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Semantic accessibility effects of character semantic radicals in Chinese phonograms' recognition

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Introduction: Prior research concentrated on testifying to the presence of the semantic activation of semantic radicals as well as the separate role of a couple of modulating factors like Transparency of phonograms, Genuineness of phonograms, and Position of semantic radicals.

Method: The present study first proposed a hierarchy on the ease of semantic activation, namely, a hypothesis on the semantic accessibility of character semantic radicals in Chinese phonogram recognition, and empirically investigated the hypothesis. Specifically, the three modulating factors were manipulated in a lexical decision task.

Results and discussion: The highest semantic accessibility was observed for the character semantic radicals seated in the high-frequency positions of opaque phonograms, followed by the character semantic radicals seated in the high-frequency positions of transparent phonograms, and the lowest semantic accessibility was observed for the character semantic radicals seated in the high-frequency or low-frequency positions of pseudo-phonograms. Results partially supported the hypothesis, suggesting that the semantic behavior of character semantic radicals was shaped by the host phonograms, which embodied the configuration of such modulating factors as phonograms' transparency, genuineness, and semantic radicals' position.

KEYWORDS

character semantic radicals, semantic accessibility, modulating factors, Chinese character recognition, semantic processing

Introduction

The Chinese writing system comprises two primary character types: simple characters and compound characters. Among compound characters, ideo-phonetic compounds, or phonograms, constitute the predominant category, accounting for approximately 81% of Chinese characters (Chen et al., 1996). Radicals, the building blocks of compound characters, originate from simple characters through historical evolution (Wang D. et al., 2019). Some simple characters underwent simplification to become non-character radicals, while others retained their independent status as character radicals (Wang D. et al., 2019). Character radicals exhibit dual functionality: they may serve as semantic radicals, contributing to meaning representation, or as phonetic radicals, offering pronunciation guidance (Wang D. et al., 2019). Semantic and phonetic radicals together constitute phonograms. Structurally, semantic radicals predominantly occupy the left position in left-right configured phonograms, whereas phonetic radicals typically appear on the right because

∼90% of left-right structured phonograms (constituting two-thirds of all phonograms) follow a semantic-phonetic (SP) pattern, while only 10% exhibit a phonetic-semantic (PS) arrangement (Zhang et al., 2014). Functionally, semantic radicals primarily fulfill indicative and categorizing roles, while phonetic radicals mainly provide phonological information (Li, 1996; Zhang and Wang, 2024; Lee et al., 2006; Wang et al., 2016). For instance, the phonogram "踩" (/cai3/, to trample) consists of the left semantic radical "足" (/zu2/, foot), which giving hints to the phonogram's meaning and categories (foot-related actions), and the right the right phonetic radical "采" (/cai3/, to pick), which cues the pronunciation (/cai3/). This structural and functional dichotomy exemplifies the systematic organization of Chinese phonograms, wherein semantic and phonetic radicals operate synergistically to facilitate character recognition and processing. The semantic relatedness between the semantic radical and the phonogram in which it occurs, namely transparency, is variable. For instance, some characters, such as such as "踩" shown above, are highly connected in semantics with their semantic radical "⻊" (i.e., semantically transparent characters), whereas other characters have no immediately intuitive semantic connections with their embedded semantic radicals (i.e., semantically opaque characters), e.g., "踌" (*to hesitate*) or "距" (*to be apart from*).

Previous empirical research on the processing of semantic radicals

Previous studies have provided substantial evidence for the semantic activation of character semantic radicals. However, whether non-character semantic radicals can also be semantically activated remains uncertain. For example, in a primed naming experiment, Zhou et al. (2013) manipulated semantic relatedness between character semantic radicals in primes and targets to explore the sub-lexical semantic activation of semantic radicals. All the primes were semantically opaque characters. Results showed that targets preceded primes with related semantic radicals were named faster than those preceded primes with unrelated semantic radicals (e.g., as for the target "箭", *sword*, when following the prime with related semantic radical "弓", *bow vs.* when following the prime with unrelated unrelated semantic radical "禾", *rice plant*). The priming effect indicated that character semantic radicals could be activated when embedded in characters. Similarly, Tong et al. (2021) employed a lexical decision task using character semantic radicals as primes, and found that transparent targets were responded faster than controls, while opaque targets were responded slower than controls. These results support that character semantic radicals were activated and then facilitated/inhibited the recognition of the whole character targets. In contrast, Chen and Weekes (2004), using a radical priming task, did not find a significant difference between the response latency to semantically transparent characters and that to opaque ones, suggesting the inactivation of non-character semantic radicals. However, more nuance findings come from (Wang B. et al., 2019), who employed a similar priming paradigm requiring participants to judge the direction of actions suggested by Chinese body action verbs. These verbs were all phonograms embedding with character semantic radical "⻊" or non-character semantic radical radical "扌". The results showed that, under the radical-primed the action directions suggested by target phonograms and their semantic radicals were congruent, the response times were shorter, as compared to that when action directions suggested by target phonograms and their semantic radicals were incongruent. This result indicated that semantic information of character or non-character semantic radicals, could be activated and acted on the processing of phonogram recognition.

Beyond demonstrating the presence or absence of semantic activation of semantic radicals, many studies have examined factors modulating the semantic behavior of semantic radicals. Semantic transparency is a well-studied variable. For example, Zhang and Zhang (2016) employed a lexical decision paradigm to investigate the processing efficiency of Chinese characters in relation to their phonogram transparency. Their findings demonstrated significantly faster response latencies for targets exhibiting both semantic and grammatical consistency (S+G+) between semantic radicals and their host phonograms, as opposed to those displaying semantic inconsistency despite grammatical consistency (S-G+). This observed latency advantage provides compelling evidence for differential activation patterns of semantic radicals, with stronger facilitation effects occurring in semantically transparent character configurations compared to opaque ones. With the same task, Wang et al. (2017) reported a shorter reaction time and a smaller P200 (160–230 ms), and a larger N400 (320–420 ms) for transparent targets relative to opaque ones. The smaller P200 was explained as an easier extraction of semantic information of embedded semantic radicals, and the larger N400 was interpreted as showing greater semantic activation of embedded semantic radicals in the late stage of phonogram recognition. This result indicated that the semantic radicals embedded in transparent characters were extracted more easily and activated stronger than those embedded in the opaque characters. Similarly, using a semantic transparency judgment task in which participants were asked to judge whether target phonograms were transparent, Hui-Wen Hsiao et al. (2007) found a faster and more accurate response for semantically transparent targets as compared to semantically opaque ones, which suggested an easier activation of semantic radicals in transparent phonograms.

Another important modulating factor is the position of semantic radicals. Most semantic radicals appear on the left or at the top of the phonograms so generally the left and top positions were the high frequency positions. Researchers have found that semantic radicals on high-frequency positions were activated faster than those on low-frequency ones. For example, using a lexical decision task, Liu et al. (2021) found that characters with semantic radicals on the left or at the top were responded faster than those with semantic radicals on the right or at the bottom, suggestive of easier semantic activation of semantic radicals on the high-frequency position. In addition, using a radical priming paradigm and a character decision task, Zhang et al. (2021) manipulated the position of priming semantic radicals and semantic transparency of target characters. Results demonstrated that when the prime radicals were on the left, shorter response latency to semantically transparent targets was observed as compared to that to the opaque ones. Such a pattern was not observed when the prime radicals were on the right. This result indicated that semantic radicals' position could modulate the activation of semantic radicals.

Finally, some studies have focused on the semantic behavior of semantic radicals when they were embedded in real vs. pseudo-phonograms (or pseudo-characters). For instance, Lin et al. (2015), using the fMRI technique and a character decision task, examined the semantic activation of hand radical "扌" and water radical radical "氵" when they were embedded in pseudo-characters. The that greater activation of the premotor cortex for hand radical "扌" would be observed as compared to that for water radical "氵" if the semantic information of semantic radicals could be activated radical was semantically related with hand actions. However, such activation difference in premotor cortex was not found, suggestive of the inactivation of semantic radicals when they were placed in pseudo-contexts. In contrast, with a lexical decision task, Chung et al. (2012) reported that pseudo-characters elicited greater N400 amplitudes as compared to non-characters. Pseudo-characters, whose semantic and phonetic radicals were in the legal position, without any actual meaning. Non-characters were the same as pseudo-characters except that their semantic and phonetic radicals were in an illegal position. It seemed that the greater N400 could be interpreted as the paradox of expected meaning cued by semantic radicals and the difficulty of semantic integration during pseudo-character processing. Put another way, semantic radicals might be activated and give semantic cues to pseudo-characters even if these characters didn't carry any meaning at all.

In sum, previous research has confirmed that semantic activation of semantic radicals does occur and is influenced by various structural characteristics of the host character—most notably, semantic transparency, radical position and lexical status. However, most existing studies have treated these factors in isolation, leaving the interaction and underlying mechanism underexplored. To bridge this gap, theoretical models of word recognition offer a promising framework.

Theoretical Perspectives on the processing of semantic radicals

Building on the empirical findings, several theoretical models have been developed to account for the mechanism underlying the semantic activation of semantic radicals. In particular, models that distinguish between holistic and segmental processing may offer useful perspectives for interpreting the semantic activation of semantic radicals in various conditions.

A prominent theoretical foundation is the dual-route model for word recognition (Taft and Forster, 1975), which posits that lexical access is mediated by a segmental pathway and a holistic rout. According to this model, the segmental processing route proposes a mandatory initial stage in processing complex words, whereby prefixes are systematically stripped away to access stem representations (e.g., rejuvenate→ juvenate+re-), even for bound morphemes lacking independent lexical status (e.g., -mit in submit). This decompositional mechanism operates in tandem with a holistic whole-word retrieval pathway that enables direct lexical access for monomorphemic items (e.g., coin).

Furthermore, the Dual Route Cascaded (DRC) model, proposed by Coltheart et al. (2001), posits two parallel processing pathways for visual word recognition: a lexical route that retrieves word meaning and pronunciation through direct orthographic lexicon access, and a non-lexical (sub-lexical) route that convert orthographic segments to phonological representation through grapheme-to-phoneme correspondence (GPC) rules. Although originally developed for alphabetic systems, the DRC model's conceptual distinction between holistic and component-based (segmental) processing offers valuable insights for understanding Chinese character recognition mechanisms. Specifically, Chinese phonograms, composed of semantic and phonetic radicals, may engage analogous dual processing pathways: a lexical route for direct character-level recognition and a sub-lexical route for radical-level orthographic recognition.

Complementing this, the Lexical Constituency Model (LCM) proposed by Perfetti et al. (2005) offer a framework tailored to Chinese characters processing. This model posits that word representation in Chinese consist of three interlocking constituents: orthography, phonology, and semantics. Successful word recognition requires coordination across these components, with sub-lexical units such as semantic radicals contributing to early stages of semantic access—even when they are not standalone lexical entries. As the model suggests, "word identification entails the retrieval of a phonological form and meaning information from a graphic form" (Perfetti et al., 2005).

Recent theoretical developments, as synthesized by Stevens and Plaut (2022), have expanded the frameworks by demonstrating how multiple morpho-lexical variables modulate recognition efficiency across languages. These key moderating factors include: (1) morpheme frequency effects (observed cross-linguistically in French, Finnish, and Italian), (2) morphological family size (quantified as the number of derived/compound words sharing a common stem); (3) orthographic-semantic consistency (operationalized as the frequency-weighted semantic similarity between a stem's independent meaning and its contextualized meanings); and (4) semantic transparency (the degree to which a complex word's meaning is compositionally derivable from its morphological constituents).

Based on the studies mentioned above, it is evident that prior research focused on confirming the presence of the semantic activation of semantic radicals. Great efforts were also taken to characterize the myriads of factors such as semantic radicals' position, semantic transparency of phonograms, and the genuineness of the embedding phonogram as a Chinese character, which would presumably act upon the sub-lexical semantic activation event in one way or another. Almost all of these studies, however, placed a high eye on the separate role of a couple of specific factors and thus generally confined themselves to the sub-lexical happening itself. Shifting the perspective of the semantic relevancy and functional bother of semantic radicals to their host phonograms, we are led to a few intriguing questions: How does it come that these factors each act upon the semantic activation event? What's the underlying on-goings that give rise to the factors' superficial modulation effect? What would happen if these factors were combined all together and configured prominently in a phonogram in various alternative ways? Would these factors interact and collaborate to produce a mixed modulation effect? How would semantic radicals semantically behave when displaced into such prominently-configured Chinese characters (hereafter called "PCC")?

The present study

Proceeding from these questions, we are especially interested in three of the above-mentioned modulating factors, namely, the genuineness of the host phonogram as a Chinese character (the status as established Chinese characters or pseudocharacters, G, for short), semantic radicals' position (i.e., location at the high-frequency position or low-frequency position. P, for short), and the semantic transparency of the host phonograms (i.e., transparent or opaque phonograms. T, for short). All the semantic radicals involved in this study were character ones. We hypothesize that there are 4 possible configurations of these three factors: "G+P+T+", "G+P+T-", "G-P+T-", and "G-P-T-", which would give rise to 4 types of prominently-configured Chinese phonograms or phonogram-like characters. For convenience of exposition, they were respectively labeled PCC1, PCC2, PCC3 and PCC4. As a matter of fact, only the first two types could be successfully mapped onto 2 types of counterpart genuine Chinese characters truly existing in the language. For example, the first type, namely, PCC1, could be exactly mapped onto and thus signified by the Chinese genuine character "跃" (/yue4/, *to jump)* and the second by "踍" (/chuo1/, *to idle*). The other two types, which were found no corresponding genuine Chinese characters available in the language, could, however, be no less exactly signified by 2 types of newly-improvised Chinese pseudo-characters. For instance, PCC3 could be signified by the newly-improvised Chinese pseudo-character "⿰𧾷马" and PCC4 by "⿰马𧾷".

Keeping an eye on the function of each of these factors, we further hypothesize that these three factors, if structured and configured differently, would differentially affect the semantic radicals embedded therein. They would reshape the semantic availability, or accessibility, of the semantic radicals. The overarching logic behind this is that each of these three factors has a different weight and a distinctive efficacy in endowing the semantic radicals with their semantic potency. Let's go to the length of each of the three factors.

The first factor, "G", namely the genuine status of the host phonogram as a Chinese character, might serve as a necessary contextual situation in which the semantic radicals were properly identified and activated. It is highly possible that a semantic radical if alienated from its genuine phonogram context, would not normally be identified (and thus not semantically activated). Or, even if it is identified, it may not be normally activated, unable to behave as it normally behaves.

The second factor, "P", namely the position of the semantic radical in the host phonogram, has a strong influence in creating a preference for or discomfort with the native Chinese speaker's character-reading habit (a typical native Chinese speaker would read from left to right). The preference choice would naturally lead to effortless and efficient processing of the sub-lexical unit, whereas the discomfort choice would most likely lead to attentional ignorance of the sub-lexical unit. This differential allocation of attention could make the semantic information of the semantic radical available in different degrees.

The third and last factor, "T", namely the transparency of the host phonogram that embeds the semantic radical, directly affects how the sub-lexical unit operates in relation to its lexical host. The transparent phonograms, which are semantically linked to the embedded semantic radicals, may gain a great semantic advantage over them in terms of interacting with and supporting the semantic behavior of the semantic radicals. However, the opaque phonograms, which are not semantically linked to the embedded semantic radicals, cannot afford to interact and assist with the semantic behavior of the semantic radicals.

Things being as they are, the combination of these three modulation factors would have a strong impact on the magnitude, the salience, and the contextual support of the semantic information of the embedded semantic radicals. The same type of semantic radicals might have different ease or facility in retrieving their semantic information when embedded in varied types of phonograms constructed from distinct configurations of these three factors. Those possessing substantial semantic information, enjoying high processing salience, and receiving semantic support from host phonograms would be subject to easy access, while those possessing less substantial semantic information, enjoying less processing salience, and receiving less or no semantic support from host phonograms would be plunged into difficult access. Easy access means less effortful, faster, and thus more efficient retrieval of semantic information, while difficult access means much more effortful, slower, and thus more awkward retrieval of semantic information. That is to say, configuring the three factors would directly determine the semantic accessibility of the embedded semantic radicals.

Building on the above assumptions, we propose the following hierarchy of the ease of the semantic activation of semantic radicals, namely a hypothesis on the Semantic Accessibility for Semantic Radicals embedded in PCC (hereafter, $SASR_{PCC}$ for short): $SASR_{PCC1} > SASR_{PCC2} > SASR_{PCC3} > SASR_{PCC4}$ (Note: $SASR_{PCC1} = SASR_{G+P+T+}$; $SASR_{PCC2} = SASR_{G+P+T-}$; $SASR_{PCC3} = SASR_{G-P+T-}$; $SASR_{PCC1} = SASR_{G-P-T-}$).

However, this is a mere theoretical hypothesis. A careful empirical investigation is needed to test the proposed SASRPCC hierarchy and to explore how different configurations of the three modulating factors shape the semantic accessibility of embedded character semantic radicals. To this end, the present study addresses the following research questions.

RQ1: Can character semantic radicals be semantically activated when embedded in phonograms that are prominently configured by transparency, position, and genuineness (PCCs)?

RQ2: How do transparency, radical position, and phonogram genuineness individually and interactively influence the semantic activation of character semantic radicals in PCCs?

RQ3: Can a reliable hierarchy of semantic accessibility be established across different PCC types configured by the three factors?

Method

Participants

A total of 38 participants (all females, aged 20–30 years, mean age = 24.65 years, SD=1.76) took part in the experiment. They were undergraduate or graduate students recruited from Sichuan International Studies University (SISU). All of them were native Mandarin speakers who grew up in Mainland China and were right-handed, with normal or corrected-to-normal vision. Each had begun systematic English (L2) learning through formal education after the age of 12 and had passed the Test for English Majors-Band 8 (TEM-8), a nationally standardized examination that certifies advanced English proficiency for university-level English majors in China. None of the participants had received any formal instruction in, or reported prior exposure to, a third language (L3). They were asked to provide written informed consent before participation and got paid after the experiment.

Materials and design

The experiment adopted a 2 (Prime type: effector-based character *vs.* control asterisk "*") × 6 (Target type: PCC1 *vs.* PCC2 *vs.* PCC3 *vs.* PCC4 *vs.* $PCC_{Control1}$ *vs.* $PCC_{Control2}$) design. The prime type included a human foot effector-based character "脚" (/jiao3/, *foot*), a human mouth effector-based effector-based character "嘴" (/zui3/, *mouth*), a human hand effector-based character "手" (/shou3/, *hand*) and a control asterisk "*".

As for the target type, six types of Chinese phonogram characters (including pseudo-characters) were included altogether. The first type was Chinese phonograms that: (1) based on either human foot-, mouth-, or hand- semantic radical; (2) prominently configured from the three factors, namely, G+ (Genuineness), P+ (Position), and T+ (Transparency). The first type (PCC1), as illustrated in the foregoing (e.g., the Chinese phonogram "踩" /cai4/, *to jump*) was a semantically transparent phonogram with character semantic radical on the high-frequency position (G+P+T+). The second type (PCC2) was the same as the first type except that the factor concerned was "T-" (G+P+T-, e.g., the Chinese phonogram "蹉" ,/chuo1/, *to idle*). The third type (PCC3) was almost the same as the second type except that the factor concerned was "G-" (G-P+T-, e.g., "[illegible]"), namely pseudo-characters. The fourth type was the same as the third type except that the factor concerned was "P-" (G-P-T-, e.g., "[illegible]"), namely character semantic radicals appearing in the low-frequency position.

The fifth target type "$PCC_{Control1}$", which served as a control character for the first target type, was foot/mouth/hand effector meaning-loaded only characters that contained neither character nor non-character foot/mouth/hand semantic radicals (e.g., the Chinese character "奔", /ben1/, *to run*, denotes the human foot effector-executed motion meaning but contains no foot semantic radical). The sixth type "$PCC_{Control2}$", which served as a control character for the second target type, was a genuine Chinese character that bore no semantic relevance to the human foot, mouth, or hand effector (e.g., the Chinese Chinese character "弄", /nong4/, *to manipulate*, bearing no relevance to the human foot, mouth, or hand effector.

TABLE 1 Sample stimuli of primes and targets in the experiment.

Primes		Targets	
Effector-based character, e.g., 脚	Control asterisk*	PCC1 (G+P+T+)	e.g., "跃" (/yue4/, *to jump*)
		$PCC_{control1}$	e.g., "奔" (/ben1/, *to run*)
		PCC2 (G+P+T-)	e.g., "蹉" (/cuo1/, *to idle*)
		$PCC_{control2}$	e.g., "弄" (/nong4/, *to make*)
		PCC3 (G-P+T-)	e.g., [illegible]
		PCC4 (G-P-T-)	e.g., [illegible]

Each of the six target types consisted of 25 Chinese phonogram characters or pseudo-characters (see Table 1 for sample materials). The first two types (PCC1 and PCC2), together with the fifth and sixth types ($PCC_{Control1}$ and $PCC_{Control2}$), which were all genuine Chinese characters. These four categories were matched on part of speech (both being verbs), and mean frequency. A one-way analysis of variance (ANOVA) indicated that mean character frequency did not differ significantly across target conditions [$F_{(3,96)} = 1.743$, $p = 0.163$], based on the frequency indices from the Corpus Center of Beijing Language and Culture University (https://bcc.blcu.edu.cn/lang/zh).

Visual complexity, indexed by stroke count per character (sourced from *Xiandai Hanyu Zidian* [Modern Chinese Dictionary]), was also analyzed. A one-way ANOVA revealed a significant difference in mean character strokes across target conditions [$F_{(5,144)} = 5.070$, $p < 0.001$, MSE $= 7.481$, $\eta^2 = 0.150$]. *Post hoc* analysis with LSD showed that targets in $PCC_{control1}$ contained significant fewer strokes than those in PCC1, PCC2, PCC3, and PCC4 ($ps < 0.05$) and the strokes of targets in $PCC_{control2}$ similarly exhibited lower strokes relative to those in PCC1, PCC2, PCC3, and PCC4 ($ps < 0.05$). No other significant differences on strokes were found.

To ensure consistency in morphological familiarity, we also evaluated the productivity of the semantic radicals embedded in the phonograms, operationalized as the number of commonly used characters each radical appears in. All radicals selected were high-productivity semantic radicals. For instance, radicals such as "足" (foot), "口" (mouth), and "手" (hand) (hand) appear in approximately 99.32 characters on average, based on statistical analyses of the semantic radical system in Chinese phonograms (Li, 1996).

In addition, another group of pseudo-characters were improvised as fillers, totaling 50, to meet the needs of the lexical decision task as adopted in the present experiment. All pseudo-characters as fillers were made via the Eudcedit Software within the Windows environment.

Two types of primes were matched with 6 types of targets and 50 fillers, with a total of 400 prime-target pairs and trials.

For PCC1, PCC2, $PCC_{Control1}$, and $PCC_{Control2}$, the semantic relatedness between the whole character and the human *foot*, *mouth*, or *hand* effector-based primes were rated on a 7-point scale

TABLE 2 Mean RT (ms) and SD for targets in this experiment.

Prime type	Target type					
	PCC1; (G+P+T+)	PCC2; (G+P+T-)	PCC3; (G-P+T-)	PCC4; (G-P-T-)	$PCC_{Control1}$	$PCC_{Control2}$
Effector-based character	602.44; (80.94)	579.85; (82.55)	664.47; (102.00)	571.09; (68.76)	582.27; (14.20)	573.21; (13.19)
Control asterisk	626.50; (110.36)	608.38; (101.68)	667.93; (100.76)	583.85; (71.63)	609.44; (18.67)	593.53; (18.55)

(with "1" standing for minimal relatedness/transparency, and "7" for maximal relatedness/transparency). 16 Chinese undergraduates (14 females, 2 males) who were excluded from the character decision task participated in the questionnaire. Results showed that semantic transparency for transparent targets was significantly higher than that for opaque ones ($p < 0.05$). And no significant differences were found among the four target types ($p > 0.05$).

Procedure

Participants were seated approximately 65 cm from a computer in a comfortable chair. Each trial began with a fixation signal for 300 ms, followed by a blank screen for 300 ms. The prime was then presented for 500 ms. Then the target, either a phonogram or a pseudo-phonogram, was presented to the participants until a response was made or until 1,500 ms elapsed. The next trial began after an 800 ms interval. Participants were instructed to determine whether the target character was a real character as quickly as possible by pressing the "F" or "J" keys. The configuration for "pressing key" was counterbalanced across participants, with half using "F" for "YES" and "J" for "NO", and the other half vice versa. Accuracy and reaction times were recorded. This experiment was conducted in the Key Laboratory of Foreign Language Learning and Cognitive Neuroscience in SISU.

Results

Data from 34 participants were included in the statistical analysis (data of 4 participants were excluded because of the low accuracy). The mean accuracy for the primed lexical decision task was 94.72%. The errors and reaction time data exceeding 3 SD (2.38%) from the mean RT of each condition were discarded from further analyses. Table 2 exhibits the mean reaction times in this Experiment.

Prime Type (Effector-based character, Control asterisk) and Target Type (PCC1, PCC2, PCC3, PC4, $PCC_{control1}$, $PCC_{control2}$) were factors in an analysis of variance with repeated measures for target reaction times. F values are reported by subjects (F_1) and by items (F_2). The effects of **Prime Type** [$F_{1(1,33)}$ =9.446, $p = 0.004$, MSE = 6,660.994, $\eta^2 = 0.223$; $F_{2(1,274)} = 32.057$, $p < 0.001$, MSE = 1,605.101, $\eta^2 = 0.105$] **and Target Type** [$F_{1(2.165,86.298)}$ =32.771, $p = 0.000$, MSE = 8,401.192, η^2 =0.4983; $F_{2(5,274)}$ =38.551, $p < 0.001$, MSE = 1,605.101, $\eta^2 = 0.413$] were both significant. The interaction between Prime Type and Target Prime Type was not significant ($p = 0.187$ by subjects and $p = 0.380$ by items). However, in line with our theoretical motivations, we conducted planned *post hoc* comparisons to examine whether semantic priming effects were observed within individual target conditions.

Post hoc multiple comparisons between different prime types collapsed over levels of target types showed the following: The RTs to targets PCC1 preceded by effector-based characters (602.44 ms) were significantly faster than those preceded by control asterisk (626.500 ms) ($p = 0.036$ by subjects and $p < 0.001$ by items). The RTs to targets PCC2 preceded by effector-based characters (579.853 ms) were significantly faster than those preceded by control asterisk (608.382 ms) ($p = 0.006$ by subjects and $p < 0.001$ by items). The RTs to targets PCC4 effector-based characters (571.008 ms) were significantly faster than those preceded by the control asterisk (583.853 ms) ($p = 0.005$ by subjects and $p < 0.001$ by items). The RTs to target $PCC_{control1}$ effector-based characters (582.265ms) were significantly faster than those preceded by the control asterisk (609.441ms) ($p = 0.031$ by subjects and $p < 0.001$ by items). The RTs to targets $PCC_{control2}$ effector-based characters (573.206 ms) were marginally significantly faster than those preceded by control asterisk (593.529 ms) by subjects ($p = 0.061$), but this significant difference was not found by items ($p = 0.931$). The difference between the RTs to targets PCC3 (664.471 ms) and to those preceded by the control asterisk (667.931 ms), however, was not significant ($p = 0.727$ by subjects and $p = 0.262$ by items). These results demonstrated the existence of priming effects for targets, and certain configurations of phonograms are more susceptible to semantic priming, even though the interaction was not significant.

With the accuracy measure, the effect of **Prime Type** was not significant by subjects and by items [$F_{1(1,33)}$ =2.476, $p = 0.124$, MSE = 19.002, $\eta^2 = 0.063$; $F_{2(1,274)} = 0.040$, $p = 0.843$, MSE=47.370, $\eta^2 = 0.000$]. The effect of **Target Type** was significant by subjects and by items [$F_{1(1,33)}$ =29.679, $p < 0.001$, MSE=422.525, $\eta^2 = 0.445$; $F_{2(1,274)}$ =51.701, $p < 0.001$, MSE=47.370, $\eta^2 = 0.485$]. The interaction of Prime Type and Target Type was significant by subjects [$F_{1(1,33)} = 2.711$, $p = 0.022$, MSE = 37.279, $\eta^2 = 0.068$], but not significant by items [$F_{2(1,274)} = 0.621$, $p = 0.684$, MSE = 29.422, $\eta^2 = 0.011$].

The simple effect analysis by subjects showed that the ACCs to targets PCC4 preceded by effector-based characters (97.22%) were significantly lower than those preceded by control asterisk (99.16%) ($p = 0.021$). The ACCs to targets PCC2 preceded by effector-based characters (96.16%) were significantly higher than those preceded by control asterisk (93.68%) ($p = 0.015$). These results demonstrated that the effector-based priming characters could exert either facilitative or interfering effects on target Chinese characters recognition accuracy when the host phonograms were semantically opaque or when the pseudocharacters contained semantic radicals in low-frequency positional configurations.

One-way ANOVA was run on the ΔRT for the four types of targets (i.e., PCC1, PCC2, PCC3, and PCC4). The four ΔRTs were calculated as follows: (1) $\Delta RT_{PCC1} = (RT_{PCCcontrol1}$ – $RT_{PCC1})$, (2) $\Delta RT_{PCC2} = (RT_{PCCcontrol2}$ - $RT_{PCC2})$, (3) ΔRT_{PCC3}

= ($RT_{PCC3controlprime}$ – $RT_{PCC3effector-basedcharacter}$), (4) ΔRT_{PCC4} = ($RT_{PCC4controlprime}$ - $RT_{PCC4effector-basedcharacter}$). Results showed that the effect of ΔRT was not significant [$F_{(2.312,76.302)}$ = 0.970, p = 0.394, MSE = 1,419.426, η^2 = 0.029]. Simple effect analysis showed that there were significant differences between ΔRT_{PCC1} and ΔRT_{PCC2} (p = 0.002), ΔRT_{PCC2} and ΔRT_{PCC3} (p = 0.009), ΔRT_{PCC2} and ΔRT_{PCC4} (p = 0.000). Otherwise, there were no other significant differences. These results suggested that Transparency had caused differences in the priming effects for the 2 types of genuine target characters.

A further paired *t-sample* test performed on the averaged ΔRTs for the 2 types of genuine character targets and for the 2 types of pseudo-character targets showed that there were significant differences in the averaged ΔRTs between the two types of target characters (p = 0.001). This result suggested that Genuineness had caused differences in the priming effects.

In sum, the above results suggested that the semantic radicals, whether they were embedded in the genuine character targets or pseudo-character targets, were almost all semantically activated. The priming effects for the four types of targets follow a descending order: $\Delta RT_{PCC2} > \Delta RT_{PCC1} > \Delta RT_{PCC3}/\Delta RT_{PCC4}$.

Discussion

Beyond demonstrating the existence of semantic activation of semantic radicals and characterizing the separate roles of modulation factors, the present study further explored the machinery and effects resulting from the different configurations of a couple of modulation factors. Each factor-genuineness, position, and transparency-was assumed to have distinct functional weight and efficacy in shaping and constructing the semantic potential and behavior of the semantic radical. Different ways of structuring and configuring these factors could create a differential machinery that acts on the semantic radical, constructing its pool of semantic information, as well as reforming its facility with the retrieval of semantic information. In other words, semantic radicals embodying different configurations of modulation factors may take on different semantic accessibility, which, when ranked together, may exhibit a distinct order or hierarchy. The current study provides a preliminary test of this hypothesis.

Our results first demonstrated that semantic radicals were reliably activated in genuine phonograms. In contrast, in pseudo-phonograms, semantic activation of the semantic radicals was observed only when they were located in low-frequency positions, whereas no semantic activation was found when the same radicals appeared in high-frequency positions. This finding is consistent with the previous research (Lin et al., 2015; Jiang et al., 2025) and aligns with the Lexical Constituency Model (Perfetti et al., 2005), which posits that semantics, orthography, and phonology are interlocked constituents of lexical representations and may be directly accessed during orthographic processing. Furthermore, the observed semantic activation of semantic radicals in pseudo-characters contexts under low-frequency positioning also echoes predictions from the non-lexical route of the DRC model (Coltheart et al., 2001) and the segmental route in model for word recognition (Taft and Forster, 1975), which allows for meaning retrieval through sub-lexical decomposition in the absence of lexical entries.

The results showed that the Genuineness of the host character had caused a difference in priming effects that, based on the experimental design, actually represented the semantic accessibility of the embedded character semantic radical. Specifically, semantic activation of semantic radicals was more robust when they were embedded in genuine phonograms than in pseudo-phonograms. This finding aligns with previous studies (e.g., Tong et al., 2021; Jiang et al., 2025) and highlights the critical role of lexical status in modulating semantic activation of semantic radicals. In other words, whether the host character is an authentic Chinese character play a importance role in determining the semantic activation behavior of the character semantic radical, namely the presence or absence of activation, as well as the magnitude of the activation.

Somewhat unexpectedly, results from the experiment also showed that Transparency had caused differences in the priming effects for the 2 types of genuine target characters. Specifically, character semantic radicals embedded in opaque target characters exhibited unexpectedly larger priming effects than those embedded in transparent target ones. This contrasts with prior studies (Wang et al., 2017; Tong et al., 2021), which reported that character semantic radicals embedded in the transparent phonograms might gain a great semantic advantage in interacting and supporting the semantic behavior of the semantic radicals. A possible explanation lies in the differential semantic activation dependency mechanisms: For transparent phonograms, both the whole character and its semantic radical maintain connections with the prime, allowing lexical access to rely on either the holistic representation or the activation of the semantic radical, thereby reducing dependency on radical-specific activation. For opaque phonograms, the absence of a direct semantic connection between the whole character and the prime force the recognition system to depend exclusively on the semantic radical's activation, thereby amplifying observed priming effects. While further empirical research is needed to clarify the underlying mechanisms, the present findings suggest that a phonogram's transparency dynamically reshapes the semantic accessibility of its constituent semantic radical. In other words, the processing of a semantic radical appears to emerge not only from its fixed properties, but also from dynamic interactions between sublexical and whole-character representations within the Chinese lexical processing system.

The results from the experiment showed that the Position of character semantic radical made no difference in priming effects for the 2 types of pseudo-phonograms. In the foregoing, it has been argued that whether a character semantic radical is located in the typical left (i.e. high-frequency) position or in the atypical right (i.e. low-frequency) position of a phonogram might have a great influence on the attentional allocation in phonogram processing. The typical left position might better match the habit of a typical native Chinese speaker to read from left to right. However, this speculation was not confirmed in the present study, which was beyond our expectations. The current null finding regarding semantic radical position effects in pseudo-phonogram processing stands in contrast to established evidence from Zhang et al.'s (2021) study of genuine characters, which demonstrated left-positioned (i.e., high-frequency) semantic radicals' advantage in facilitating transparent target recognition. This discrepancy may stem from fundamental representational differences between pseudo- and genuine-phonogram processing. Whereas genuine characters benefit from established lexical representations that interact with positional expectations, pseudo-phonograms lack such consolidated whole-word representations, potentially diminishing the functional impact of radical positioning. The absence of position effects in our pseudo-phonogram data suggests that the well-documented left-position preference in Chinese character processing—often attributed to reading direction habits and hemispheric lateralization—may be contingent upon the availability of established lexical representations. When processing novel character configurations (pseudo-phonograms), the visual system appears to adopt a more flexible positional strategy, possibly because these stimuli lack the entrenched orthographic-semantic mappings that typically engage position-sensitive processing routines in genuine character recognition. However, this speculation warrants further exploration.

From an overall perspective, an ordered magnitude of priming effects was perceived for the four types of real character or pseudo-character targets which were derived from 4 formats of the configuration of the three modulation factors, namely, phonograms' Genuineness, semantic radicals' Position, and phonograms' Transparency. These results partially confirmed the hierarchy of the ease of semantic activation of character semantic radicals as proposed at the start:

$SASR_{PCC2} > SASR_{PCC1} > SASR_{PCC3}/SASR_{PCC4}$ (Note: $SASR_{PCC1} = SASR_{G+P+T+}$; $SASR_{PCC2} = SASR_{G+P+T-}$; $SASR_{PCC3} = SR_{G-P+T-}$; $SASR_{PCC4} = SASR_{G-P-T-}$)

In other words, this study has proved the existence of the semantic accessibility effects of character semantic radicals.

This finding was somewhat revealing in that it suggests a complicated machinery behind the surface behavior of the character semantic radical. The semantic activation of the semantic radical, as well as the modulation factors involved, may be only the tip of the iceberg. The semantic accessibility, which signifies the effect of the varied configuration of the modulation factors, could be a special probe to detect and unravel the underlying machinery.

However, the present study is only a first attempt in this regard. It may have raised more questions than it attempted to answer. Future studies utilizing other Chinese semantic radicals and more varied experimental paradigms would be recommended.

Conclusion

The semantic activation of character semantic radicals is a topic of great interest. Previous research has focused on demonstrating the actual presence of the sub-lexical activation event as well as the presence of the separate role of a pair of factors bearing on the event. No known investigation has been devoted to examining the effect of a couple of factors configured prominently together on the embedded semantic radicals as well as on their host characters. The present study is an initiative in this respect through the manipulation of three modulating factors.

It was found that the structuring and configuring of these modulation factors in varied manners would endow semantic radicals with varied semantic potency and reshape their semantic accessibility. The hypothesis on the semantic accessibility of character semantic radicals built on 4 types of configurations of three modulation factors, namely, the Genuineness of host phonograms, the Position of semantic radicals' being in the host phonogram, and the Transparency of host phonogram, was partially supported. Future research would be preferably oriented toward examining the effects from the configuration of expanded Chinese semantic radicals, be they character or non-character ones.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by Institutional Review Board (IRB) of Sichuan International Studies University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

MJ: Writing – original draft, Resources, Investigation, Funding acquisition, Writing – review & editing, Conceptualization, Project administration, Supervision. TC: Writing – review & editing, Formal analysis, Writing – original draft, Data curation, Conceptualization, Validation, Methodology, Investigation. YT: Conceptualization, Validation, Writing – review & editing, Supervision. JD: Validation, Formal analysis, Investigation, Writing – review & editing. DQ: Formal analysis, Writing – review & editing, Data curation, Visualization, Methodology, Software.

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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.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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References

Chen, M. J., and Weekes, B. S. (2004). Effects of semantic radicals on Chinese character categorization and character decision. *Chin. J. Psychol.* 46, 181–196. doi: 10.6129/CJP.2004.460203.07

Chen, Y. P., Allport, D. A., and Marshall, J. C. (1996). What are the functional orthographic units in Chinese word recognition: the stroke or the stroke pattern? *Quart. J. Exp. Psychol.* A49, 1024–1043. doi: 10.1080/027249896392423

Chung, K. K., Tong, X., and McBride-Chang, C. (2012). Evidence for a deficit in orthographic structure processing in Chinese developmental dyslexia: an event-related potential study. *Brain Res.* 1472, 20–31. doi: 10.1016/j.brainres.2012.06.010

Coltheart, M., Rastle, K., Perry, C., Langdon, R., and Ziegler, J. C. (2001). DRC: a dual route cascaded model of visual word recognition and reading aloud. *Psychol. Rev.* 1081, 204–256. doi: 10.1037/0033-295X.108.1.204

Hui-Wen Hsiao, J., Shillcock, R., and Lavidor, M. (2007). An examination of semantic radical combinability effects with lateralized cues in Chinese character recognition. *Percept. Psychophys.* 69, 338–344. doi: 10.3758/BF03193754

Jiang, M., Luo, Q., Wang, X., and Qu, D. (2025). Semantic radicals' semantic attachment to their composed phonograms. *BMC Psychol.* 13:1. doi: 10.1186/s40359-025-02855-1

Lee, C. Y., Tsai, J. L., Huang, H. W., Hung, D. L., and Tzeng, O. J. (2006). The temporal signatures of semantic and phonological activations for Chinese sublexical processing: an event-related potential study. *Brain Res.* 1121, 150–159. doi: 10.1016/j.brainres.2006.08.117

Li, G. (1996). On the semantic radical system in Chinese phonograms. *Chin. Soc. Sci.* 3, 186–193.

Lin, N., Wang, X., Zhao, Y., Liu, Y., Li, X., and Bi, Y. (2015). Premotor cortex activation elicited during word comprehension relies on access of specific action concepts. *J. Cognit. Neurosci.* 27, 2051–2062. doi: 10.1162/jocn_a_00852

Liu, L., Jiang, Y., Zhang, Q., and Li, Z. (2021). Influence of the position and transparency of semantic radicals on semantic activation in chinese phonogram recognition. *Stud. Psychol. Behav.* 5, 585–591. Available online at: https://psybeh.tjnu.edu.cn/CN/Y2021/V19/I5/585

Perfetti, C. A., Liu, Y., and Tan, L. H. (2005). The lexical constituency model: some implications of research on Chinese for general theories of reading. *Psychol. Rev.* 1121, 43–59. doi: 10.1037/0033-295X.112.1.43

Stevens, P., and Plaut, D. C. (2022). From decomposition to distributed theories of morphological processing in reading. *Psychonomic Bullet. Rev.* 29, 1673–1702. doi: 10.3758/s13423-022-02086-0

Taft, M., and Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *J. Verbal learn. Verbal Behav.* 14, 638–647. doi: 10.1016/S0022-5371(75)80051-X

Tong, X., Xu, M., Zhao, J., and Yu, L. (2021). The graded priming effect of semantic radical on Chinese character recognition. *Front. Psychol.* 12:611066. doi: 10.3389/fpsyg.2021.611066

Wang, B., Li, Z. R., Wu, L. M., and Zhang, J. J. (2019). Effects of embodied simulation on understanding Chinese body action verbs. *Acta Psychologica Sinica* 51, 1291–1305 doi: 10.3724/SP.J.1041.2019.01291

Wang, D., Wang, T., Qin, S., and Zhang, J. (2019). Positional effects of lexical components in the radical priming paradigm. *Acta Psychologica Sinica* 51, 163–176. doi: 10.3724/SP.J.1041.2019.00163

Wang, X., Wu, Y., Zhao, S., Ni, C., and Zhang, M. (2016). The effects of semantic radicals and phonetic radicals in Chinese phonogram recognition. *Acta Psychol. Sin.* 48, 130–140. doi: 10.3724/SP.J.1041.2016.00130

Wang, X. S., Pei, M., Wu, Y., and Su, Y. J. (2017). Semantic radicals contribute more than phonetic radicals to the recognition of Chinese phonograms: behavioral and ERP evidence in a factorial study. *Front. Psychol.* 8:2230. doi: 10.1016/j.neulet.2012.02.080

Zhang, J., and Wang, B. (2024). A psycholinguistic exploration of the cognitive function of semantic radicals: a review of thirty years of research. *J. Northwest Normal Univer.* 61, 104–117.

Zhang, J., Wang, J., and Yin, C. (2014). The role of phonetic and semantic radicals in phonological and semantic processing of Chinese phonograms: evidence from component perception and eye-movement studies. *Acta Psychologica Sinica* 46, 885–900. doi: 10.3724/SP.J.1041.2014.00885

Zhang, J., and Zhang, Y. (2016). The time course of semantic radical's semantic and syntax activation under radical priming paradigm. *Acta Psychologica Sinica* 48:1070. doi: 10.3724/SP.J.1041.2016.01070

Zhang, Y., Gao, Y., Zhang, J. (2021). The positional effect of semantic and grammatical activation of semantic radical priming, paradigm. *Stud. Psychol. Behav.* 19, 721–727. Available online at: https://psybeh.tjnu.edu.cn/EN/Y2021/V19/I6/721

Zhou, L., Peng, G., Zheng, H. Y., Su, I. F., and Wang, W. S. (2013). Sub-lexical phonological and semantic processing of semantic radicals: a primed naming study. *Read Writing* 26, 967–989. doi: 10.1007/s11145-012-9402-7

Appendix

TABLE A1 Primes and targets used in this experiment.

Item No.	Primes	Target type					
		PCC1	PCC$_{control1}$	PCC2	PCC$_{control2}$	PCC3	PCC4
1	脚/*	跃	奔	蹉	弄	[illegible]	[illegible]
2	脚/*	趋	登	趄	率	[illegible]	[illegible]
3	脚/*	踩	来	距	丢	[illegible]	[illegible]
4	脚/*	踢	去	替	替	[illegible]	[illegible]
5	脚/*	跑	躲	卖	卖	[illegible]	[illegible]
6	脚/*	跌	舞	踦	弃	[illegible]	[illegible]
7	脚/*	赴	走	趁	串	[illegible]	[illegible]
8	脚/*	赶	离	起	乘	[illegible]	[illegible]
9	脚/*	跺	守	踌	居	[illegible]	[illegible]
10	脚/*	踏	窜	躇	舀	[illegible]	[illegible]
11	脚/*	跨	徊	跎	画	[illegible]	[illegible]
12	脚/*	跳	冲	蹩	竞	[illegible]	[illegible]
13	脚/*	站	出	端	度	[illegible]	[illegible]
14	嘴/*	喝	闹	嗅	耍	[illegible]	[illegible]
15	嘴/*	唱	食	向	丧	[illegible]	[illegible]
16	嘴/*	叫	答	吊	系	[illegible]	[illegible]
17	嘴/*	吸	尝	占	要	[illegible]	[illegible]
18	嘴/*	呐	笑	吝	盖	[illegible]	[illegible]
19	嘴/*	呕	曰	呈	发	吽	[illegible]
20	嘴/*	鸣	夸	叩	反	[illegible]	[illegible]
21	嘴/*	吻	责	合	奏	[illegible]	[illegible]
22	嘴/*	吠	斥	启	甩	[illegible]	[illegible]
23	手/*	拿	牵	升	升	[illegible]	[illegible]
24	手/*	攀	叠	委	委	[illegible]	[illegible]
25	手/*	掌	夹	挲	坐	[illegible]	[illegible]