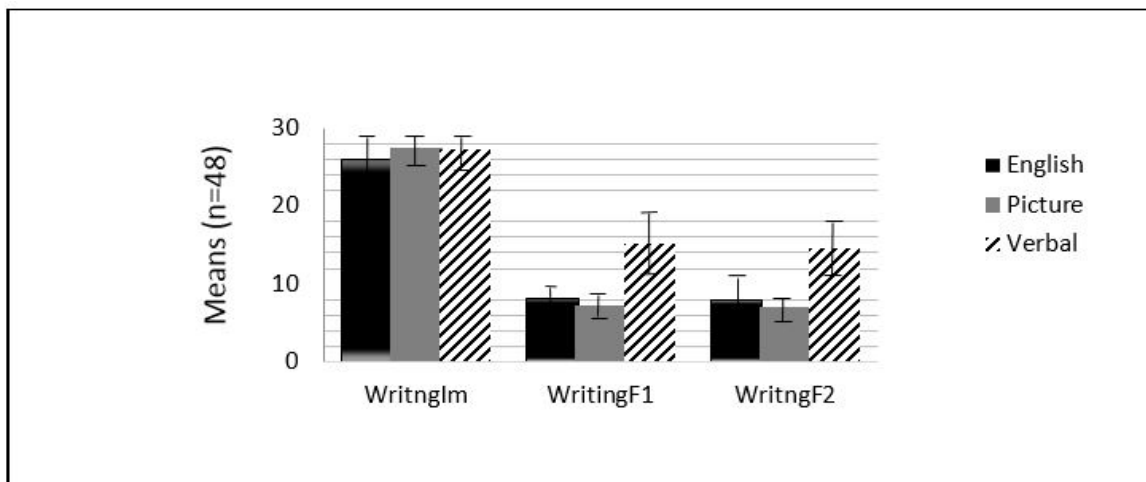


Figure 1. Performance of writing across phases for 18 characters shown in the teacher-select session.

Imagery and writing performances. The association between the participants' self-perceived image making and writing performances revealed moderate strengths (see Table 1). Specifically, image making was significantly associated with the immediate, $r = .32, p < .05$, and first follow-up writing, $r = .34, p < .05$. The second follow-up writing, however, did not show a significant association with imagery experience, $r = .12, p \geq .05$, but was significantly related with the first follow-up writing, $r = .86, p < .01$. There were no significant associations between the two follow-up writing tests and immediate writing, $r = .21, .13, p \geq .05$.

Table 1

Spearman's Rho Correlation Coefficients of the Strengths Between Image Perception and Writing Performance Across Phases (n=48)

Variables	1	2	3	4	M	SD
1. Imagery perception ^a	--				3.29	1.85
2. Writing immediate	.32*	--			26.94	3.66
3. Writing follow-up 1	.34*	.21	--		10.17	3.41
4. Writing follow-up 2	.12	.13	.86**	--	9.86	3.52

Note. ^a Imagery values were the total scores on the *Image Making by Teaching Method* questionnaire. * $p < .05$, ** $p < .01$.

The preferred method and image making. The student-select session in the main study included a total of 276 character-selection and learning cases, in which 28% of the selections were made to learn the characters in the English method, 45% in the pictorial method, and 27% in the verbal method (see Figure 2). Compared to the English and verbal methods, the pictorial method was the most preferable method selected by the participants to learn the six characters, $\chi^2 = 17.01$, $df = 2$, $\alpha = .00$. Among all the character learning cases ($n=274$), 74% were reported by the participants having experienced mental images of the character meaning. The pictorial method was reported significantly better than the English method in the image making experience in immediate writing, $p < .05$. However, this method failed to produce higher scores relative to the other two methods in the follow-up writing tests.

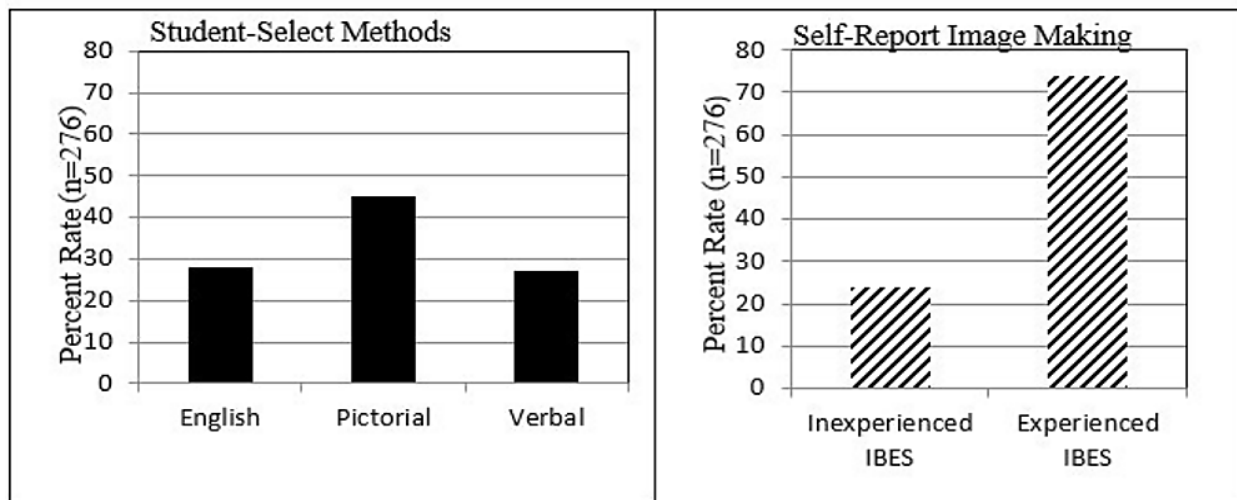


Figure 2. Student-select methods of learning 6 characters and self-report image making experience.

Survey studies. The qualitative survey results yielded three major categories of the responses as to the reasons why the participants selected a certain method to learn each of the six characters in the student-select session. The three categories included comments indicating: (1) knowing the meaning and translation; (2) seeing the images for meaning; and (3) knowing the Chinese meaning to have the images and remember the structure. The three categories of responses predominantly pointed to knowing more meanings of the characters, either in English or Chinese. Having mental images served as a mediational strategy for understanding Chinese meanings or for memorizing the character structures. The participants could make images by using all the three instructional methods. Those who used the pictorial and verbal methods much more frequently reported to have generated images than those used the English method.

Summary. The results generally accept the hypothesis that visual imagery strategy associated with character-denoted meaning predicts better performance in character writing. This was first evident in the consistently better writing performances in the verbal-contextual method in three phases. Reportedly, imagery was used by the participants as a mediational cognitive strategy to connect and adapt meaning to the new characters. However, it was found that the participants varied broadly in using the verbal-contextual method in character learning. The hypothesis is also supported by an association test in which imagery was found significantly associated with the immediate and one-week writing tests, but not in the four-week writing test. The pictorial method only had an immediate benefit.

Discussion

The results have revealed a mismatch between the students' preferred instructional method (i.e., pictorial) and the most productive method (i.e., verbal). In the light of individual differences and the levels of Chinese, imagery showed positive but limited effects in the participants' character learning in this research. These findings are consistent with a number of psychological studies of imagery function cited earlier. For the present purpose, the researchers will address the findings in the writing results as well as the role of imagery in these results. As explained earlier, the Neuro-Semantic Language Learning Theory (NsLLT), along with relevant findings from cognitive research in learning and memory, is used as the suggested neuroeducation model for cognitive analysis of the results.

The advantage of the verbal-contextual method aligns with the literature on conceptual encoding. In general, this result indicates that the more meanings matched the learner's semantic systems, the better performance was demonstrated on the character writing results. Under the NsLLT's meaning equation, the verbal-contextual method offered more relevant meanings for conceptual understanding (NsLLT, Level 3), including the concepts previously acquired in English, semantic components of the characters, and relational or spatial relationships of the components. These meaningful units formed relevant contextual information, which created more neural connections leading to increased strengths and access points for character encoding and retrieval. Comparatively, the English and pictorial methods were most likely constrained at the level of perceptual patterns (NsLLT, Level 2). Although the English method also invoked internal images, as indicated by some participants, this method did not offer enough meaning connections and additional access points associated with the character structures. Recent neurobiological findings may explain this mechanism of neural connections leading to long-term memory (NsLLT, Levels 3 & 4), which is developed in part by the growth and extension of dendrites that connect and reinforce neural pathways for information, consolidation, and representation (Segal, 2005; Zull, 2011).

The significant decrease of writing performance in the pictorial method may be largely due to the difficulty in meaningful interpretation of the pictures to be associated with the character structures. In other words, the pictures and character structures are incongruent in meaning. This was evident in the participants' comments, indicating that some pictures were difficult to understand. Fragmented perceptual patterns of the pictures, together with the character structures, were combined as image bundles maintained in the temporary visual working memory. These perceived images most probably have invoked higher brain activities when being viewed (see Ganis et al., 2004; Mazard et. al, 2005); thus, leaving better images in the immediate recall. This result conforms with the Long-Term Potentiation hypothesis, postulating that neurons are potentially active in recent activity patterns (see Kamiński et al., 2017). However, when recalling the characters from the pictures in the follow-up tests, unsuccessful or decayed neural connections occurred, due to incongruence between the picture meaning and learner's meaning, insufficient interpretation, heavy cognitive load, and distraction from character-irrelevant information in the pictures. In other words, the perceived image bundles were not recruited in the conceptual systems, but represented as temporary visual patterns (NsLLT, Level 2). This is consistent with a previous report that self-generated images of characters were found to have better sustained effects than teacher-supplied images, which proved to only have immediate benefits (Kuo & Hooper, 2004).

The experience of imagery and its role in the writing process can be unraveled based on the participants' subjective rating and commentary reports. Evidently, the participants used imagery strategy to help with the association of character meaning with the structures in both the memorization and writing phases. This strategy was dominantly used when the character components were not familiar to the participants. On the other hand, some participants who memorized individual characters in the English method indicated that they had already known the components, so English translation alone gave them clear meaning.

Subjective data also revealed that making mental images associated with the structures were not easy for many characters. One important reason that the participants chose the pictorial method was because they had to depend on the pictures to make images associated with the characters. For most of the new characters, it seemed that mental images with verbal coding supplied clearer meaning with perceived certainty (see Klemen & Chambers, 2012). For the characters memorized in the verbal-contextual method, the participants intended to generate fine-grained images for complete meaning relevant to the character structure. This is consistent with recent neuroimaging studies which found that using verbal-contextual messages may invoke audiovisual integration to form multilayered cross-modal concepts (Campbell, 2008; Stevenson, VanDerKlok, Pisoni, & James, 2011). One important finding was that the verbal-contextual method played an additional function in visualizing the "placement of the scene", which could be detailed image features with spatial connection. This may be the reason that the verbal-contextual method could invoke more relevant and effective mental images of the character structures overlapped with character meaning. Therefore, with more contextual information of these components to access to the conceptual circuits (NsLLT, Level 3), the participants showed better recall of the characters, even those with new components.

However, images are integrated electrical patterns that may require relatively large amount of cognitive resource from distributed brain areas (Zull, 2011), so using images to learn new information varied among the participants. This may partly explain the variations of the performance in the verbal-contextual method. As to why the second recall test did not show significant association with imagery as was the first test, one reason may be that consolidated circuits for meaning representation did not necessarily invoke images for mediation so that there was less cognitive load. For the role of imagery at different stages of character learning, the researchers suggest more detailed examination in future research.

Conclusion

All in all, the results indicate that the effects of imagery are closely linked to the levels of meaning the participants had for the meanings of the characters. At the participants' current level of Chinese, character conceptual encoding via the use of imagery had to be supported with more increased meanings related to the characters; for example, using the verbal-contextual method to help with the interpretation of the pictures to increase access points to the stored mental images; or, adjusting the verbal language and visuals to the levels of meanings acquired by the learner.

Different from the previous research on the behavioral interpretation of differentiated instructional methods in character learning, this research explored the cognitive underpinnings of the writing and imagery-based metacognitive processes. This supports the need and feasibility to draw on interdisciplinary literature from cognitive psychology, neuroscience, and language as a suggested neuroeducation model to understand language acquisition and learning in general.

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