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ARTICLE

The role of consciousness in Chinese nominal metaphor processing: a psychophysical approach

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Abstract
Conceptual metaphor theory (CMT) holds that most conceptual metaphors are processed unconsciously. However, whether multiple words can be integrated into a holistic metaphoric sentence without consciousness remains controversial in cognitive science and psychology. This study aims to investigate the role of consciousness in processing Chinese nominal metaphoric sentences '*A是B*' *(A is[like]* B) with a psychophysical experimental paradigm referred to as breaking continuous flash suppression (b-CFS). We manipulated sentence types (metaphoric, literal and anomalous) and word forms (upright, inverted) in a two-staged experiment (CFS and non-CFS). No difference was found in the breakthrough times among all three types of sentences in the CFS stage, while literal sentences were detected more slowly than either metaphoric or anomalous sentences in the non-CFS stage. The results suggest that the integration of multiple words may not succeed without the participation of consciousness, let alone metaphoric processing. These findings may redefine 'unconscious' in CMT as 'preconscious' and support the indirect access view regarding how the metaphoric meaning is processed in the brain.

Keywords: conceptual metaphor theory; consciousness; continuous flash suppression; metaphoric sentences; unconscious

1. Introduction

Metaphors are an interdisciplinary research area involving linguistics, anthropology, neuroscience and sociology (Holyoak & Stamenković, 2018; Tang et al., 2017). Thus, metaphor and consciousness are closely related (Baars, 1998). Almost all hypotheses or theories concerning consciousness can be viewed as variants of the famous theoretical framework 'the metaphor of theater' since heuristic metaphors are vital for the understanding and dissemination of scientific theories among the public,

especially when scientists are faced with a novel topic without any precedent. For instance, the anatomist Harvey (1578–1657) used pumps to depict the heart in the human body, and the British physicist Rutherford (1871–1937) used planets to illustrate atomic structure. Additionally, conceptual metaphor theory (CMT), a key theoretical foundation for cognitive linguistics, provocatively claims that our brain processes most metaphors automatically and unconsciously (Lakoff, 1993; Lakoff & Johnson, 1999). It holds that predefined and fixed mappings exist between the various semantic components across the source domain and the target domain in a metaphor (for instance, 'LOVE IS A JOURNEY', in which 'traveler' is mapped to 'love', and 'problems' to 'obstacles'), and the mapping can result from the co-activation of corresponding neurons underlying subjective and sensorimotor experiences (embodied experiences) with little cognitive effort or consciousness (Gibbs & Chen, 2018; Lakoff, 1993). As Lakoff (1993, p. 245) asserted, 'The system of conventional conceptual metaphor is mostly unconscious, automatic, and is used with no noticeable effort, just like our linguistic system and the rest of our conceptual system'.

However, the unconsciousness of metaphor processing may be riddled by the controversy over the scope or boundary of consciousness in language comprehension. Although previous studies have demonstrated that orthographic, phonological, syntactic and semantic analyses of individual words can be automatic even when observers are consciously unaware of them (Berkovitch & Dehaene, 2019; Cheng et al., 2022; Costello et al., 2009; Yang & Yeh, 2011; Yeh et al., 2012), whether multiple words can be combined into a holistic meaningful phrase or sentence without consciousness has been controversial for decades in cognitive sciences and psychology (Moors et al., 2017; Sklar et al., 2018). Researchers have used various paradigms, including masking, crowding and continuous flash suppression (CFS, Tsuchiya & Koch, 2005), to obtain substantial evidence for the unconscious processing of compound words, phrases or sentences (Armstrong & Dienes, 2014; Hung & Hsieh, 2015, 2021; Sklar et al., 2012; Tu et al., 2020). Among them, CFS is a common psychophysical approach based on interocular rivalry, a fact that perception alternates between two eyes when different stimuli are presented to each eye. In CFS, the flashing, high-contrast masks presented to one eye dominate perceptual awareness until the targets presented to the other eye break into consciousness, which causes the target to remain 'subliminal' for up to several seconds (Tsuchiya & Koch, 2005). Many studies have adopted a variant of CFS known as the b-CFS (breaking continuous flash suppression) paradigm where the breakthrough time (the time for the invisible target to break off suppression into consciousness) is taken as an index of unconscious information processing (Jiang et al., 2007; Stein et al., 2011). Remarkably, Sklar et al. reported that three-word sentences in Hebrew with incoherent meanings (e.g., 'I *ironed* coffee') were found to break off CFS more quickly than semantically coherent sentences (e.g., 'I *drank* coffee') (Sklar et al., 2012). Using another variant of CFS (discontinuous flash suppression), Hung and Hsieh found that unconscious integration of multiple words in English occurred since a suppressed 2-word pair (birds eat) affected the lexical decision between an incongruent target word (drank) and a congruent one (worms) (Hung & Hsieh, 2021). Tu and his colleagues reported that Chinese four-character idioms (e.g., '青云直-上', rapid advancement in one's career) could be integrated as a meaningful whole when the first three masked characters were presented simultaneously rather than sequentially (Tu et al., 2020). Meanwhile, in a masked priming study, syntax could be processed in the absence of awareness, although the priming effect was relatively short-lived

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(Hung & Hsieh, 2015). In another improved masked priming study, passive voice sentences could be distinguished from active subordinate sentences, such as 'A is injecting B' and 'A is injected by B' (Armstrong & Dienes, 2014). Furthermore, some brain imaging and electrophysiological studies have demonstrated unconscious semantic or syntactic processing through neurological indicators regardless of the null effect in behavioral tasks (Axelrod et al., 2015; Batterink & Neville, 2013; Jiménez-Ortega et al., 2017). For example, a continuous left front partial negative component in the 100–400 ms time window (similar to N400, a well-known neurophysiological component for semantic violation[1]) was regarded as a sign of unconscious syntactic processing when there were invisible grammatical errors in consecutively presented 10-word sentences in a cross-modal attentional blink paradigm (Batterink & Neville, 2013). Another fMRI-CFS study by Axelrod et al. revealed that the brain language network could process long word sequences unconsciously by virtue of minimal but significant activity in the left frontotemporal area when processing six temporally segregated words at an interval of 400 ms (Axelrod et al., 2015).

Nevertheless, many researchers remain skeptical of high-level syntactic or semantic processing outside consciousness (Mongelli et al., 2019; Rabagliati et al., 2018; Yang, Tien, et al., 2017; Zhou et al., 2016). Although the findings of Sklar et al. are considered the first evidence of multiword integration under CFS, they conflict with the commonly reported breakthrough speed advantage induced by familiar (coherent) stimuli and have not been verified by recent large-scale replication studies (Cheng et al., 2019; Rabagliati et al., 2018; Yang, Zhou, et al., 2017). Cheng failed to replicate the result of Yang & Yeh regarding the emotional meaning integrated by two Chinese characters. Yang et al. found that Chinese idioms with four characters could not be integrated under the CFS priming paradigm. (Yang, Zhou, et al., 2017). When the first three words in the idiom '画龍點睛' (meaning 'drawing a dot in the dragon eye' but 'making the finishing point' metaphorically) were suppressed by CFS, the incongruent '雲' (cloud) not only affected the accuracy and response times of the location task but also induced N400 in comparison to the fourth congruent '睛' (eye). More recently, Mongelli et al. designed a novel text masking priming experiment in which Dutch words can appear successively (three words) or simultaneously (two words) to form a short sentence that is congruent or incongruent with the target picture (Mongelli et al., 2019). The congruent condition was that a masked/unmarked phrase, 'a man was pushing a woman', was followed by a picture of the corresponding action, while incongruence occurred when the sentence was followed by a picture of the opposite action (a woman was pushing a man). When the preceding sentence was not masked, a clear sense violation index N400 was observed, but it disappeared when just one or two words in the preceding sentence were masked. Thus, the more conservative view prevailed that any complex cognitive task, such as integrating multiple words, could by no means be accomplished without consciousness (Moors et al., 2019; Rabagliati et al., 2018; Zher-Wen & Yu, 2023).

Meanwhile, returning to cognitive linguistics, the issue of whether metaphor is a matter of unconscious thought has also been haunted by the controversy regarding the boundary of consciousness (Gibbs & Chen, 2018; Steen, 2011; Xu et al., 2016). The majority of metaphor research, especially in CMT, has focused on the 'unconscious'

[1]We thank one of the anonymous reviewers for more clarification on the component here.

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nature of metaphor; however, the deliberate metaphor theory (DMT)[2] distinguishes 'deliberate' metaphors, which require conscious awareness to handle cross-domain mapping, from 'non-deliberate' metaphors in which simple lexical disambiguation may suffice without implicating conscious comparisons across two domains (Steen, 2011, 2017). The career metaphor hypothesis may compromise the controversy between DMT and CMT, implying that novel metaphors entailing conscious cross-domain mapping can become categorized and unconscious due to wide applications and long-term use (Bowdle & Gentner, 2005). However, it remains of great necessity to revisit the term 'unconscious', especially for conventional metaphors (dead metaphors) in CMT, with a certain visual 'blinding' experimental paradigm.

The central objective of our research is to examine whether metaphoric meaning can be processed unconsciously. We followed Sklar et al. (2012) by using the b-CFS paradigm. It is hypothesized that longer stimulus durations under CFS can trigger stronger and more sustainable brain activation, facilitating semantic integration of multiple words or short sentences (Stein et al., 2011; Tsuchiya & Koch, 2005). Notably, previous literature reports that nearly half of all b-CFS studies have used a binocular control experiment stage (non-CFS) in which subjects perform the same tasks as in CFS while the stimuli are not subject to interocular suppression(Stein, 2019). The logic behind the control experimental design is that the stimuli and tasks are essentially the same for both non-CFS and CFS; thus, the difference between the two stages is only the presence or absence of 'conscious awareness' (Kido & Makioka, 2014). The partial awareness hypothesis states that the boundary between unconscious and conscious is not all-or-none but rather a nonlinear hierarchy with several intermediate states called 'precociousness' or 'partial awareness' (Kouider et al., 2010). Furthermore, the hypothesis supports the global neuronal workspace model in conscious awareness or consciousness literature, where two types of unconscious states are distinguished: subliminal and preconscious (Dehaene et al., 2006). In the subliminal state, bottom-up, stimulus-driven processing is too weak to reach the conscious state, while semantic information can be used for further processing once some top-down attention is available in the preconscious state. Here, information processing under the CFS condition is regarded as 'subliminal', while the processing under the non-CFS condition can be regarded as 'preconscious'.

In addition, we manipulated the form or orientation of the characters (upright or inverted) to dissociate high-level semantic integration from low-level orthographic processing. The inversion of a Chinese character did not change the characters' structure (number of strokes) but altered the familiarity or the overall orthographic features. Some scholars have contended that we must exclude effects from low-level processing, such as inversion or fragments, so as to prove that high-level processing is responsible for suppression time differences (Gayet et al., 2014). Generally speaking, the accuracy and speed of recognition of Chinese characters may be reduced if viewed upside down, which is considered a hallmark of orthographic processing in prior literature on visual cognition (Kao et al., 2010; Luo et al., 2017; Wang et al., 2011). However, some previous CFS studies have displayed that the inversion of Chinese characters contributes to a faster breakthrough time from interocular suppression when processing double-character words (compound words) and four-character idioms, even if a higher level of semantic processing is not found (Yang & Yeh,

[2]We thank one of the anonymous reviewers for clarifying the theory.

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2011; Yang, Zhou, et al., 2017). Thus, the reasoning behind our two-factor design was that if one type of sentence could break off suppression faster than the other because of higher-level semantics, this speed difference would vanish or reduce when the stimuli are presented upside down; otherwise, the difference in suppression times between the two sentence types continued in the inverted condition, low-level variations in physical properties would be responsible.

Regarding the cognitive mechanism of metaphor processing, it has also been debated to what extent understanding metaphors is more laborious than understanding literal sentences (Gibbs & Chen, 2018; Steen, 2017). There are two main contrasting views. First, the indirect access model, or 'standard pragmatic view', holds that metaphoric language is merely defective and a revolt against literal meaning, which takes priority in thinking and communication (Grice, 1989). Both behavioral and ERP evidence indicates that metaphor processing consumes more cognitive resources (Coulson & Van Petten, 2002; Lai et al., 2009; Noveck et al., 2001; Pynte et al., 1996; Wu et al., 2012). In contrast, the direct access model or 'parallel processing view' suggests that metaphoric meaning can be directly accessible or processed in parallel with literal meaning in an appropriate context (Bambini et al., 2011; Gibbs & Chen, 2018; Giora, 1997; Glucksberg et al., 1982). However, the abovementioned behavioral or ERP evidence has been obtained mostly in conscious or unmasked experimental environments, anything but 'unconscious' processing in strict senses. To the best of our knowledge, only one study has investigated unconscious metaphor processing with a cross-modal masked priming paradigm combined with ERP technology (Weiland et al., 2014). The study demonstrated that the semantic network attributed to masked literal primes contributed to saving labor in processing target metaphors, supporting the 'indirect access view' rather than the 'direct access view' regarding metaphor processing in English. However, it still entails more evidence from other languages.

Chinese characters are rooted in the ancient people's careful observation and deep understanding of natural things. The evolution process from the concrete material world to symbolic Chinese characters may have involved substantial metaphoric thinking over several thousand years, which inspires us to investigate the role of consciousness in processing conventional Chinese metaphoric sentences (five characters). We used the nominal metaphoric sentences 'A 是 B'(*A is[like] B*)as stimuli, such as '时间是金钱' (time is money) and '儿童是花朵' (children are flowers). Our research hypothesis was that although 'time' and 'money' or 'children' and 'flowers' belonged to different semantic categories, people could still process them unconsciously by activating the correspondence between two regions in the brain (Gibbs & Chen, 2018; Lakoff & Johnson, 1999). This sentence pattern was suitable for our study because it was the most typical construction containing both the target domain A and the source domain B with a syntactically linking word '是' in between such that it was also easy to design comparable literal counterparts well-matched both in word type and function, such as '香蕉是水果' (bananas are fruit). Furthermore, in order to replicate Sklar et al.'s experiments as much as possible, we included a third pattern, which was anomalous or semantically unacceptable, such as '时间是水果'. Given the intriguing 'incoherence advantage' of Hebrew phrases over breaking times in their findings, we predicted that Chinese anomalous sentences would break off CFS suppression the fastest and metaphoric sentences could be faster than literal sentences because metaphors were 'less coherent' than literal meanings in the 'indirect access view'. Last, the comparisons would also address our minor research question

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concerning whether literal meanings could be extracted from multiple Chinese words in the absence of consciousness as Hebrew words could in Sklar et al. (2012).

2. Method

2.1. Participants

A total of 36 university students (21 females) were recruited, aged from 21 to 28 years, with an average age of 24.1 years (SD =1.7). They were all healthy native Chinese speakers without the history of mental illness. Most participants were not myopic or astigmatic, and 40% of them had a corrected visual acuity of not less than 1.2 with glasses. All were unaware of the purpose of the experiment and signed written informed consent in advance. The experiment comprised two stages: Stage I (CFS) with a stereoscope for 40 minutes and Stage II (non-CFS) without a stereoscope for 20 minutes. Each participant received a certain amount of financial compensation. The experimental protocol was approved by the Ethics and Human Research Committee of the Key Laboratory of Neuro-information, Ministry of Education, University of Electronic Science and Technology of China (UESTC).

2.2. Apparatus

The experiment was conducted in a specialized laboratory of visual psychophysics. The visual stimuli were displayed on a 21-inch Dell color CRT display with an average brightness of 22 cd/m^2, a frame rate of 80 Hz and a spatial resolution of 1280 × 1024 pixels. MATLAB 2013b and Psychtoolbox were used to write the experimental program (Brainard, 1997). Through a mirror stereoscope comprising two groups of small mirrors (two by two forming a 45° angle), the participant observed the target stimulus presented in a font of Courier New 25 on a white background in monocular viewing mode (CFS). The stereoscope was placed 57 cm away from the displayer so that each eye could only see half of the display and the two different stimuli being presented to two eyes produced interocular suppression. During the experiment, participants were instructed to keep their heads on a chin rest as still as possible (otherwise, readjust) and respond quickly with the keys 'Z', 'O' and 'K' on a standard keyboard.

2.3. Stimuli

The experiment used the sentence pattern 'A 是 B' (A is B), where A and B were Chinese two-character nouns. The experimental materials included metaphoric sentences, 30 literal sentences (short for 'sentences with literal meaning') and 30 anomalous sentences (or semantically unacceptable sentences). They were adapted from the material inventory of a previous study through a self-made questionnaire (Wu et al., 2012). First, we selected 124 metaphoric sentences from the inventory to make the questionnaire [e.g.,生命是旅程(life is a journey), 教师是园丁(a teacher is a gardener)] and distributed it on an online survey platform called Survey Star powered by www.wjx.cn. Seventy-five volunteers were then asked to score every sentence based on a seven-point familiarity and semantic acceptability scale. After the statistics of 90 valid questionnaires, 45 sentences with the highest familiarity were obtained (M = 5.96, SD = 0.69). Another 45 literal meaning sentences

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[e.g., 椅子是家具(a chair is furniture),香蕉是水果 (a banana is fruit)] and 45 wrong sentences [e.g., 真话是汽车(truth is a car), 爸爸是网站(dad is a website)] were also screened from the inventory. All three kinds of sentences were scored on a 7-point familiarity scale by another 25 volunteers from the same background as the participants. Finally, 120 sentences were secured as the experimental stimuli, with 30 sentences in each category. The mean values of semantic familiarity of the three categories with standard deviations are shown in Table 1. The statistical analysis revealed no significant differences in familiarity between metaphoric and literal sentences ($p > 0.05$), although there were significant differences between metaphoric and anomalous sentences as well as between literal and anomalous sentences ($ps < 0.001$).

2.4. Procedure

Prior to the experiment, the participants underwent a simple dominant eye test (Porta, 1593). Four of the 36 participants were classified as left-eye dominant, and the rest were classified as right-eye dominant. Those who had consistently achieved accuracy above 90% in 20 to 60 practice trials could continue the two-session formal experiment. Both stages include a text visibility judgment (Task 1) and a sentence position judgment (Task 2). Participants were required to perform a two-alternative forced task in the interval between the two stages to guarantee that they did not perceive the majority of suppressed sentences. Figure 1 illustrates a schematic diagram of the two stages of the experiment.

Experiment Stage I (CFS) started with two symmetrical black frames (viewing angle 10.70° ×10.70°, thickness 0.2°) on a white background and a cross fixation point (0.8° ×0.8°) in each. The participants were instructed to secure their chin on the chin rest and look into the mirrors without frequent blinking. The experimenter adjusted the stereoscope to fuse the participant's eyes until he or she could see only a frame with a fixation point in their field of vision. The target sentence appeared in one eye as soon as the participant pressed any key, while dynamic Mondrian images (5.5° × 5.5°) continuously flashed in the other. The Mondrian masking images consisted of a series of squares, which changed color, size and contrast randomly and flashed at a rate of 10 Hz. The target sentence was presented directly above the fixation point (the distance from the mid-word '是' (is or are) was of visual angle 1.27°), and the contrast continued to rise from 0% to 50% and remained unchanged within 500 ms. To ensure that the target was not visible initially and to minimize the effect of anticipation, the presentations of the target stimuli were delayed by 0, 100 and 200 ms randomly after the onset of flashing images. Participants were asked to press the 'Z' key as soon as they could see any part of a character breaking through flashing images and then use the keys to determine the location of the target, respectively: 'O' for the position above the fixation and 'K' for the position below. The next trial started upon the key press or

Table 1. Mean and standard deviation (in brackets) of familiarity scoring for all types of sentences

Types	Examples	Familiarity
Metaphoric	生命是旅程 Life is a journey	6.37(0.35)
Literal	老虎是动物 The tiger is an animal	6.45(0.2)
Anomalous	爸爸是网站 Dad is a website	1.83(0.09)

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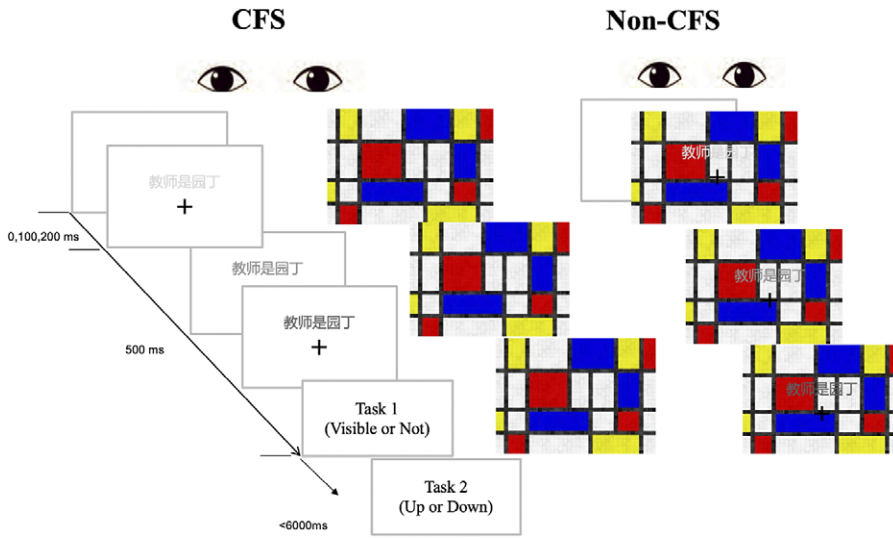

Figure 1. Schematic diagram of the CFS stage (left) and non-CFS stage (right). The contrast of "教师是园丁" (Teachers are gardeners) varied from 0% to 50% to ensure that the target was not visible initially.

after 6 seconds without a response. Each target sentence appeared twice in the upright form and inverted form. The presentations of stimuli were balanced between two vertical halves of the screen. The subjects could choose to rest their eyes after every 45 trials over a total of 540 trials. The experimental program collected both RTs and accuracies in Task 1 (from onset of the target sentence to the 'Z' response) and accuracy in Task 2.

The procedure in Stage II (Non-CFS) differed from that of the CFS stage in the following three ways. First, the subjects saw only a box with their naked eyes and perceived any part of a character in the target sentence slowly emerging from flashing squares. Second, the subjects reacted quickly when they perceived the target binocularly because there was no interocular suppression. The contrast gradient time of target stimuli was adjusted from 500 to 3300 ms to facilitate comparison with the data in Stage I based on the experience in a previous CFS study with Chinese emotional words (Yang & Yeh, 2011). Third, the total number of trials was only a quarter of that in Stage I (135 trials).

Additionally, in the interval of two stages, participants were given a subjective visibility test of 180 two-character words, half of which had been included in the previous target set. Participants were asked to decide whether each word had been seen in the previous experiment as quickly as possible. The statistical results showed that the average accuracy (SD) was 32.4% (SD = 17.8%), far below the 50% chance level ($t32 = -5.036$, $p < 0.001$, two-tailed), which confirmed that most participants (only two over 60%) could not consciously perceive the content of suppressed target sentences.

3. Analysis and results

Two participants withdrew due to difficulty fusing their eyes during the experiment, and the data from another two whose detection accuracy exceeded 60% in Stage I

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were deleted because they were deemed 'contaminated' by consciousness. The data of the remaining 32 subjects were valid and analyzed across stage 1 (CFS: interocular) and stage 2 (non-CFS: binocular). Since the position judgment rate of all subjects was high, we only calculated trials in which subjects responded correctly. To exclude outliers, we excluded trials with RTs (reaction times) greater than 6000 ms (set as timeout) or lower than 200 ms and trials in which RTs were three standard deviations from the sample mean. The reason for this data screening was that if the target was not detected within 6000 ms or was detected abnormally quickly compared to the sample mean, the observed RTs might reflect unknown factors (such as inattention or a wrong button press caused by anxiety). Based on these criteria, however, under 5% of the total number of corrected trials were excluded from our analysis. The remaining data on both RTs and accuracies were analyzed with repeated measures analysis of variance (ANOVA) using SPSS 2.0 for two factors 2 (word form: upright, inverted) × 3 (semantic type: metaphoric, literal and anomalous), and the results are shown in Figure 2 (CFS) and Figure 3 (non-CFS).

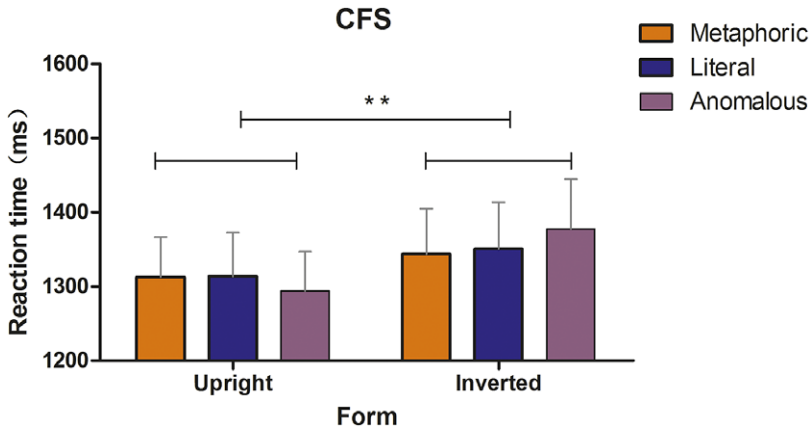

Figure 2. RTs for metaphor, literal, and anomalous sentences in the CFS phase. Error bars indicate standard errors of the mean (n=32). * *: p< 0.01

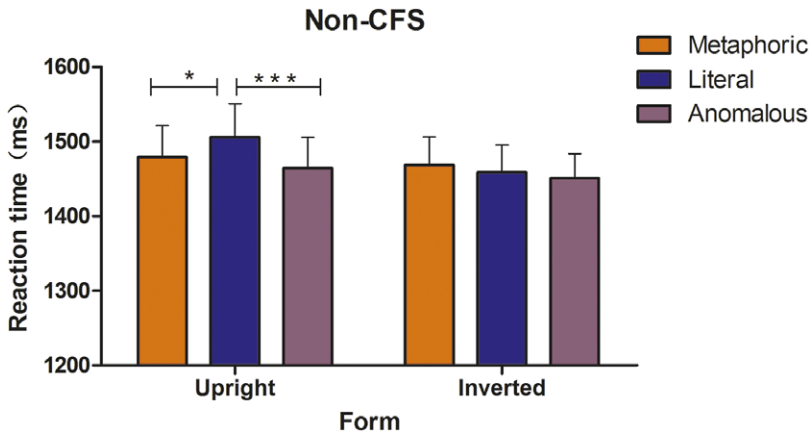

Figure 3. RTs for metaphor, literal, and anomalous sentences in the non-CFS phase. Error bars indicate standard errors of the mean (n=32). *: p < 0.05, * * *: p < 0.001

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In Stage I (CFS), the main effect of semantic type for RTs was not significant $M_{\text{metaphoric}}$ = 1328 ms, M_{literal} = 1332 ms, $M_{\text{anomalous}}$ = 1336 ms, $F(2,62) = 0.141$, $p > 0.05$, $\eta^2 = 0.005$. In contrast, the main effect of word form was significant, M_{upright} = 1307 ms, M_{inverted} = 1357 ms, $F(1,31) = 7.926$, $p < 0.01$, $\eta^2 = 0.204$, and the upright sentences broke through CFS suppression 50 milliseconds faster on average than the inverted sentences. There was no significant interaction effect between semantic type and form, $F(2,62) = 1.363$, $p > 0.05$, $\eta^2 = 0.042$. Furthermore, the accuracy analysis displayed no significance for the main effects of semantic type, $F(2,62) = 1.842$, $p > 0.05$, $\eta^2 = 0.056$, word form, $F(1,31) = 0.949$, $p > 0.05$, $\eta^2 = 0.030$ or the interaction effect $F(2,62) = 1.324$, $p > 0.05$, $\eta^2 = 0.041$. No response-accuracy trade-off was found.

In Stage 2 (Non-CFS), the main effect of semantic type on RTs was significant, $F(2,62) = 4.851$, $p < 0.05$, $\eta^2 = 0.135$, but the main effect of character form was not, $F(1, 31) = 2.086$, $p > 0.05$, $\eta^2 = 0.063$. This interaction between word form and semantic type was significant, $F(2,62) = 4.326$, $p < 0.05$, $\eta^2 = 0.122$. Multiple comparisons indicated that there was a significant difference between literal and anomalous sentences ($p < 0.05$, $M_{\text{metaphoric}}$ = 1474 ms, M_{literal} = 1483 ms, $M_{\text{anomalous}}$ = 1458 ms) and a marginal difference between metaphoric and anomalous sentences ($p = 0.053$), but no difference between metaphoric sentences and literal sentences ($p > 0.05$). The simple effect analysis showed that the RTs for all three types of sentences were not significantly different under inverted conditions. Only in the upright condition was there a significant difference between the literal and anomalous, sentences ($p < 0.001$), between metaphoric sentences and literal sentences ($p < 0.05$), and a marginally significant difference between metaphoric sentences and anomalous sentences ($p = 0.067$), $M_{\text{upright \& metaphoric}}$ = 1480 ms, $M_{\text{upright \& literal}}$ = 1506 ms, $M_{\text{upright \& anomalous}}$ = 1464 ms. The overall trend indicated that the anomalous sentences broke through the CFS suppression and entered consciousness the fastest, the literal sentences the slowest and the metaphoric sentences in between. However, the analysis of accuracies showed no significance level for the main effect of either semantic type, $F(2,62) = 0.098$, $p > 0.05$, $\eta^2 = .003$, or word form, $F(1,31) = 0.371$, $p > 0.05$, $\eta^2 = 0.012$, or for the interaction effect $F(2,62) = 0.486$, $p > 0.05$, $\eta^2 = 0.015$. The response-accuracy trade-off remained unseen.

4. Discussion

After investigating the role of consciousness in comprehending Chinese nominal metaphoric sentences in a two-staged experiment (CFS and non-CFS), we obtained the following three findings. First, the meaning of Chinese sentences cannot break through interocular suppression, whether metaphoric or literal. Second, the inversion effect was obvious, with upright sentences entering consciousness faster than inverted sentences. Third, in the non-CFS stage, when the sentences were upright, the metaphoric meaning broke out of perceptual interference or CFS-like masking faster than the literal meaning but more slowly than the anomalous sentence. The findings of this study support the global neuronal workspace model in which subliminal states and preconscious states are distinguished (Dehaene et al., 2006). In the subliminal state, multiple words cannot be processed up to the holistic semantic level, let alone metaphoric meaning. In contrast, in the preconscious state (non-CFS), Chinese

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sentences could be processed to the high-level semantic or even metaphoric level due to less suppression or some degree of top-down attentional resources.

Above all, neither literal nor metaphoric meaning of Chinese short sentences could be processed unconsciously. Our findings were consistent with those of another Chinese CFS study in which four-character idioms could not be integrated through five experiments (Yang, Zhou, et al., 2017). Even under the similar b-CFS paradigm (Experiment 5), the researchers did not find any difference in reaction times to break through suppression in recognizing the correct four-character idiom compared to the control (four-character random sequence). Moreover, our finding was also in line with those of previous studies with other 'blinding' measures (Mongelli et al., 2019; Zhou et al., 2016). Zhou et al. reported the failure to integrate four-character Chinese idioms (e.g., '骑虎难-下'; it is difficult to get *off* a tiger) in the visual crowding paradigm. The incongruence effect ('骑虎难-上', it is difficult to get *on* a tiger) was not present in the crowding condition but was in the non-crowding condition. Meanwhile, Mongelli et al. did not find an incongruent effect when masked short phrases were followed by a target picture describing the opposite action regardless of whether the phrases were presented successively or simultaneously. Thus, these findings support our hypothesis that consciousness may play a crucial role in the process of sentence-level integration.

The null effect of three categories in the CFS stage is at odds with both our predictions on metaphor processing outside of consciousness and 'incoherence advantage' reported by Sklar et al. (2012). One may hold that language type may be the reason for the inconsistency. Hebrew differs from Chinese characters in orthography: Hebrew is alphabetic while Chinese is ideographic. However, this interpretation is untenable, as the recent replication study has failed with English equivalents, which are both alphabetic (Rabagliati et al., 2018). Surprisingly, the results in our non-CFS stage coincide with those in Sklar et al.'s CFS condition despite the inclusion of a third kind of sentence (metaphoric) in the current study. Unfortunately, Sklar et al. did not conduct the classic non-CFS experiment as we did but adopted a control experiment involving pure conscious processing. Thus, we suspect that 'incoherence advantage' at breaking times might have resulted from preconscious processing rather than subliminal processing. Our suspicion may have been increased by the fact that there is typically a breakthrough speed advantage for familiar (coherent) stimuli in most of b-CFS literature (Stein, 2019). Thus, we posit that the integration of multiple words may have been achieved preconsciously rather than subliminally.

Other previous remarkable findings of unconscious integration of multiple words are also challenged methodologically or theoretically. Regarding CFS evidence, Axelrod et al. (2015) found a selective response to suppressed sentences compared to unpronounceable nonwords in the left frontal cortex. However, since sentences and chains of nonwords differ significantly on a semantic level, nonwords without any mapping to meaning may not contribute specifically to real integration. Another CFS-like study either did not provide objective awareness tests or used above-chance awareness in addition to the relatively small sample size (Hung & Hsieh, 2021). In addition, Batterink and Neville (2013) reported evidence of unconscious syntactic processing in an attentional blink paradigm. However, there is evidence that attentional blinking disrupts conscious report behaviors but does not affect perceptual integration mechanisms or feedback processing (Luck et al., 1996). Furthermore, Although Nakamura et al. (2018) reported that the N400 effect was triggered by

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masked subject-verb disagreement (e.g., dog-open) in contrast to subject-verb agreement (e.g., dog-runs), the authors confessed that the effect might simply reflect a physical-level difference (or response bias) in words between congruent (dog-runs) and incongruent (dog-opens) pairs rather than a true semantic integration process. Recently, despite the remarkable result that masked Chinese idioms (e.g., '青云直上', Qingyun Zhi-shang) can be integrated if the masked primes are presented simultaneously, further investigation is required to verify whether the inclusion of a number of aware participants in their statistics compromised the degree of 'unconsciousness' (Tu et al., 2020). More recently, Zher-Wen and Yu (2021) echoed our findings in their study by claiming that the acquisition of semantic information and generalization of task-priming can only occur under less visible conditions but not subliminal ones (Zher-Wen & Yu, 2021). Taking all of this evidence into consideration, it appears that reports of subliminal multiword integration have been largely disproven (Zher-Wen & Yu, 2023). Therefore, we believe that the semantic integration of temporally or spatially separated characters, whether metaphoric or literal, requires the participation of consciousness.

Next, inverted sentences broke off CFS suppression more quickly than upright sentences, even though no significant difference was found in breakthrough times between the three kinds of sentences. This inversion effect is consistent with some previous CFS-based evidence that both two-character words (compound words) and four-character idioms were associated with short breakthrough times when they were presented upside down compared to when they were presented upright (Yang & Yeh, 2011; Yang, Zhou, et al., 2017). It suggests that the orientation of Chinese characters can be processed without consciousness, echoing a pioneering CFS study in which familiar words entered consciousness more quickly than unfamiliar words in the unconscious state (Jiang et al., 2007). This finding also confirms that our experimental procedure had sufficient detection power for Chinese character processing up to the sentence level. In contrast, the inversion effect vanished in current preconscious experiment (non-CFS). The statistical analysis showed that the interaction effect between Chinese character form and semantic type was significant, although the main effect of Chinese character form was not. The simple effect analysis revealed a significant difference in the response time of the three types of sentences only in the upright condition. We speculate that a complex interaction existed between the processing of Chinese character form and semantics under 'partial awareness' in which some amount of attention resource enabled the effect of semantic differences among the three types of sentences to exceed that of character form, resulting in the absence of the inversion effect in the non-CFS experiment. In brief, the presence or absence of the inversion effect of Chinese characters in the two different stages of the experiment also confirmed that our experimental design was reliable and effective.

Regarding the linguistic community's debate on the unconscious processing of metaphors (Gibbs, 2011; Steen, 2011, 2017; Xu et al., 2016), we propose that this debate can be solved by redefining the connotation of the 'unconscious' of conceptual metaphors. That is, 'unconscious' in the assumption of Lakoff (1993) should be 'preconscious' rather than 'subliminal', as distinguished in the global neuronal workspace model. The following three points will be the basis for the proposal. First, the premise of Lakoff's definition of 'unconscious' is 'just like our linguistic system and the rest of our conceptual system', in which he takes it for granted that our language or even conceptual system works unconsciously.

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However, according to the above-mentioned literature review, there is no agreement on whether language can be processed up to the semantic or conceptual level in the subliminal unconscious (Baumeister & Masicampo, 2010; Gayet et al., 2014; Moors et al., 2017, 2019; Sterzer et al., 2014). Therefore, the premise of Lakoff's view is not necessarily true. Second, Gibbs, a proponent of CMT, believes that 'the use of metaphoric language is usually unconscious, but it depends on how consciousness is defined' (Gibbs, 2011), which echoes our proposal. What linguists such as Gibbs refer to as 'unconscious' is probably what the global neuronal workspace model classifies as 'preconscious'. In the current non-CFS experiment, it was under such 'preconsciousness' that metaphors were distinguished from literal sentences through overcoming the CFS-like perceptual interference (Kido & Makioka, 2014). Additionally, it is worth mentioning that Lakoff's original statement contains the word 'mostly' to limit the scope of 'unconscious'. One direction for future empirical exploration could be more explicit delineation of the scope of Lakoff's wording of 'mostly'. Third, Gibbs clearly cited the example of the Stroop effect and the case of skilled drivers' effortless driving to illustrate the connotation of 'automatic' (Gibbs & Chen, 2018). The Stroop effect describes the fact that people's automatic processing of word meaning slows down their naming of the font color when the meaning and the color are inconsistent. However, this classic experimental effect is based on the fact that subjects are partially 'aware' of the color of the word. Moreover, according to Gibbs, 'skilled driving appears to be an automatic skill, and in most cases, conscious control is not required'. In our view, he was likely to equate 'attention' with 'consciousness' in this instance, but there is a significant difference between the two terms (Tamietto & De Gelder, 2010). In brief, the term 'unconscious' in CMT theory is close to the connotation of 'implicit' or 'preconscious' rather than 'subliminal' in psychology (Zher-Wen & Yu, 2023).

Finally, the results of the preconscious condition in our experiment (non-CFS) support the indirect access view with regard to metaphoric processing (Grice, 1989; Lai et al., 2009; Pynte et al., 1996). Based on the partial awareness hypothesis and the global neuronal workspace model, in the preconscious state where some top-down attentional resources are available, people have a biased cognition of things and are more inclined to capture things that meet the expected characteristics (Dehaene et al., 2006; Kouider et al., 2010). In this sense, semantically coherent or most expected sentences (literal meaning) may capture the most of attentional resources at the expense of reaction speed in localization task, resulting in the longest reaction time. This happens when participants are required to judge the position of targets(localization) as quickly as possible, just as the automatic access of word meaning may slow down the color naming task in Stroop effect. In contrast, semantically unacceptable or least expected sentences (anomalous meaning) may capture the least of attentional resources, resulting in the shortest reaction times. It is also plausible that metaphoric sentences afford moderate reaction times because they are less expectable than literal sentences but more expectable than anomalous sentences. This interpretation is in accord with Weiland et al.'s 'literal meaning first' claim in the cross-modal masked priming paradigm that automatic literal processing could pre-activate the semantic network of metaphoric meaning that would otherwise be 'more laborious' to process (Weiland et al., 2014). However, this interpretation does not align with the fact that familiar or meaningful stimuli usually have a breakthrough speed

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advantage.[3] We attribute the misalignment to the difference between CFS stage and non-CFS stage. In CFS, there is only bottom-up processing due to strong interocular suppression while some top-down attentional resources are available due to less suppression induced by CFS-like perceptual interferences in non-CFS (Kido & Makioka, 2014). To our knowledge, the present study might be the first attempt to validate the priority of literal meaning processing through the psychophysical experimental paradigm (CFS or non-CFS) rather than those conventional measures like visual masking. Nevertheless, given the inherent psychological complexity of response times and current context-free experimental design, we cannot rule out the direct access view that metaphoric meaning can be processed in parallel with literal meaning in a suitable context (Bambini et al., 2011; Coulson & Van Petten, 2002). In the future, CFS and more sensitive ERP techniques should be combined to explore the time course of metaphor processing in the absence of consciousness.

5. Conclusion

The present study was designed to determine the role of consciousness in understanding Chinese metaphoric sentences in the b-CFS paradigm. Our results indicated that different stages of unconsciousness can modulate the processing level of Chinese metaphoric sentences. Neither metaphoric nor literal meaning could be processed in the subliminal state (CFS). In the preconscious state (non-CFS), metaphoric meaning may be partially processed automatically, but it is generally less thorough than the literal meaning in sentence processing. The findings of this study suggest that the term 'unconscious' in CMT theory should be redefined as 'preconscious' and support the indirect access view on the mechanism of metaphor processing in the brain.

Data availability statement. The raw data supporting the conclusion of this article are available at https://osf.io/6974h/?view_only=8287a5316c4740a3b388f1f23082ee33.

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Competing interest. The authors declare none.

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