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Text leads, images and videos follow: the impact of processing paths and input modalities on metaphorical competence in Chinese foreign language learners

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Introduction: Metaphorical competence is crucial in the accurate and authentic use of a second language. Processing paths (rational processing verses contextual guessing) and input modalities (unimodal verses multimodal) are major factors that may influence learners' metaphorical acquisition. This study explored how these variables relate to influence Chinese foreign language (CFL) learners' metaphorical competence.

Methods: Advanced CFL participants ($N = 60$) were divided into four groups using combinations of various processing paths (rational processing and contextual guessing) and input modalities (unimodal and multimodal), and subsequently completed three posttests. The data were subjected to correlation analysis using SPSS software.

Results: Rational processing excelled in metaphor comprehension competence (MCC), particularly with unimodal input, although metaphor production competence (MPC) showed an overall decline, especially in multimodal conditions; the rational processing path significantly outperformed the contextual guessing path in the immediate posttest in the three delayed posttests, but the effect diminished over time; Using the rational processing path, test times significantly affected MCC, whereas, MPC was affected by input modality and test times; Using the contextual guessing path, test times significantly affected MCC; With unimodal input, processing paths and test times significantly affected MCC, whereas processing paths affected MPC; With multimodal input, test times significantly affected MCC. MCC increased with time, whereas MPC decreased.

Discussion: This research confirms the applicability of Depth-of-processing Theory, Cognitive Load Theory, and spaced learning strategies in enhancing metaphorical competence through different processing paths and input modalities, thereby expanding their relevance in the domain of CFL acquisition.

KEYWORDS

Chinese idioms, rational processing, contextual guessing, input modality, metaphorical competence

1 Introduction

Chinese idioms are complementary in metaphorical connotations that are crucial in native speakers' language use and are a fundamental characteristic of Chinese communication. For L2 learners, mastering these idioms is an essential step toward achieving idiomatic language proficiency (Danesi, 1992; Littlemore, 2001). Metaphorical competence (Flahive and Carrell, 1977; Gardner and Winner, 1978; Danesi, 1986, 1992; Low, 1988; Littlemore, 2001; Pollio and Smith, 2018) is considered an advanced linguistic competence that is typically categorized into metaphor comprehension competence (MCC) and metaphor production competence (MPC) (Kogan, 1983). The extent to which language users comprehend a metaphorical system significantly affects their communication fluency and vividness (Low, 1988). However, L2 learners frequently experience additional cognitive challenges due to their limited access to standard meanings, unfamiliar cultural implications, usage conventions, and scarcity of prefabricated phrases (Kathpalia and Carmel, 2011). Consequently, the development of metaphorical competence among L2 learners has immense practical value for achieving accurate and idiomatic language expression (Littlemore, 2001), and has been shown to significantly enhance language proficiency and communicative ability (Littlemore and Low, 2006a; Lantolf and Bobrova, 2014), with new research highlighting its critical role in developing metaphorical awareness and competence in Chinese foreign language (CFL) through concept-based instruction (Liu and Hsieh, 2020).

Metaphorical competence, which refers to an individual's competence in comprehending and producing metaphors (Littlemore and Low, 2006a,b), is widely recognized as vital for L2 learning. Existing literature primarily addresses either its general role in vocabulary acquisition or focuses on specific aspects of language learning, such as vocabulary acquisition, reading comprehension, and writing production (Kathpalia and Carmel, 2011; Wang and Cheng, 2016; Hoang and Boers, 2018; O'Reilly and Marsden, 2023). Cultivating metaphorical competence facilitates language learning by reducing negative cultural transfer and enhancing second language proficiency (Low, 1988; Littlemore and Low, 2006a; Huang, 2010). Acquiring metaphorical competence involves decoding meanings influenced by linguistic and cultural contexts. This process requires learners to engage in metaphorical content, which may vary depending on cognitive processing courses such as logical reasoning to decode metaphors (rational processing) or inferring meanings from contextual clues (contextual guessing). Furthermore, input modalities such as text, images, or videos are crucial in defining these courses by providing varying levels of linguistic and contextual support. However, research on the interactive effects of different cognitive processing paths and multimodal input modalities on the acquisition of metaphorical idioms in the CFL are insufficient. Moreover, many studies have focused solely on metaphor comprehension, with a few addressing metaphor production despite metaphor comprehension being an equally important aspect of metaphorical competence. Understanding these interactions is essential for enhancing teaching strategies and improving learning outcomes in CFL.

This study aimed to address these gaps by investigating the impact of different cognitive processing paths and input modalities on MCC and MPC among CFL learners. By investigating how these factors relate, this study aimed to provide new insights into the acquisition of Chinese idioms and development of metaphorical competence in a CFL context.

The study was guided by the following research questions:

- How do MCC and MPC scores vary in different processing paths and input modalities in the immediate, 3-day, and 7-day posttests?
- What are the differences in the effects of different processing paths and input modalities on MCC and MPC in the three posttests?
- How do input modalities and test times independently influence MCC and MPC under different processing paths?
- How do the processing paths and test times independently influence MCC and MPC under different input modalities?

2 Literature review

Metaphors are a frequently used form of linguistic expression and basic method of thinking regarding human existence (Lakoff and Johnson, 2008). The acquisition and processing of metaphors in a second language involves complex cognitive mechanisms. According to Burgess and Chiarello (1996), comprehending metaphors involves complex relationships between bottom-up semantic activation and top-down pragmatic constraints. Bottom-up processes emphasize the activation of lexical and semantic representations, whereas top-down processes focus on contextual integration to infer meaning. This dual-pathway model forms a theoretical foundation for understanding how L2 learners process and acquire metaphors. Subsequent studies have further explored and applied this model in various contexts (e.g., Nippold et al., 2000, 2001; Park and Lim, 2011; Yi et al., 2013).

Based on this framework, Wang et al. (2022) identified two primary processing guidelines: rational processing and contextual guessing. Rational processing involves bottom-up mechanisms, emphasizing logical relationships between the tenor and vehicle of a metaphor through a "tenor-rationale-vehicle" pathway. In contrast, contextual guessing corresponds to top-down mechanisms that rely on contextual and situational cues to infer the metaphorical meaning of a vehicle. Some scholars have argued that rational processing helps learners delve into the internal structure of metaphors, causing a decoding process that enhances their comprehension and application. Metaphors can be recognized if the isomorphism between ontology and metaphor is revealed (Xu, 2014). People tend to grasp the meaning of metaphors with an explicit rationale efficiently and accurately (Chiappe et al., 2003; Thibodeau and Durgin, 2011). However, others have found that contextual guessing is more conducive to learners inferring the meaning of metaphors based on contextual information without direct linguistic input (Gibbs, 1980). Context plays an irreplaceable role in metaphorical comprehension, generation, creation (Wei, 2018), and cross-cultural communication (Sperber and Wilson, 1986). However, there is still considerable debate regarding the effective courses for L2 learners. Specifically, the rational processing course is effective and consistent with graphic and textual modalities because these formats facilitate bottom-up processing by visually highlighting the logical relationships between metaphor components. Conversely, the contextual guessing course benefits more from video input modalities, which provide complementary situational and contextual cues that support top-down mechanisms for inferring metaphorical meaning (Wang et al., 2022). This understanding of the input modality under different cognitive processing paths forms the basis for the design of this study.

Another critical factor influencing metaphor acquisition is the input modality. Research indicates that multimodal inputs such as text paired with images or videos can enhance learning outcomes by simultaneously engaging multiple sensory channels (VanPatten and Oikennon, 1996; Tindall-Ford et al., 1997). Processing information through different channels complements understanding and retention, as explained by the limited capacity of sensory processing channels (Baddeley and Hitch, 1974). However, the advantages of multimodal inputs over unimodal inputs are not always significant. According to Cognitive Load Theory (Sweller and Chandler, 1994; Paas et al., 2003), information processing is limited by cognitive capacity, and overloading this capacity can hinder learning and memory consolidation (Mayer, 2009, p. 118). For instance, Brown et al. (2008) found no significant effect of multimodal input on L2 vocabulary learning, whereas Diao and Sweller (2007) noted adequate outcomes from visual-only input more so than audiovisual input in EFL vocabulary learning. Similarly, Hong and Zhang (2017) reported that visual-only input was more effective than audiovisual input for CFL learners who acquired the Chinese "ba" sentence structure. Although many studies have highlighted the benefits of multimodal input, a minority, such as Wang et al. (2022), argue that modalities can exhibit their respective advantages under different processing paths. However, research on the effects of multimodal input on the acquisition of Chinese metaphorical idioms is insufficient.

Although substantial research has been conducted on the role of metaphor comprehension in SLA, a notable gap exists in the exploration of metaphor production and relationships between different cognitive processing paths and input modalities, particularly among CFL learners. This gap is particularly significant as metaphor production is just as essential as comprehension in achieving full metaphorical competence. Furthermore, the impact of these processing paths and input modalities on memory persistence in metaphor acquisition, that is, how learners retain metaphorical knowledge over time, has received insufficient attention. This disparity emerged because of the relative ease of implementing methods to measure metaphor comprehension, compared to the more complex challenges involved in data collection and analysis for metaphor production, which frequently require more subjective evaluation criteria (Shi and Liu, 2010). To address this gap, this study tested MCC and MPC. Notably, MCC was assessed through multiple-choice and judgment questions, whereas MPC was evaluated using fill-in-the-blank and interpretation questions, thereby allowing a more comprehensive measurement of learners' metaphorical competence. This study aimed to address these gaps by examining the effects of different cognitive processing paths and input modalities on metaphor comprehension and production. Additionally, this study explored how these factors influence learners' retention of metaphorical knowledge over three time intervals. It is predicted that multimodal input significantly enhances metaphor comprehension and production, with retention influenced by the nature of the input and testing intervals. The findings reveal similarities and differences in CFL learners' idiom acquisition compared to prior studies, providing further insights into CFL learning.

3 Methodology

3.1 Participants

Forty advanced CFL learners from non-Hanzi cultural backgrounds were recruited during the target word selection phase. All participants achieved an HSK5 or higher, and their recent Chinese exam results were collected to ensure that there were no significant differences in their Chinese proficiency levels. Sixty advanced CFL learners were selected for the main study using a two-step process. First, participants who had passed the HSK5 in the past 2 years with scores exceeding 200 were included. A statistical test confirmed no significant difference in proficiency ($p < 0.05$). Second, a power analysis using G.Power 3.1 (Faul et al., 2007) determined the required sample size of 60; the sample was divided into four groups of 15 participants. The participants were mostly undergraduates or postgraduates from Vietnam, Thailand, and Korea studying at Chinese universities.

3.2 Material and modalities

The study selected target idioms based on the *Reference Framework for Teaching Chinese Culture, National Conditions for International Chinese Language Education,* and cultural textbooks such as *Cultural Panorama* and *Speaking Chinese and Talking about Culture*. These idioms, which represent metaphorical Chinese cultural words with low lexical transparency, were screened to ensure suitability. First, to minimize the effects of syllable processing (Zheng et al., 2022), the syllabic length of the target words was controlled to 3–4 syllables, resulting in 30 selected idioms. Second, semantic transparency was assessed by recruiting 25 native Chinese speakers with Chinese language degrees to rate idioms on a 5-point Likert-type scale (1 = "very semantically transparent" to 5 = "not very semantically transparent"). Words with a transparency score of three or more were shortlisted. To ensure low lexical familiarity for CFL learners, a pilot study was conducted with 20 advanced CFL learners with proficiency comparable to that of the experimental participants. They rated familiarity using a 5-point Likert-type scale (1 = "never seen" to 5 = "know and used the metaphor"). Idioms scoring between four and five were finalized as the target set.

Based on Wang et al.'s (2022) findings, the design incorporates two distinct types of multimodal input to explore their roles in metaphor acquisition: Graphic-textual and video. Graphic-textual input supports bottom-up processing by clarifying logical relations, whereas video input enhances top-down processing through contextual cues. To evaluate these modalities, the study divided participants into four experimental groups, with each group combining one of the two processing paths and one of the two input modalities, so that all combinations could be tested. Each modality presentation lasted 20 s.

Unimodal rational processing: Text sourced from authoritative resources, such as the New Modern Chinese Dictionary (7th ed.) (2018), Idioms Dictionary (Latest Revised Edition) (2016), Baidu Hanyu (https://dict.baidu.com/), and HanDian (https://www.zdic.net/). Multimodal rational processing: The same text as in unimodal rational processing, paired with images retrieved through web searches to enhance visualization. Contextual Guessing Unimodal: Text derived from video dialogues or narrations in the CVC Chinese Audiovisual Corpus (https://client.chinafocus.net.cn/), reflecting real-life usage and context.

Contextual Guessing Multimodal: The same text as in Contextual Guessing Unimodal is paired with corresponding video scenes from the CVC Chinese Audiovisual Corpus to provide a dynamic visual context (Ginther, 2002; Ockey, 2007). This dual-modal approach caters to diverse cognitive preferences and forms the basis for comparing the impacts of these modalities on MCC and MPC.

3.3 Procedures

3.3.1 Pre-test

Thirty CFL learners with the same Chinese proficiency levels as the participants were presented with 60 idioms and asked to indicate their familiarity and understanding. The results were counted according to the order of the target words. Thirty unknown idioms were used in the experiment to ensure that the participants' familiarity with the target words was minimized during the formal experiment.

3.3.2 Formal experiment

The participants ($N = 60$) were divided into four groups based on the four modalities ($N = 15$ per group). The idioms were presented using Psychopy (v2023.2.3) on a Windows 11 laptop. The input for each idiom lasted 20 s. The participants were instructed to focus solely on the screen without an external aid. The experimental idiom "xiōng yǒu chéng zhú" was used as an example to show how each group was tested (see Figure 1).

3.3.3 Posttest

The posttest consisted of three phases: immediate posttest, 3-day posttest, and 7-day posttest. Following Zhou et al. (2022), who demonstrated the effectiveness of teaching interventions in improving metaphorical competence, participants received a review intervention using the same initial modality 1 day after the immediate and 3-day posttests. This ensured consistency in the word acquisition and memory retention.

Participants were tested on 30 target words after viewing the end of the modality presentation, using four types of questions: fill-in-the-blank questions requiring the most appropriately learned word, eight multiple-choice questions, judgment (correct/incorrect) questions, and six paraphrase questions (think-aloud protocol, TAP) (Shi and Liu, 2010). The questions assessed metaphorical comprehension (multiple-choice, judgment) and production (fill-in-the-blank, paraphrasing). Test responses were recorded, with results reflecting metaphorical competence through changes in test scores (Stamenkovi et al., 2019; O'Reilly and Marsden, 2021).

Multiple-choice and judgment questions were evaluated using binary scoring (one point for a correct answer and zero for an incorrect answer), with a maximum score of 30 points and a 30-min time limit. Fill-in-the-blanks and paraphrased questions were scored on a scale of zero, 0.5, and one, based on partial precision following Henriksen's (1999) vocabulary knowledge framework. Each word was designed with four types of questions, arranged in a snowballing manner and distributed across three tests to ensure that each test featured different question sequences while maintaining balanced coverage. This study used the percentage conversion method (Popham, 2008; Thorndike and Thorndike-Christ, 2013) by converting raw scores into percentages so that the results of different tests could be standardized to a common scale for easy interpretation and comparison (Anastasi and Urbina, 1997). The total metaphor comprehension and metaphor production scores were 16 and 14, respectively, and the formula was as follows: percentage scores = (actual scores/total scores) × 100.

3.4 Experiment design

A three-factor mixed experimental design of 2 (processing paths: rational processing, contextual guessing) ×2 (input modalities: unimodal, multimodal) ×3 (testing phase: immediate, 3-day, 7-day posttests) was used, in which the processing paths and input modalities were between subjects, indicating that participants were assigned to four groups: rational processing unimodal, rational processing multimodal, context guessing unimodal, and context guessing multimodal. The testing stage was within-subject, indicating that each participant was analyzed under different test phases.

MCC and MPC were considered as measurement conditions, with each participant assessed independently for comprehension and production in each of the testing phases. The similarities and differences between MCC and MPC were compared in the three posttests as well as in the main effects and interaction effects of the three factors. The intervals between the test times were relatively short, and because the score differences were minimal, time was not considered as a random effect in the analysis. All the variables in the three-factor analysis were considered as fixed effects.

3.5 Data analysis

Statistical analyses were performed using IBM SPSS Statistics 27.0 for Windows. The study used a three-factor mixed experimental design; however, not all factors were analyzed simultaneously in a three-way relationship because of the focus of this research. Instead, descriptive statistics were computed to examine the effects of processing paths and input modalities on MCC and MPC in the three posttest stages. The mean scores (M) and standard deviations (SD) of the posttest scores under different processing paths (rational processing and contextual guessing), input modalities (unimodal and multimodal), and test times (immediate, 3-day delayed, and 7-day delayed) were calculated.

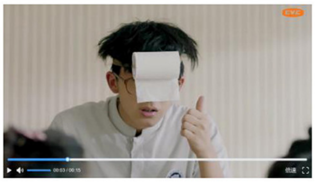
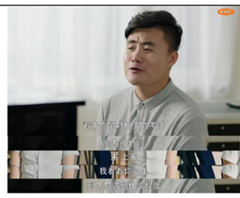
Group	Stimuli-presenting mode (Present 20 seconds)
A. Rational processing unimodal (N=15)	胸有成竹：画竹子前心中已有竹子的形象，比喻做事之前心中已有充分的考虑。
B. Rational processing multimodal (N=15)	 胸有成竹：画竹子前心中已有竹子的形象，比喻做事之前心中已有充分的考虑。
C. Contextual guessing unimodal (N=15)	**胸有成竹** 陈惊同学， 你干吗呢， 看来你是对明天的考试胸有成竹啊， 来，上来， 我看看你心里到底有谱到什么程度。
D. Contextual guessing multimodal (N=15)	  
	a. Initial Contextual Activation Stage (no lines) (0-3s); b. Attention Allocation Transition Stage (4-6s); c. Target Idiom Presentation Stage (7-15s)

FIGURE 1
Examples of four groups of xiōng yǒu chéng zhú. xiōng yǒu chéng zhú in Groups A and B—Before painting a bamboo, one already has a clear image of it in mind. It serves as a metaphor for having thorough planning and consideration before taking action. xiōng yǒu chéng zhú in Groups C and D—"Chen Jing, what are you up to? It seems you're quite confident about tomorrow's exam. Come on, come up here. Let me see just how well-prepared you really are." Adapted with permission from the CVC Chinese Audio-Visual Corpus (https://client.chinafocus.net.cn/), copyright protected by Beijing Audiovisual Technology Co., Ltd. (under the license of Beijing Audiovisual Technology Co., Ltd.).

Additionally, progress (Δ) and retention rates (%) were computed to quantify performance improvements and retention over time.

Subsequently, one-way ANOVA was used to assess the effects of individual factors (processing paths, input modalities, and test times) on MCC and MPC. Two-way ANOVA was used to analyze the relationship effects of processing paths, input modalities, and test times in pairs, focusing on the primary relationship relevant to metaphorical competence. Considering the sample size and scope of the study, the decision to limit the analysis to two-way relationships was made to adequately understand the main effects and their relationship while avoiding overcomplexity.

4 Results

4.1 Performance and changes in the three posttests under different processing paths and input modalities

The results of the three posttests were analyzed using four indicators: M, SD, degree of progress (Δ), and retention rate (%) (see Table 1).

Mean performance (M) in the MCC: unimodal rational processing (79.03) > multimodal rational processing (76.81) > multimodal contextual guessing (74.31) > unimodal contextual guessing (71.67); mean performance (M) in the MPC: unimodal rational processing (49.98) > multimodal rational processing (40.07) > unimodal contextual guessing (38.55) > multimodal contextual guessing (38.33). Notably, SD of MCC (fluctuating performance): rational processing unimodal (11.41) < rational processing multimodal (12.80) < contextual guessing unimodal (14.73) < contextual guessing multimodal (15.39).

Notably, SD of MPC (fluctuating performance): rational processing multimodal (12.55) < contextual guessing unimodal (19.3) < contextual guessing multimodal (20.62) < rational processing multimodal (20.91).

Notably, Δ in MCC: contextual guessing unimodal (25.417) > contextual guessing multimodal (19.583) > rational processing unimodal (18.75) > rational processing multimodal (8.334); Δ in MPC: contextual guessing unimodal (−0.896) > contextual guessing multimodal (−10.696) > rational processing unimodal (−13.27) > rational processing multimodal (−22.577).

Retention (%) of MCC: contextual guessing unimodal (143.66) > contextual guessing multimodal (131.12) > rational processing

TABLE 1 Comparison of the four indicators of MCC and MPC in the three scores under different processing paths and input modalities.

Processing paths	Input modalities	Test	M		SD		Δ		R	
			MCC	MPC	MCC	MPC	MCC	MPC	MCC	MPC
Rational procession	Unimodal	1	70	57.556	12.092	17.195	18.75	−13.27	126.79	76.94
		2	78.333	48.095	13.543	23.062				
		3	88.75	44.286	8.583	22.459				
	Multimodal	1	73.333	55.434	10.687	18.414	8.334	−22.577	111.36	59.29
		2	75.417	31.905	13.251	10.669				
		3	81.667	32.857	14.460	8.559				
Contextual guessing	Unimodal	1	58.333	40.658	15.064	16.720	25.417	−0.896	143.66	97.80
		2	72.917	35.238	10.996	18.304				
		3	83.750	39.762	18.114	22.863				
	Multimodal	1	62.917	43.554	16.275	19.187	19.583	−10.696	131.12	75.45
		2	77.5	38.571	14.903	22.917				
		3	82.5	32.858	14.978	19.756				

Test 1–3 denote immediate posttest, 3-day posttest, and 7-day posttest, respectively.
M, Average score; SD, Standard Deviation; Δ, Level of progress; R, Retention rate (%); MCC, Metaphor Comprehension Competence; MPC, Metaphor Production Competence.

unimodal (126.79) > rational processing multimodal (111.36). Retention (%) of MPC: contextual guessing unimodal (97.80) > rational processing unimodal (76.94) > contextual guessing multimodal (75.45) > rational processing multimodal (59.29).

In terms of M for metaphor comprehension, unimodal rational processing Unimodal excelled (79.03), followed by multimodal rational processing multimodal (76.81), contextual guessing multimodal (74.31), and unimodal contextual guessing (71.67). This indicated that rational processing is more effective at enhancing metaphor comprehension. The SD data showed that the lowest fluctuation occurred in the scores for unimodal rational processing unimodal (11.41), followed by multimodal rational processing multimodal (12.80), unimodal contextual guessing (14.73), and contextual guessing multimodal (15.39). This indicated a more stable improvement in MCC for unimodal rational processing. The Δ showed that the contextual guessing unimodal mode improved considerably (25.417), followed by the contextual guessing multimodal mode (19.583), rational processing unimodal mode (18.75), and rational processing multimodal mode (8.3334). In terms of retention (%), contextual guessing unimodal was the highest (143.66), followed by contextual guessing multimodal (131.12), rational processing unimodal (126.79), and rational processing multimodal (111.36). In terms of M for metaphor production, unimodal rational processing unimodal had the highest score (49.98), followed by multimodal rational processing multimodal (40.07), unimodal contextual guessing unimodal (38.55), and multimodal contextual guessing multimodal (38.33). In terms of SD, multimodal rational processing fluctuated the least (12.55), followed by unimodal contextual guessing (19.3), multimodal contextual guessing (20.62), and unimodal rational processing (20.91). The Δ demonstrated that metaphorical competence decreased in all modalities, with contextual guessing unimodal decreasing the least (−0.896), followed by contextual guessing multimodal (−10.696), justification processing unimodal (−13.27), and justification processing multimodal decreasing considerably (−22.577). The retention rate (%) indicated that unimodal contextual guessing was the highest (97.80), followed by unimodal rational processing (76.94), multimodal contextual guessing (75.45), and multimodal rational processing (59.29).

Figure 2 further illustrates the performance changes in the three tests: (1) Metaphor Comprehension: Unimodal and multimodal modalities under rational processing and contextual guessing showed consistent improvements from the immediate posttest to the 7-day posttest, indicating significant gains in MCC. (2) Metaphor Production: Except for contextual guessing unimodal, which slightly decreased in the third test, all other modalities exhibited a decline, particularly in the rational processing of multimodal and contextual guessing of multimodal inputs. This suggests challenges in retaining MPC under multimodal conditions. (3) Rational processing began with higher scores and showed greater improvement with the unimodal modality achieving the highest final score (88.75). Contextual guessing inputs had lower initial scores but exhibited improvements in both modalities. (4) Unimodal verses Multimodal: Multimodal input did not significantly outperform unimodal input in MCC, and led to more pronounced declines in MPC, especially in rational multimodal processing, in which the scores declined from 55.434 to 32.857. This suggests that multimodal inputs may introduce a cognitive overload which affects performance.

4.2 Effect of different paths and input modalities on metaphorical competence in the three posttests

Notably, M for rational processing ($M = 71.667$) were significantly higher than those for contextual guessing ($M = 60.625$), indicating that learners who used rational processing excelled in metaphor comprehension. However, the input modality did not significantly influence the MCC scores ($F(1,56) = 1.25$, $p > 0.05$). In contrast, the processing paths had a significant impact

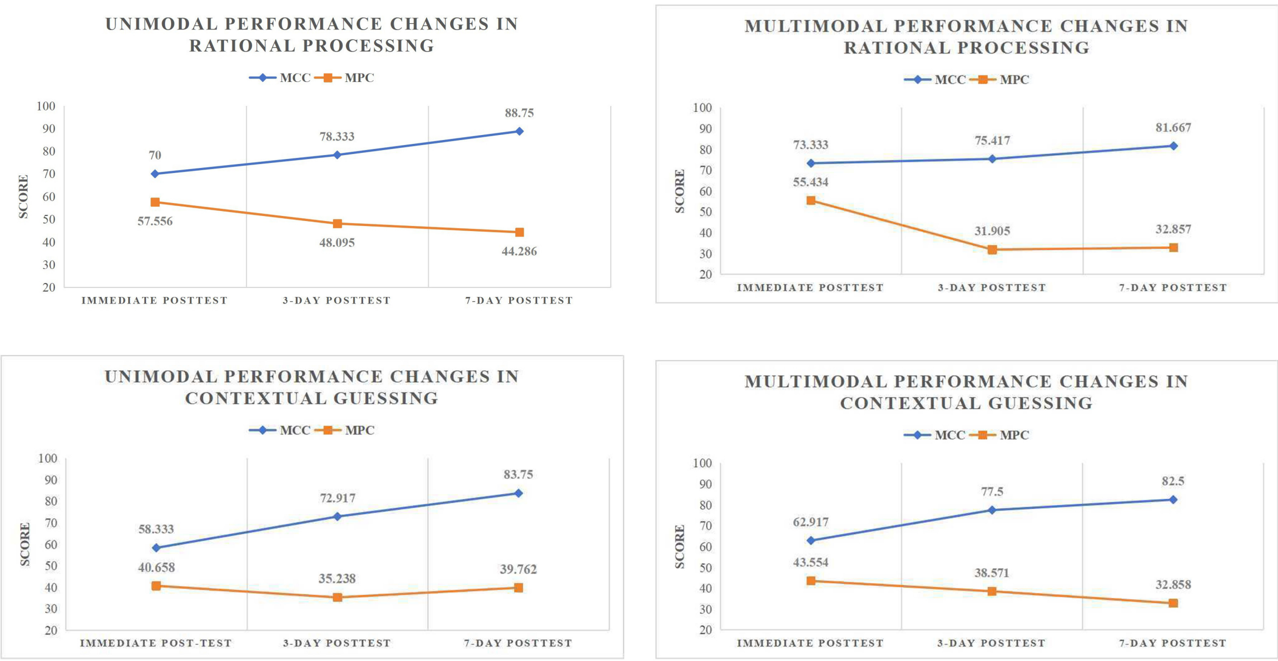


FIGURE 2
Changes in MCC and MPC performance under different processing paths and input modalities.

on MCC scores ($F(1,56)=9.687$, $p = 0.003 < 0.05$). The mean score for rational processing ($M = 56.495$) was higher than for contextual guessing ($M = 42.106$), suggesting that rational processing is more conducive to metaphorical competence.

In the 3-day posttest, neither processing paths nor input modalities significantly influenced the MCC or MPC scores. The results of a one-way ANOVA showed that the processing paths and input modalities did not significantly affect MPC ($p > 0.05$). However, the relationship effect between processing paths and input modalities was marginally significant for metaphorical competence ($p = 0.056$), indicating that paths and modalities may not be critical factors influencing metaphorical competence in the current experimental design and sample.

In the 7-day posttest, neither processing paths nor input modalities significantly influenced MCC or MPC scores. A one-way ANOVA indicated that neither input modalities nor processing paths had a significant effect on memory retention in MCC or MPC over a longer duration ($p > 0.05$). This finding suggests the need for further exploration over extended periods.

4.3 Effects of input modalities and test times on MCC and MPC under different processing paths

As shown in Table 1, under the rational processing path, the effect of test times on MCC scores was significant, whereas the input modality was not. A two-way ANOVA revealed a highly significant main effect of test times ($F_{(1, 84)} = 1.135$, $p = 0.000 < 0.05$), but no significant effect of input modality ($p > 0.05$). Notably, M in test times showed the following pattern: 7-day posttest ($M = 85.21$), 3-day posttest ($M = 76.88$), and immediate posttest ($M = 71.67$). This indicates that MCC improved with the test time. For MPC, the input modality and test times exhibited significant effects. A two-way ANOVA revealed significant differences in the input modality ($F_{(1, 84)} = 7.140$, $p = 0.009 < 0.05$) and test times ($F(1,84) = 1.135$, $p = 0.000 < 0.05$). Unimodal inputs ($M = 38.553$) showed slightly higher M than multimodal inputs ($M = 38.328$). Test times significantly influenced scores, with the following means: immediate posttest ($M = 42.106$) > 3-day posttest ($M = 36.905$) > 7-day posttest ($M = 36.31$). This suggests a regression in performance for MPC over time.

In the contextual guessing path, the test times significantly influenced MCC, whereas the input modality did not. A two-way ANOVA revealed a significant effect of test times ($F_{(1, 84)} = 16.902$, $p = 0.000 < 0.05$), with M of the 7-day posttest ($M = 83.13$), 3-day posttest ($M = 75.21$), and immediate posttest ($M = 60.63$). However, neither the input modality nor the test times significantly affected the MPC scores ($p > 0.05$).

4.4 Effects of processing paths and test times on MCC and MPC under different input modalities

In the unimodal input condition, processing paths and test times significantly influenced MCC scores. A two-way ANOVA revealed significant effects of processing paths ($F = 6.778$, $p = 0.011 < 0.05$) and test times ($F = 20.344$, $p = 0.000 < 0.05$), but no interaction effect was observed between the two ($F = 0.582$, p

> 0.05). The M indicated exemplary performance under rational processing ($M = 79.028$) more than contextual guessing ($M = 71.667$). In the test times, M were as follows: 7-day posttest ($M = 86.25$), 3-day posttest ($M = 75.625$), and immediate posttest ($M = 64.167$). For MPC, the processing paths had a significant effect ($F = 7.138$, $p = 0.009 < 0.05$), but the test times did not ($p > 0.05$). Rational processing scores ($M = 49.979$) exceeded those for contextual guessing ($M = 38.553$), suggesting that rational processing enhanced learners' MPC under unimodal input.

In the multimodal input condition, the test times significantly influenced MCC scores, whereas the processing paths did not. A two-way ANOVA revealed a significant main effect of test times ($F = 7.336$, $p < 0.05$), with M as follows: 7-day posttest ($M = 82.083$), 3-day posttest ($M = 76.458$), and immediate posttest ($M = 68.125$). The processing paths were not significantly different ($P > 0.05$). For MPC, the test times had a significant effect ($F = 8.05$, $p < 0.05$), whereas the processing path did not. Notably, M in test times were as follows: immediate posttest ($M = 49.494$), 3-day posttest ($M = 35.238$), and 7-day posttest ($M = 32.858$), indicating a gradual decline in MPC performance under multimodal input over time.

5 Discussion

5.1 Effects of four different input modes on MCC and MPC

In Section 4.1, MCC achieved the highest average score and lowest standard deviation under the rational processing mode. This finding indicates that rational processing is the most effective input method for improving learners' metaphor comprehension, with less variability in scores than contextual guessing. This is consistent with Schmidt's (1990) Attention Assumption Theory, which emphasizes that intentional attention and reflection intensify metaphorical understanding through logical and causal connections.

However, for MPC, the scores decreased in all input modes, particularly under multimodal rational processing. This may be due to the excessive cognitive load imposed by dense multimodal inputs (e.g., pictures and videos), which is consistent with Sweller's (1988) Cognitive Load Theory, suggesting that information overload can impair learning outcomes. Compared to multimodal input, unimodal input had a slightly stronger impact on metaphor comprehension, but was less effective for metaphor production, in which the performance decline under multimodal input was more pronounced. This finding supports Mayer and Moreno's (2003) Cognitive Theory of Multimedia Learning, which posits that multimodal inputs can overwhelm learners with excessive stimuli.

The rational processing path demonstrated a higher baseline and more significant improvement, particularly in comprehension. Contextual guessing showed potential for gradual improvement in production through repeated exposure to contextual cues while being initially weak. These findings highlight that rational processing fosters stability and effectiveness in comprehension, whereas contextual guessing benefits production. This is consistent with Boers's (2000) assertion that intensive metaphorical awareness aids lexical memory and applications. These results extend the theories of attention, cognitive load, and multimedia learning to metaphor instruction and suggest that balancing input density and cognitive load is critical for optimal learning outcomes. Future studies should explore strategies to optimize the multimodal design of MPC.

5.2 Analysis of the changes in the processing paths and input modalities on the acquisition effect in the three delayed posttests

In the immediate posttest, MCC was significantly excellent under rational processing compared to under contextual guessing. This finding supports Craik and Lockhart's (1972) Depth-of-processing Theory, which emphasizes that intensive information processing enhances memory retention. The structured approach to rational processing is consistent with Gibbs Jr's (2005) theory that metaphor comprehension requires a comprehensive understanding beyond contextual guessing. However, the lack of systematic analysis in contextual guessing leads to weaker acquisition, corroborating Boers's (2000) view that intensive analysis improves metaphorical mastery.

For MPC, rational processing outperformed contextual guessing, consistent with Swain's (1985) Output Hypothesis, which emphasizes the role of linguistic competence in internalizing language structures. However, the effects diminished in both paths by the 3-day and 7-day posttests, highlighting the transient nature of the single-path interventions. This finding supports Littlemore and Low's (2006a) argument that sustaining metaphorical learning requires multiple strategies.

Interestingly, although multimodal learning theories (Fadel, 2008; Jewitt, 2009) predict enhanced retention through multisensory stimulation, the modality effect in the 7-day posttest was marginal ($p = 0.071$), indicating a complex relationship between the input mode and memory consolidation. These findings suggest that rational processing is effective immediately, but requires supplementary strategies to sustain long-term retention. Future research should explore extended timeframes and combined strategies to maintain metaphorical learning effects.

5.3 Effects of input modality and test times on metaphorical competence under different processing paths

For MCC, test times significantly influenced performance under rational processing and contextual guessing paths. This gradual improvement is consistent with practice and spacing effects (Cepeda et al., 2006; Roediger and Butler, 2011; Kang, 2016), which emphasize the benefits of distributed learning for long-term retention. The scores improved consistently from the immediate posttest to the 7-day posttest, validating these theoretical perspectives. However, the input modality had no significant effect on MCC. This contradicts the predictions of Multimodal Learning Theory (Fadel, 2008; Mayer, 2020) that multisensory input enhances memory. Other factors such as cognitive style or metaphor type may modulate the impact of modality.

For MPC, input modality and test times significantly influenced performance under rational processing, supporting Constructivist Learning Theory (Piaget, 1972). Unimodal input slightly outperformed multimodal input, which is consistent with Sweller's (1988) Cognitive Load Theory, because excessive multimodal input can overwhelm cognitive resources. Under contextual guessing, neither modality nor test times significantly affected MPC, possibly because of limited practice or the extended time required for the effects to manifest.

These findings validate the benefits of rational processing and highlight the need for customized practice schedules to optimize metaphorical learning outcomes. Modality effects, although minor for comprehension, warrant further investigation into their role in MPC.

5.4 Effects of processing paths and test times on metaphorical competence in different input modalities

For MCC, processing paths and test times had significant effects under unimodal conditions, with rational processing yielding higher scores (70 > 58.33). This supports Craik and Lockhart's (1972) Depth-of-processing Theory and underscores the importance of structured comprehension strategies. Although test times had a significant effect under multimodal conditions, processing paths did not. This attenuation suggests that multimodal representations dilute the influence of individual processing paths, which is consistent with the findings presented in Section 4.3. Metaphor comprehension scores improved incrementally in test time points, validating Incremental Learning Theory (Pavlik and Anderson, 2008), which states that gradual, repeated reviews strengthen knowledge mastery.

For MPC, processing path effects were significant under unimodal conditions, reflecting Dual Encoding Theory (Paivio, 1971), which highlights the co-processing of semantic and representational information. However, the decline in MPC over time under multimodal input suggests an increased cognitive load and information interference, consistent with Cognitive Processing Theory (Anderson, 2000).

For example, "xiōng yǒu chéng zhú" (see 3.3.2, Figure 1). Compared with Group A, learners in Group B needed to focus partially on the picture information "man, desk, and paper" when they understood the meaning of the word, and picture information frequently failed to show the original meaning and metaphorical meaning of the idiom simultaneously. Compared with Group C, learners in Group D were attracted to the first 3 s of the video material (which is not directly related to the meaning of the target word) and may not have been able to focus on the meaning of the idiom; thus, the cognitive load of the multimodal group was greater than that of the unimodal group and tended to increase over time. Furthermore, paired with the conclusion in Section 4.1, from the immediate posttest to the 7-day posttest, the rational processing multimodal had the least improvement in metaphor output scores among the four groups (a drop of 22.577 points), and the metaphor output ability of the rational processing multimodal had a smaller improvement effect than the contextual guessing multimodal. The reason is that the video information is more positively related to the text, and learners can speculate the metaphorical meanings of the words through the context related to the text, although most of the picture information can reveal the original meanings of some words, such as the experimental words "liǔ àn huā míng, yíng rèn ér jiě, yú gōng yí shān," etc. The pictures can convey the original meanings of the idiom's words but not the metaphorical meanings behind them. They can also reveal some of the implied meanings according to the learners' subjective understanding. Learners must spend more time and resources processing metaphorical information in the same amount of time, during which working memory resources, cognitive load, and attention allocation are all negatively affected, further affecting the improvement of learners' MPC.

5.5 Comparative analysis of MCC and MPC

A comparative examination of the developmental trajectories of MCC and MPC revealed significant differences in enhancement effects, processing paths, input modalities, test times, and performance under unimodal and multimodal conditions. Overall, MCC consistently outperformed MPC, exhibiting more pronounced improvement in various processing paths and input modalities, particularly under the unimodal condition of rational processing. Immediate posttests indicate that processing paths significantly influence MCC and MPC, with rational processing surpassing contextual guessing in terms of effectiveness. However, in the delayed posttests, MPC was subtly affected by the interaction between processing paths and input modalities, suggesting that input modalities contribute to the long-term retention of MPC. Notably, MCC intensifies over time, relying on conceptual networks and long-term memory, whereas MPC depends on immediate creativity.

Under unimodal conditions, distinct processing paths significantly affected MCC and MPC. In contrast, under multimodal conditions, the processing paths have less influence, and the test time becomes a pivotal factor. Notably, MCC requires longer periods for improvement, whereas MPC shows more immediate gains, underscoring the distinct cognitive processing demands.

These findings provide new perspectives and empirical support for metaphorical acquisition theory. First, the importance of cognitive processing depth is evident: rational processing significantly outperforms contextual guessing, particularly for MCC, emphasizing the role of intensive cognitive engagement in enhancing linguistic knowledge. This supports the view that rational processing facilitates the internalization of metaphoric structures, and is consistent with existing theories on the importance of intensive cognitive processing. Second, the limitations of multimodal inputs are evident. Although Multimodal Integration Theory highlights the reliance of MCC on conceptual networks and redundancy in modalities, the limited effect of input modalities on MPC suggests that high-quality textual inputs are critical. Rational processing paired with multimodal input fosters creativity and associative reasoning but can cause declines in MPC over time due to cognitive overload. Simplifying the information presentation or introducing multimodal inputs into stages may mitigate such interference. Third, the role of test times was consistent with Cognitive Information Processing (CIP) theory, highlighting distinct cognitive demands. MCC relies on long-term memory and conceptual integration and shows sustained improvement over time. In contrast, MPC depends on working memory and immediate creative thinking, which is consistent with the component model of creativity (Amabile, 1983). Gradual enhancement of MCC reflects the consolidation of long-term memory, whereas the decline in MPC underscores the constraints of working memory and the transient nature of creativity.

These findings emphasize the need to optimize rational processing and multimodal input strategies, while balancing immediate feedback and repetitive practice to sustain MPC over time.

6 Conclusion and implications

6.1 Conclusion

This study demonstrated that rational processing consistently outperformed contextual guessing in metaphor comprehension in the three testing sessions, with unimodal input yielding the competent results and exhibiting stable improvement over time. For metaphor production, rational processing with unimodal input excelled; however, overall, production declined in all conditions, especially under multimodal input. Test times significantly influenced metaphor comprehension, which improved progressively, whereas metaphor production was unaffected by input modality and declined under multimodal conditions. These findings highlight the importance of processing depth and cognitive load management, because rational processing effectively fosters metaphor comprehension by reducing cognitive overload. Additionally, spaced learning strategies were confirmed to be effective for metaphor comprehension but less so for production, necessitating further exploration of integrated approaches. This study validates cognitive theories in CSL contexts, such as Depth of Processing Theory and Cognitive Load Theory, offering insights into enhancing metaphor instruction and reinforcing the pivotal role of teachers in metaphor teaching.

6.2 Implications

Based on these findings, the implications for teachers and CFL learners in metaphorical idiom learning should focus on combining metaphor comprehension with productive use, providing metaphorical expressions and sentence structures, emphasizing cultural contexts through authentic materials, and fostering diverse learning contexts through regular assessments.

During the foundational cognitive phase (the day of instruction), presenting the original and symbolic meanings of idioms using unimodal text input helps learners avoid cognitive overload and the transition from concrete to symbolic understanding. For instance, "yíng rèn ér jiě" illustrates "Something separates when it touches the blade," symbolizing "Things are easily resolved." Simple tasks, such as identifying metaphorical phrases in a sentence, enhance metaphorical sensitivity. Incorporating imagery tied to cultural backgrounds intensifies understanding, such as relating "gāo shān liú shuǐ" to "Yu Boya plays the guqin for Zhong Ziqi" and "yǒu jiào wú lèi" to "Confucius accepted all kinds of students," transitioning information from working memory to long-term memory more effectively.

In the deepening application stage (1 week after instruction), adding multimodal video elements consolidated MCC and enhanced MPC. Moderate multimodal input engages more senses and strengthens the relationships with symbolic meaning. Fill-in-the-blank questions, sentence construction, and writing tasks reinforce comprehension and encourage output.

Optimizing the teaching process involves (1) reducing distractions from imagery by simplifying designs and focusing on core idiom imagery. For example, in "liǔ àn huā míng," retaining "willows, flowers, and sunshine" minimizes interference. Textual annotations, like "cāng hǎi sāng tián=biàn huà jù dà (change enormously)" or "shǒu zhū dài tù= bèi dòng děng dài (passive waiting)," enhance clarity. (2) Streamlining video content by removing unrelated scenes ensures focus on crucial lexical information. For instance, omitting the first 3 s of a video segment for "xiōng yǒu chéng zhú" can emphasize the crucial content, promoting intensive information processing. Additionally, interval learning strategies paired with analogy and association tasks train MPC, whereas regular reviews support long-term memory retention. Initial teaching should prioritize basic knowledge acquisition and metaphor awareness, whereas later stages should focus on intensifying metaphor understanding, productive use, and creative thinking.

7 Limitations and future prospects

This study has several limitations. First, the assessment may not fully reflect metaphorical competence due to the limitations of the assessment methodology and tools. Furthermore, the methodology is somewhat subjective and the introduction of more scientific research methods should be used in the future to increase the objectivity of the data. Second, the delayed posttests focused on short-term results, failing to observe longer-term performance and acquisition effects comprehensively. Future research could design longer experimental periods. Third, the semantic transparency of the idioms was included as a control in the design of this study, but it may still have had a potential impact on learners' processing and acquisition efficiency. A wider range of differences, such as low semantic transparency, medium semantic transparency, and high semantic transparency of the idioms, also deserve to be further explored in terms of their impact on metaphorical competence under different input modalities. Finally, variables that did not reach significant differences under current experimental designs and sample conditions cannot be conclusively deemed non-critical; adjusting experimental designs or introducing other potential variables (e.g., learners' cognitive styles, motivation, prior knowledge) could provide a more comprehensive and accurate exploration of CFL metaphor acquisition.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

This study was conducted in accordance with the ethical guidelines set out by Macau University of Science and Technology and approved by Ethical Review Board. All participants provided informed consent before taking part in the experiment, and their anonymity and confidentiality were maintained throughout the study. The study followed ethical guidelines for conducting research with human subjects, ensuring that no identifiable human images or personal data were included without explicit consent.

Author contributions

SL: Formal analysis, Investigation, Methodology, Software, Writing – original draft. YZ: Funding acquisition, Project administration, Supervision, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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