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Visual Distinctiveness and Chinese Character Recognition: A Systematic Literature Review of Character Simplification Studies

(Ketidaksamaan Visual dan Proses Pengecaman Tulisan Cina: Sorotan Literatur Bersistematik ke atas Kajian Pemudahan Aksara)

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ABSTRACT

The 1950s Chinese character simplification reform reduced the visual complexity of thousands of characters; yet, its effects on character recognition remain poorly understood. This systematic literature review examined how visual features influence Chinese character recognition. A systematic search of four databases yielded 29 empirical studies. The findings show that visual distinctiveness is multidimensional in Chinese character recognition, involving stroke-level features, component and radical structure, spatial configuration, spatial transparency, and global form, with effects shaped by character frequency, reader expertise, and task demands. However, the evidence is insufficient to determine the direct effects of simplification. Stroke reduction may support early visual processing, whereas component merging may weaken distinctiveness, but neither effect has been directly tested. Only one study included both simplified and traditional characters, and none examined simplification as an object of investigation. The main methodological limitations were the use of a single script within individual studies, reliance on stroke count as the main measure of visual complexity, samples dominated by adult university students, and heavy reliance on behavioural measures. Overall, the claim that simplification does not necessarily improve recognition remains untested. Future research should adopt comparative designs, multidimensional measures of visual form, and broader participant samples to determine whether and how simplification has changed the visual demands of Chinese character recognition.

Keywords: Chinese character recognition; visual distinctiveness; character simplification; visual complexity; systematic literature review

ABSTRAK

Reformasi pemudahan aksara Cina pada tahun 1950-an telah mengurangkan kerumitan visual bagi beribu-ribu aksara; walau bagaimanapun, kesannya terhadap pengecaman aksara masih kurang difahami. Sorotan literatur bersistematik ini dijalankan untuk mengkaji bagaimana ciri-ciri visual aksara Cina mempengaruhi proses pengecaman. Pencarian sistematik daripada empat pangkalan data telah menghasilkan 29 kajian empirikal. Dapatan kajian menunjukkan bahawa keunikan visual dalam pengecaman aksara Cina adalah bersifat multidimensi. Pengecaman dibentuk oleh ciri-ciri peringkat strok, struktur komponen dan radikal, konfigurasi ruang, ketelusan ruang, dan bentuk global. Walau bagaimanapun, bukti yang ada ini tidak mencukupi untuk menentukan kesan langsung pemudahan tersebut. Pengurangan bilangan strok mungkin menyokong pemprosesan visual awal, manakala penggabungan komponen mungkin melemahkan keunikan visual, namun kedua-dua kesan ini belum pernah diuji secara langsung. Hanya satu kajian sahaja yang melibatkan kedua-dua jenis aksara—yang dipermudahkan dan tradisional—dan tiada kajian yang meneliti pemudahan itu sebagai fokus utama penyelidikan. Kekangan metodologi utama termasuk penggunaan satu jenis skrip sahaja dalam setiap kajian, pergantungan kepada bilangan strok sebagai ukuran utama kerumitan visual, sampel yang didominasi oleh pelajar universiti dewasa, serta pergantungan yang

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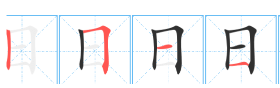
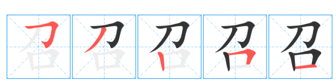
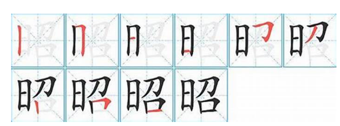
tinggi terhadap ukuran tingkah laku. Secara keseluruhannya, dakwaan bahawa pemudahan aksara tidak semestinya meningkatkan keupayaan pengecaman masih belum diuji. Penyelidikan masa hadapan wajar menggunakan reka bentuk perbandingan, ukuran multidimensi bagi bentuk visual, serta sampel peserta yang lebih pelbagai untuk menentukan sama ada dan bagaimana pemudahan aksara dapat mengubah proses pengecaman aksara Cina.

Kata Kunci: Pengecaman aksara Cina; ketidaksamaan visual; pemudahan aksara; kerumitan visual; sorotan literatur bersistematik

INTRODUCTION

Unlike alphabetic languages (e.g., English, German, French and Malay), which use symbols to represent vowel and consonantal phonemes, the Chinese writing system is a morphosyllabic system, with each character representing both a morpheme (unit of meaning) and a syllable (unit of sound) (Kuo et al., 2024; Zhang & McBride-Chang, 2011). The basic components of Chinese orthography—strokes, radicals, and structural configuration (Yu et al., 2023)—result in the inherent visual complexity of Chinese characters. Compound characters, which require multi-component visual processing, account for approximately 95% of Chinese characters (Nguyen et al., 2023). Table 1 illustrates this orthography through three example characters, namely 日, 召, and 昭, showing how strokes combine into components, components into radicals, and radicals into whole characters.

TABLE 1. Illustration of orthography of 日,召,昭

Feature	日	召	昭
Character	日(rì, "sun")	召(zhāo, call out)	昭(zhāo, brightness)
Structural Pattern	Simple	$\frac{A}{B}$ Top - Bottom	A|B Left - Right
Stroke Count	4	5	9
Phonetic Radical	/	A: 刀(*dāo*, "knife")	B: 召(*zhāo*, call out)
Semantic Radical	/	B: 口(*kǒu*, "mouth")	A: 日(*rì*, "sun")
Components	/	刀, 口	日，刀，口
Strokes	 1. □ (vertical) 2. 横折 (horizontal-turning) 3. 横 (horizontal) 4. 横 (horizontal)	 1. 横折□ (horizontal-turning-hook) 2. 撇 (left-falling) 3. □ (vertical) 4. 横折 (horizontal-turning) 5. 横 (horizontal)	 1. □ (vertical) 2. 横折 (horizontal-turning) 3. 横 (horizontal) 4. 横 (horizontal) 5. 横折□ (horizontal-turning-hook) 6. 撇 (left-falling) 7. □ (vertical) 8. 横折 (horizontal-turning) 9. 横 (horizontal)

Note: The characters 日, 召, and 昭 illustrate the hierarchical organization of Chinese orthography, from simple characters to compound characters with increasing structural complexity. The character 昭 contains 日 as its semantic radical and 召 as its phonetic radical, demonstrating how strokes combine into components, which in turn form radicals that construct the whole character.)

The Chinese character reformation in the 1950s reduced the visual complexity of characters by reducing the number of strokes to enhance literacy rates (Chen, 1999). Simplified characters have about 22.50% fewer strokes than the traditional ones (Gao & Kao, 2002). The methods used in the simplification process were varied and not consistently applied (Seybolt & Chiang, 1979). Meanwhile, the simplification changed characters in multiple dimensions at the same time. It reduced stroke counts, altered components, and reshaped spatial structures. In some cases, it changed phonetic or semantic radicals themselves (Liu et al., 2018). For example, the traditional characters 僅(*jǐn*, "only"), 儀(*yí*, "ceremony"), and 漢(*hàn*, "Han/Chinese"), which possess distinctive visual features, were simplified to □, □, and □ respectively, resulting in substantially greater visual similarity (Tsang et al., 2024). Guan (as cited in Seybolt & Chiang, 1979) claims that simplified characters are harder to learn than traditional forms. Li et al. (2012) note that simplified characters might be easier to learn to write but harder to learn to read, although such an inference may be regarded as overly simplistic. Han et al. (2022) analyze over 500,000 images of Chinese characters throughout more than three thousand years and find that there is no clear trend toward simplification. Modern characters, whether traditional or simplified, are visually more complex than oracle bone script. They explain that this is due to a trade-off: characters must maintain distinctiveness, while simplification is subject to constraints.

These viewpoints combine into a widely repeated argument: simplification has not directly improved character recognition. Chen (1999) describes the intentions behind the reforms from historical and policy perspectives. Guan (as cited in Seybolt & Chiang, 1979) offers a claim without empirical evidence. Hemelstrand and Inoue (2025) for example, compare the two scripts at the level of the lexicon, and Han et al. (2022) analyse properties of the script itself and do not examine readers. McBride-Chang et al. (2005) and McBride (2016) focus on the cognitive factors that predict how children read characters. Unfortunately, simplification is not a variable that gets tested in these studies. Although recent experimental results are reported by Hemelstrand et al. (2024), they deal with the effect of visual complexity on literacy outcomes, not with a direct comparison between simplified and traditional forms. No comparison has been made by these sources between how readers recognize simplified characters and their traditional counterparts although McBride-Chang et al. (2005) has noted this gap two decades ago, attributing it partly to historical and political circumstances.

PROBLEM STATEMENT

There have been few studies examining how readers recognize matched simplified and traditional characters. Studies of visual features treat features as a separate property, with only one dimension manipulated at a time, whereas simplification is a transformation between two forms of the same character. It alters multiple dimensions simultaneously, and these changes may operate in different directions. Evidence from any single dimension therefore cannot support a conclusion about transformation as the whole. Hence, this review focuses not on the effect of simplification itself, but on the evidential basis of the claim made about that effect. Therefore, this review was conducted to achieve the following research objectives:

RESEARCH OBJECTIVES

1. To identify the visual features of the Chinese characters studied in relation to character recognition and examine their contributions.
2. To evaluate what the existing evidence reveals about the effect of character simplification on visual distinctiveness and recognition, and where the evidence is insufficient.
3. To examine the methodological factors that limit the existing evidence.

CONCEPTUAL FRAMEWORK

Recognizing a Chinese character depends on two properties that can work in opposite directions (Hemelstrand & Inoue, 2025; Han et al., 2022). The first is complexity, i.e., how much visual information the reader must process whereas the second is distinctiveness, i.e., how different the character's form is from other characters. These properties are different in nature: complexity is a property of the character itself, whereas distinctiveness emerges only when a character is compared with others.

In compound characters, the two properties are closely related. Radicals contribute much of a character's visual structure, and they can also distinguish it from other characters that share its other component. Simplification acted on these same elements: reducing the stroke count of radicals lowered complexity; unfortunately, simplifying different radicals into visually similar forms may also have reduced distinctiveness (Chen & Yuen, 1991; Li et al., 2012).

METHODOLOGY

RESEARCH DESIGN

This study employs a systematic literature review (SLR) methodology to synthesize existing research on visual distinctiveness and character recognition in Chinese. To address the research objectives, this SLR follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines (Moher et al., 2010; Page et al., 2021) to ensure transparency and replicability in reporting. As the included studies employed a wide range of research designs and methods, a qualitative content analysis was used for data synthesis.

This review uses PICOC (Population, Intervention, Comparison, Outcome, Context) to define the scope and inclusion criteria (Booth et al., 2016). This approach has been adopted in systematic reviews within linguistics and cognitive science (e.g., Salehuddin & Mahmud, 2024; Salehuddin et al., 2025). The review process included protocol development, literature search, study screening and selection, data extraction, and qualitative synthesis and analysis.

REVIEW PROTOCOL (PICOC FRAMEWORK)

A review protocol was developed prior to the literature search using the PICOC framework (Table 2), which was further operationalized into explicit screening indicators (Table 3).

TABLE 2. Application of PICOC Framework to Define Research Scope

Component	Definition	Application to this SLR
Population (P)	The target population or unit of analysis addressed by the included studies	Empirical studies involving human participants that examine Chinese character recognition or processing at the character level, including native Chinese readers and L2 Chinese learners across different age groups (focusing on their cognitive processing of character rather than pedagogical outcomes)
Intervention (I)	The phenomenon or variables of interest being investigated	Visual features of Chinese characters, including stroke count, radical structure, component configuration, structural complexity, visual similarity, and effects associated with the Chinese character simplification reform.
Comparison (C)	Comparative conditions or contrasts examined in the studies	Comparisons between traditional and simplified Chinese characters, as well as contrasts between characters differing in visual complexity, distinctiveness, or orthographic structure.
Outcome (O)	Measured outcomes relevant to the research questions	Character recognition–related outcomes, including accuracy, reaction time, perceptual or visual distinctiveness, reading efficiency, cognitive processing measures, and morphological awareness.
Context (C)	Research settings and methodological contexts	Studies conducted within psycholinguistic, cognitive, educational, and orthographic research contexts, employing methods such as behavioral experiments, eye-tracking, corpus analyses, or cross-sectional designs.

TABLE 3. Operationalized PICOC Framework for Study Selection

Component	Operational Definition (for screening)	Inclusion Indicators (practical use)
Population (P)	Studies involving human participants performing character-level recognition or processing tasks	Reaction time / accuracy tasks on single characters; naming, lexical decision, semantic judgment at character level
Intervention (I)	Manipulation or analysis of visual or orthographic features of Chinese characters	Stroke count, radical structure, component position, visual similarity, simplification vs. traditional forms
Comparison (C)	Explicit comparison between character types or visual conditions	Simplified vs. traditional; high vs. low complexity; similar vs. dissimilar characters
Outcome (O)	Quantitative or qualitative measures of recognition or processing efficiency	Reaction time, accuracy, error rates, eye-movement measures, ERP components (as measures of visual/orthographic processing load)
Context (C)	Empirical experimental or observational research settings	Behavioral experiments, eye-tracking, ERP, corpus-based perception studies

SEARCH STRATEGY (DATABASE)

Four databases, namely, Web of Science, Scopus, CNKI (China National Knowledge Infrastructure), and TCI-HSS (Taiwan Citation Index-Humanities and Social Sciences) were searched to capture the studies published either in English or Chinese.

Search terms were developed based on the PICOC framework and refined through pilot searches. The detailed search strings are in Table 4.

TABLE 4. Search Databases, Search Fields and Search Strings

Database	Search Fields	Search String / Keywords
Web of Science	Title, Abstract, Keywords	TS = (("Chinese character*" OR "Chinese orthograph*") AND ("visual complexity" OR "orthographic complexity" OR "stroke count" OR "radical awareness" OR "component structure" OR "morphological awareness") AND ("character recognition" OR "visual processing"))
Scopus	Title, Abstract, Keywords	TITLE-ABS-KEY (("Chinese character*" OR "Chinese orthograph*") AND ("visual complexity" OR "orthographic complexity" OR "stroke count" OR "radical awareness" OR "component structure" OR "morphological awareness") AND ("character recognition" OR "visual processing"))
CNKI	Title, Abstract, Keywords	((□字+中文字符)*(□□复□度+正字法复□度+笔画数+部首意□)*(□别)*(□□))
TCI-HSS	Title, Abstract, Keywords	("漢字".ti or "漢字".kw or "字形".ti or "字形".kw) and ("辨識".ti or "辨識".kw or "辨識".ab or "識字".ti or "識字".kw)

For the CNKI and TCI-HSS database, search terms were translated and adapted into commonly used Chinese academic terms in both simplified and traditional forms.

INCLUSION AND EXCLUSION CRITERIA

Studies were included only if they were published either in English or Chinese. Inclusion and exclusion criteria were established and applied consistently during screening (Table 5).

TABLE 5. Inclusion and Exclusion Criteria

Criteria	Inclusion	Exclusion
Population	Native or L2 Chinese learners	Participants with diagnosed reading disorders (e.g., dyslexia), neurological impairments, or other special populations.
Publication type	Peer-reviewed journal articles	Conference papers, theses, book chapters, reviews
Language	English or Chinese	Other languages
Research focus	Chinese character recognition or processing at the character level	Word-level or sentence-level only; purely phonological or semantic processing without visual manipulation; classroom pedagogy or instructional efficacy
Study type	Empirical studies with original data	Theoretical, conceptual, or review studies
Key variables	Visual or orthographic features (e.g., stroke count, radicals (including both semantic and phonetic radicals), visual complexity, simplification)	Studies not addressing visual/orthographic features; ERP studies focused solely on wave characteristics without feature-based experimental design; Visual complexity treated only as a secondary control in non-recognition tasks

SELECTION PROCESS

To capture all relevant empirical studies, there were no initial restrictions on the publication year. An initial search yielded 274 records: 45 from Web of Science, 44 from Scopus, 133 from CNKI, 52 from TCI-HSS. After removing 99 theses/dissertations from CNKI and TCI-HSS, 175 journal articles were imported into Zotero. After excluding 17 duplicates, 158 records remained for title screening. Title screening excluded 49 records, leaving 109 for abstract screening, of which 62 studies were selected for full-text assessment. Of these, 33 were excluded, leaving 29 studies for synthesis. The final set included 10 written in English (with 4 from TCI-HSS) and 19 written in Chinese (15 from CNKI, 4 from TCI-HSS).

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INCLUDED STUDIES

Twenty-nine included studies examined visual features and their effects on character recognition using naming, decision tasks, matching tasks, learning paradigms, and neurocognitive measures. Visual complexity included stroke count, stroke type, radical or component structure, spatial configuration, symmetry, and global–local organization. Most studies focused on simplified Chinese characters, whereas fewer examined traditional characters or compared simplified and traditional forms.

Zhou and Jiang (2023) and Chen (2022) were excluded because their primary focus was on the development of processing strategies in second language acquisition rather than on the effects of visual or orthographic features on character-level recognition. In contrast, second-language studies that used recognition performance as an outcome variable were included (Chen & Peng, 2017; Chen et al., 2015).

The overall study identification, screening, eligibility assessment, and inclusion process is summarized in Figure 1 using a PRISMA flow diagram.

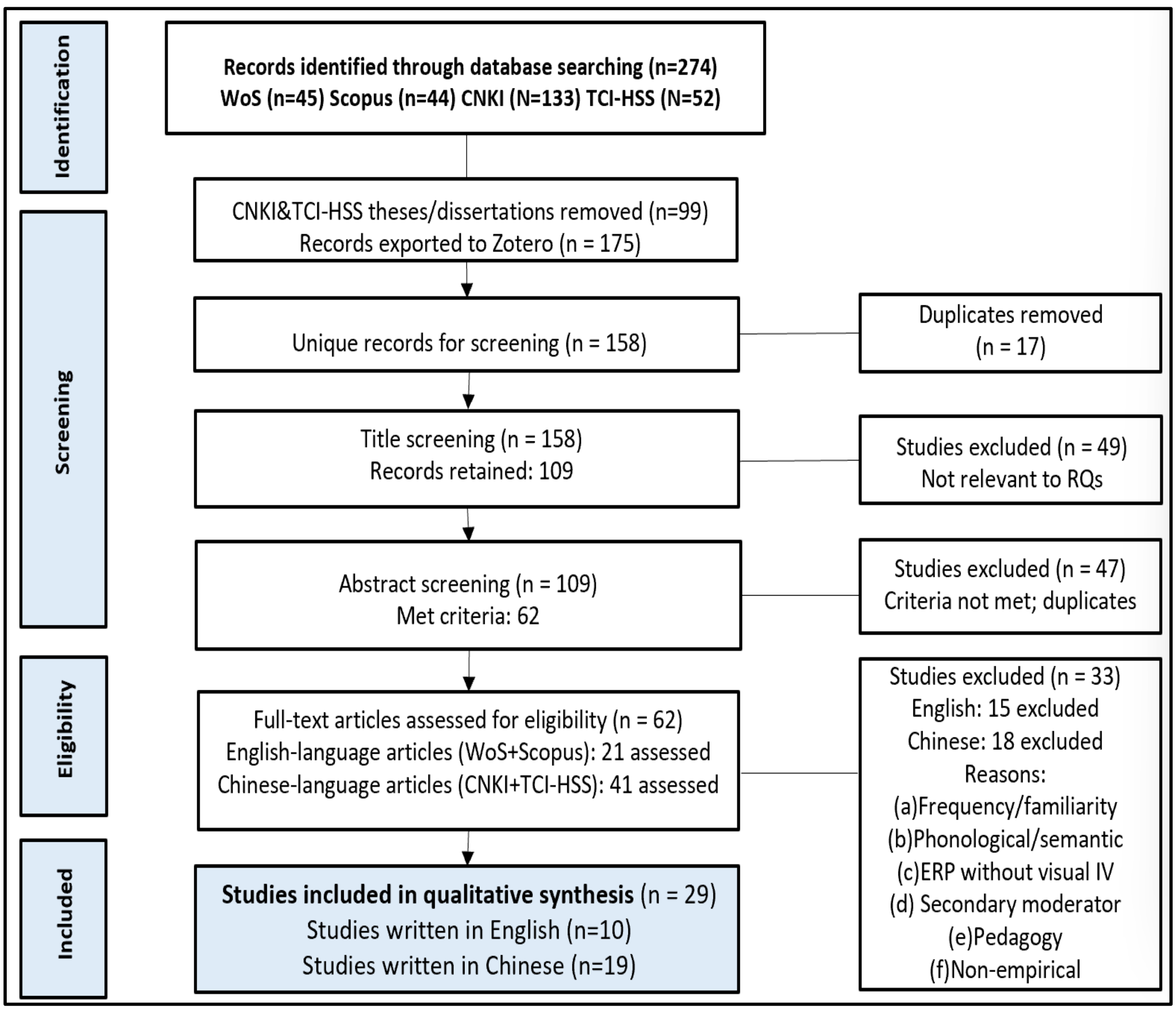

FIGURE 1. PRISMA flow chart showing the process of article screening and selection process for this SLR (n = number)

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DATA EXTRACTION AND SYNTHESIS

DATA EXTRACTION

Full texts were available for 23 of the 29 studies; for the remaining six, only abstract-level information was available and participant details were incomplete. After the full-text eligibility assessment, data were extracted from the 29 included studies. A structured template developed specifically for this review was used. For each included study, the following information was extracted where available: (1) bibliographic details; (2) publication language; (3) participant characteristics; (4) task type; (5) visual complexity dimensions; (6) character type; and (7) key findings. Additionally, based on the centrality of visual features, each study was assigned a functional role.

SYNTHESIS APPROACH

A quantitative meta-analysis was not feasible due to heterogeneity in participants, experimental tasks, visual complexity, and outcome measures. Therefore, qualitative content analysis approach was used. Studies were grouped by their primary visual dimensions.

TABLE 6. Characteristics and key findings from the extracted studies

#	References	Language	Participants	Task Type	Visual Complexity Dimension	Character Type	Key Finding	Role in Synthesis
1	Tong et al. (2017)	English	Children	Decision	Radical structure + position	Traditional	Sensitivity to radical structure develops with age and supports character recognition	Supporting evidence
2	Liu, Yeh & Hsiao (2018)	English	Adults	Matching	Global–local configuration	Simplified / Traditional	Visual expertise transfers across scripts when global structure is shared	Boundary/ conditional
3	Yang, Zhang & Wang (2016)	English	Adults	Naming	Stroke count	Simplified	Higher stroke count increases attentional load (P2) and slows recognition	Core evidence
4	Hsu, Lee & Marantz (2011)	English	Adults	ERP / Neuro	Stroke count	Traditional	Visual complexity effects emerge early (~200ms) and are influenced by reading expertise	Core evidence
5	Hsiao & Cheng (2013)	English	Adults	Naming	Global–local configuration	Traditional	Information distribution, not complexity alone, drives visual field asymmetry	Boundary/ conditional
6	Tseng et al. (2023)	English	Children	Learning / Training	Stroke count	Artificial	High visual complexity increases reliance on phonological support during character learning	Supporting evidence
7	Wu & Chen (2003)	English	Not reported in abstract	Naming + Decision	Orthographic similarity + component structure	Traditional (+ pseudo-character)	Orthographically similar primes inhibit target recognition; isolated component primes facilitate decision but not naming; pseudo-character primes have no effect	Core evidence
8	Chen & Weekes (2004)	English	Not reported in abstract	Semantic categorization + Decision	Semantic radical	Traditional	Characters whose meaning matches their semantic radical, and those with high-combinability radicals, are processed more efficiently	Supporting evidence

#	References	Language	Participants	Task Type	Visual Complexity Dimension	Character Type	Key Finding	Role in Synthesis
9	Chen & Peng (2017)	English	L2 learners (N not reported in abstract)	Character learning performance	stroke count+ component structure+ internal structure	Traditional	Only stroke count and textbook frequency predict character difficulty and acquisition performance	Boundary/ conditional
10	Yang & McConkie (1995)	English	University students	Decision	Stimulus degradation	Traditional	Semantic context and degradation affect the same processing stage regardless of contextual constraint	Boundary/ conditional
11	Yu, Zhang & Pan (1997)	Chinese	24 university students	Naming (with character rotation)	Stroke type (straight-line vs curved-line vs mixed)	Simplified (7-8 strokes, matched frequency)	Stroke type functions as holistic structural feature in character recognition	Core evidence
12	Zeng, Zhou & Yu (2001)	Chinese	Adults	Decision	Spatial transparency	Simplified (spatially compressed)	Regular and reversed structural configuration effects found; spatial transparency differences between character types explain both effects	Core evidence
13	Yu & Zhang (2014)	Chinese	Adults	Decision	Component number	Simplified / Pseudo-characters	Component number affects orthographic processing, but effect interacts with character frequency, supporting dual-route (top-down + bottom-up) processing	Core evidence
14	Xiao & Huang, (1998)	Chinese	University students	Matching + Naming	Component structure (frame structure)	Simplified	Frame structure serves as a necessary processing stage in single-character recognition, showing significant priming effects	Core evidence
15	Peng & Wang (1997)	Chinese	University students, N=20 Exp1, N=22 Exp2	Naming + Decision	Stroke count + Component structure	Simplified	Processing involves three hierarchical levels (stroke-radical-character); stroke number effect exists regardless of frequency, but radical number effect only significant in low-frequency characters	Core evidence
16	Li et al. (2005)	Chinese	University students, N=55	Decision	Stroke count + Spatial configuration	Simplified	Stroke number effect present across all structural types; structural configuration effect only in low-frequency and few-stroke conditions	Boundary/ conditional
17	Luo et al. (2010)	Chinese	University students, N=27 Exp1, N=26 Exp2	Reicher-Wheeler task + Radical judgment task	Component structure + Spatial configuration + Spatial position	Simplified (real characters + pseudo-characters + radical-symbol combinations)	Word inferiority effect found in both tasks; whole character inhibits radical processing; left-right structure processed faster than top-bottom	Core evidence
18	Li & Yang (2021)	Chinese	70 university students	Decision	Stroke count + Component structure	Simplified+ pseudo-characters	4-stroke characters show whole-character priming; 5-stroke characters show radical priming; pseudo-characters have longest RT	Supporting evidence

#	References	Language	Participants	Task Type	Visual Complexity Dimension	Character Type	Key Finding	Role in Synthesis
19	Qiu et al. (2008)	Chinese	36 university students	Decision	Stroke count + Spatial configuration + Phonological/ semantic/orthographic features	Simplified	Flanker effect found only under phonological distraction; orthographic and semantic distraction produced no significant effect compared to no-conflict baseline; response conflict condition showed the longest RT overall	Boundary/ conditional
20	Guo (2000)	Chinese	16 university students	Matching	Stroke count + Spatial configuration + Spatial frequency	Simplified	Global precedence effect: whole-character identification superior to component identification across all spatial frequencies; processing shifts from global to local level	Core evidence
21	Yu & Cao (1992)	Chinese	32 University students	Naming	Stroke count (2-15) + Frequency	Simplified	Stroke count effect shows "staircase" pattern: RT stable within small stroke ranges, increases at boundaries; frequency effect present but NO interaction with stroke count	Core evidence
22	Wang, Zhang, & Zhang (2003)	Chinese	29 university students	Stroke detection (with/without character context)	Stroke frequency + Stroke count	Simplified	Character-inferiority effect: strokes in characters detected slower (445-531ms) than isolated (251-286ms); stroke frequency effect significant	Core evidence
23	Shen, Pan, & Chen (1998)	Chinese	38 university students	Microgenetic paradigm (progressive exposure 13-150ms)	Character structure (left-right vs top-bottom) + Radical position	Simplified + pseudo-characters	Left-right structure superior to top-bottom (93.7% vs 77.2% at 100ms); radical position effects (right/bottom extracted first) independent of familiarity	Core evidence
24	Zhang & Feng (1992)	Chinese	14 university students; 13 staff	Character naming	Stroke count + Component count (orthogonal manipulation)	Simplified	For high-frequency characters, either stroke count or component count alone produces significant RT differences; for low-frequency characters, significant effects emerge only when both dimensions differ simultaneously	Core evidence
25	Chen & Huang (1999)	Chinese	30 university students	Character naming	Structural symmetry (mirror symmetry along axis)	Simplified	Symmetrical characters named faster, BUT effect only for LOW-frequency (not high) and MANY-stroke (not few) characters	Core evidence
26	Wu & Fang (1988)	Chinese	Not reported in abstract	Illusory conjunction	Conceptual distinctiveness	Traditional + pseudo-characters + non-lexical components)	Units of higher conceptual distinctiveness resist illusory conjunction; the basic unit of recognition is not fixed	Core evidence
27	Yang & Wu (2014)	Chinese	University students (N=40 per experiment)	Primed character decision (SOA 243 ms, 43 ms)	Semantic radical (form similarity)	Traditional + pseudo/non-characters)	Form similarity inhibits high-frequency targets independently of semantic facilitation; the semantic radical operates as an orthographic unit rather than a semantic one	Core evidence

#	References	Language	Participants	Task Type	Visual Complexity Dimension	Character Type	Key Finding	Role in Synthesis
28	Chen, Hu & Cheng (2015)	Chinese	L2 learners (N=21, alphabetic L1)	Pseudo-character selection (14 items)	Usefulness of semantic vs phonetic radical	Traditional + pseudo-characters)	Learners with basic literacy use semantic and phonetic radicals flexibly and interchangeably	Supporting evidence
29	Lin, Chou & Wu (2025)	Chinese	Adults (N=30 naming, N=30 decision)	Naming + Decision	Phonetic radical consistency (neighbourhood size balanced)	Traditional + pseudo-characters	Consistency facilitates naming and inhibits decision, in both cases only for low-frequency characters; the phonetic radical's orthographic information contributes to the effect	Core evidence

Note. Full texts were obtained for 23 of the 29 studies. For studies 7, 8, 9, 10, 26, and 28, extraction was limited to the published abstract.

OVERVIEW OF INCLUDED STUDIES

These studies examine stroke count and stroke type, component or radical structure, spatial configuration, structural symmetry, spatial transparency, global–local organization, conceptual distinctiveness, and semantic and phonetic radical properties. Sixteen studies focus on simplified Chinese characters, eleven examine traditional characters, one includes both scripts, and one employs artificial character stimuli. The one that includes both scripts (Liu et al., 2018) uses them as a tool to separate global structure from local component information, and no study examines character simplification as an object of investigation. The studies were classified as examining form-level properties (shape, position, and perceptual distinctiveness) or function-level properties (radical meaning or pronunciation).

Two patterns emerged. First, visual complexity effects are systematic but non-uniform. Visual simplicity does not entail higher distinctiveness, and the influence of specific visual features varies depending on task demands, reader expertise, and character attributes. Second, studies rarely separated a constituent's visual form from its linguistic function. Two studies (Yang & Wu, 2014; Lin et al., 2025) did so; the visual property operated independently of the linguistic property and at times overrode it.

FINDINGS

STROKE COUNT AND ORTHOGRAPHIC COMPLEXITY

Higher stroke counts increase processing demands and slow recognition speed (Yang, Zhang & Wang, 2016; Hsu et al., 2011; Yu & Cao, 1992), with effects emerging early in visual processing (150-250 milliseconds), indicating greater attentional load (Yang et al., 2016; Hsu et al., 2011).

Interestingly, the stroke count effect is not linear. Yu and Cao (1992) identified a "staircase" pattern, where reaction times remained relatively stable within small stroke count ranges but increased sharply at certain boundaries. This suggests that stroke count categories may influence recognition rather than continuous variations in complexity.

For high-frequency characters, stroke count and component count each independently affected reaction time. For low-frequency characters, however, effects only emerged when both dimensions differed significantly. This suggests that processing relies more on combined structural information when lexical information is weak (Zhang & Feng, 1992). Yang and McConkie (1995) suggest that stimulus degradation and character frequency are separable and that processing can operate independently of lexical familiarity.

Li and Yang (2021) used a stroke-to-character assembly paradigm with subliminal priming to examine how processing strategies shift according to character complexity. Results show that four-stroke characters elicited significant whole-character priming effects, whereas five-stroke characters showed stronger radical-level priming, suggesting that as complexity increases, processing strategies become more analytical and component-focused.

COMPONENT STRUCTURE AND HIERARCHICAL PROCESSING

Chinese character recognition involves more than stroke count; it also depends on the number and arrangement of components, including radicals and sub-character units. Peng and Wang (1997), for instance, provide evidence for hierarchical processing across strokes, components, and whole characters. The results show that stroke count effects were significant for both high- and low-frequency characters, whereas component-number effects were primarily strong in low-frequency characters.

Studies on component structure reveal complex interactions with character frequency and spatial configuration. Yu and Zhang (2014) demonstrate that component number affects orthographic processing, and that this effect interacts with character frequency, suggesting that both bottom-up structural analysis and top-down lexical knowledge contribute to recognition. Li et al. (2005) report that structural configuration effects (left-right versus top-bottom arrangements) were particularly evident in low-frequency and low-stroke-count conditions, indicating that visual structure becomes more important when other processing cues are weak.

The unit at which components are processed is not fixed. Wu and Fang (1988) show lower conjunction rates for stem compounds and stem components than for unique compounds and non-lexical forms, indicating that conceptual distinctiveness determines what functions as a basic representation. Wu and Chen (2003) further report that shared component form can interfere rather than facilitate: orthographically similar primes higher in frequency than the target inhibited both decision and naming, while a right-side component presented in isolation facilitated decision but not naming.

Developmental research (Tong et al., 2017) shows that sensitivity to radical structure develops with age and reading experience. Specifically, younger children (kindergartners) relied more on phonetic radicals and positional information, whereas older readers (fifth graders) demonstrated increased sensitivity to semantic radical functions.

Xiao and Huang (1998) demonstrate that frame structures (构成字框架的笔画) serve as a necessary processing stage, with significant priming effects observed when frame structures were shared between prime and target characters. Tseng et al. (2023) found that high visual complexity increases learners' reliance on phonological support. In their paired-associate learning task, learners with stronger phonological awareness performed better when stroke counts were higher.

Only one study examined the two properties as separate factors. Yang and Wu (2014) cross semantic with orthographic priming across two stimulus onset asynchronies (SOAs) while holding structural position constant. The two effects were additive, indicating different processing stages. Orthographic inhibition appeared only for high-frequency targets, and no sub-lexical semantic-radical facilitation was found, contrary to earlier reports. They conclude that the semantic radical functions as an orthographic rather than a semantic unit. Lin et al. (2025) also report an orthographic contribution to what has been treated as a phonological effect. Both effects, however, vary with target frequency. This does not give the evidence that semantic radicals are processed semantically (Chen & Weekes, 2004); rather, the two functions have rarely been distinguished.

GLOBAL-LOCAL CONFIGURATION AND HOLISTIC PROCESSING

Holistic, whole-character processing dominates over component-based processing. Guo (2000) demonstrates a robust global precedence effect, where whole-character identification was superior to component identification across all spatial frequencies. This finding was supported by Luo et al. (2010), who documented a "word inferiority effect" (字劣效□) in which the whole character inhibited radical processing—a pattern opposite to the word superiority effect observed in alphabetic languages.

The suppressive effect of whole-character processing on component detection was further confirmed by Wang, Zhang, and Zhang (2003). They found a character-inferiority effect in stroke detection tasks. Strokes embedded within characters were detected significantly slower than isolated strokes, suggesting that whole-character representations actively suppress lower-level feature processing.

Studies examining global-local processing dynamics (Hsiao & Cheng, 2013; Liu et al., 2018) reveal that information distribution across the character, rather than complexity alone, drives processing strategies and visual field asymmetries. Liu et al. (2018) demonstrate that visual expertise can transfer across simplified and traditional scripts when global structure is shared, highlighting the importance of configural information in skilled character recognition.

Shen, Pan, and Chen (1998) employed a microgenetic paradigm (i.e., progressively longer exposures, 13-150 ms) to track how character structure unfolds over time. Left-right structures achieved accuracy at 100 ms exposure, compared to top-bottom structures. Furthermore, radical position effects were independent of character familiarity, with right and bottom radicals extracted first regardless of whether characters were real, pseudo-characters, or isolated radicals. These findings show that structural processing comes before feature extraction.

ADDITIONAL FORM-LEVEL PROPERTIES

Yu, Zhang, and Pan (1997) demonstrate that stroke type (straight-line versus curved-line versus mixed) functions as a whole-shape feature in character recognition, even when stroke count is controlled. Straight-line characters were consistently recognized faster than curved-line characters across all orientations. This suggests that the quality of strokes, not just their quantity, contributes to visual distinctiveness.

An innovative dimension explored by Chen and Huang (1999) was structural symmetry based on Gestalt principles. They found that symmetrical characters were named faster than asymmetrical characters matched on stroke and component count. However, this symmetry advantage was conditional: it only emerged for low-frequency characters with many strokes, not for high-frequency or few-stroke characters.

Zeng, Zhou, and Yu (2001) introduce the concept of spatial transparency (空□通透性; i.e., the degree of open space between strokes). Compression direction could reverse the usual structural configuration effects: horizontal compression made top-bottom characters easier to recognize, while vertical compression favored left-right characters. These reversals closely matched changes in stroke spacing, supporting their spatial transparency mediation hypothesis. Characters with greater spatial transparency were recognized more efficiently.

DISCUSSION

The findings indicate that the visual distinctiveness in Chinese characters is multidimensional, with stroke, component, and whole-character levels interacting with reader expertise, character frequency, and task demands. The following sections discuss these findings in relation to the three research objectives: the visual features examined in the literature (RO1), the effects of character simplification and the limits of the current evidence (RO2), and the methodological limitations (RO3).

VISUAL FEATURES EXAMINED IN RELATION TO CHARACTER RECOGNITION

Stroke count consistently affects processing demands (Yang et al., 2016; Yu & Cao, 1992; Hsu et al., 2011), but its influence is categorical rather than continuous. The “staircase” pattern (Yu & Cao, 1992) implies that perceptual threshold matters more than the absolute number of strokes. Beyond stroke count, stroke type reflects qualitative differences in visual form. The overall contour of a character can function as a holistic perceptual cue. Therefore, stroke reduction alone is not enough to capture visual recognizability if differences in stroke type are not also considered.

At an intermediate level, component and radical structure reflect the internal organization of characters. Evidence from Peng and Wang (1997) and Zhang and Feng (1992) shows that stroke-level and component-level effects are separate and respond differently to character frequency: stroke count effects tend to be stable across frequency conditions, whereas component-level effects are stronger for low-frequency characters. This suggests that high-frequency characters may be recognized through direct lexical access, with less reliance on structural analysis. For low-frequency characters, readers depend more on component-level cues. This pattern is consistent with the dual-route accounts of character recognition (Yu & Zhang, 2014).

At a higher level, spatial configuration and global structure shape how visual information is processed. Guo (2000) and Luo et al. (2010) report that coarse structural information is extracted early in processing. Zeng et al. (2001) suggest that spatial transparency contributes independently. This highlights the role of empty space in visual recognition, not just the number or type of strokes. Together, these findings show that character recognition depends on configural processing that goes beyond simply adding up individual visual features.

EFFECTS OF CHARACTER SIMPLIFICATION ON VISUAL DISTINCTIVENESS AND RECOGNITION

Even though both simplified-script database (CNKI) and traditional-script database (TCI-HSS) have been searched, only one of the 29 included studies used both scripts as its primary materials, and none examined character simplification as an object of investigation. Liu et al. (2018) found that expertise markers can transfer across scripts when overall structures are shared, whereas effects dependent on local component familiarity cannot. However, in that study, the two scripts were used as a tool to separate global structure from local component information, rather than as objects of comparison. Therefore, the discussion below is based on inferences drawn from single-dimension evidence, not from direct tests of simplification.

At the basic perceptual level, simplification reduces stroke count (Gao & Kao, 2002). Higher stroke counts demand greater processing effort (Yang et al., 2016; Yu & Cao, 1992; Hsu et al., 2011) and slow recognition speed. Those studies compare stroke count differences between different characters, whereas simplification involves the simplified and traditional forms of the same character. Therefore, the effect obtained from cross-character comparison cannot be directly applied to the change from one written form of a character to another. The stroke count effect is not modulated by character frequency (Peng & Wang, 1997; Yu & Cao, 1992), whereas component-level effects are modulated by frequency (Zhang & Feng, 1992; Li et al., 2005; Yu & Zhang, 2014).

However, simplification may introduce higher-level processing costs. Visual distinctiveness depends not only on stroke count but also on component structure, spatial configuration, and global form. When simplification reduces or merges components, it may remove structural cues that help readers tell characters apart (Tsang et al., 2024). In some cases, multiple traditional characters are combined into a single simplified form, making previously distinct characters look more similar (e.g. 發 and 髮 were both merged into 发) (Tsang et al., 2024). This loss of distinctiveness may make recognition harder, especially for low-frequency characters, as readers rely more on component-level and configural information (Zhang & Feng, 1992; Li et al., 2005). The recognition of those merged characters has not been examined in the included studies.

Another related issue is spatial transparency. Zeng et al. (2001) propose that the distribution of open space between strokes rather than the stroke count alone mediates the visual recognition difficulty of Chinese characters. The structural effect can be reversed simply by changing the stroke spacing (Zeng et al., 2001). The configuration effect is not inherent in the configuration itself, but rather operates through the degree of stroke dispersion. Therefore, attributes such as the number of strokes, structural pattern, and stroke type, which are measured separately as parallel independent dimensions in the literature, may share the same underlying variable. Likewise, as suggested by the "staircase" pattern of stroke count effects, reducing visual complexity does not always lead to better recognition (Yu & Cao, 1992). Whether simplification helps or hurts depends on whether the perceptual threshold has been crossed.

In summary, these considerations suggest the complexity and distinctiveness trade-off proposed in the Conceptual Framework. Skilled readers may rely more on holistic processing and be less affected by the loss of fine structural detail, whereas less experienced readers may be more sensitive to reduced component distinctiveness (Tong et al., 2017; Liu et al., 2018).

Overall, the existing evidence is insufficient to determine the direct effect of simplification on recognition. Simplification involves altering multiple dimensions of a single character simultaneously (reducing strokes, merging components, changing structure), and the effects of each dimension may be in opposite directions. None of the 29 articles manipulates the set of dimensional changes of simplification. Therefore, the lack of evidence is not a matter of quantity, but rather that the existing paradigm cannot address this question.

METHODOLOGICAL LIMITATIONS OF THE EXISTING EVIDENCE

This synthesis of 29 studies reveals several methodological factors limiting existing evidence that future research should address. Current research almost exclusively samples within a single script tradition (16 studies for simplified characters and 11 studies for traditional ones), treating script as a property of the stimulus set rather than as a variable. This design makes it difficult to exclude confounding factors related to sample, task, and participant population when comparing across studies. Future research should adopt direct comparative designs using matched simplified-traditional character pairs.

Another limitation is how visual complexity is measured. Most included studies primarily relied on stroke count as the measurement criterion. Other dimensions, including component structure (Peng & Wang, 1997; Yu & Zhang, 2014), spatial configuration (Li et al., 2005; Luo et al., 2010), stroke type (Yu et al., 1997), and spatial transparency (Zeng et al., 2001), each contribute to recognition. Since the configuration effect can be reversed by stroke spacing (Zeng et al., 2001), these separately measured dimensions may share the same underlying variable. Therefore, the relationships between different dimensions remain to be examined. In addition, existing research rarely manipulates the visual form and linguistic function of components as independent factors: Yang and Wu (2014), who manipulated the two independently, found that semantic radicals function as orthographic units; Lin et al. (2025) also separated an orthographic contribution to the phonetic consistency effect. However, Chen and Weekes (2004) reported a finding that points in the opposite direction: processing was more efficient when semantic radicals were matched with the character's meaning. The discrepancy may stem from whether the two are manipulated separately. Future research should adopt more comprehensive measurement approaches.

The third limitation is the narrow scope of participant population. Twenty-two studies focused on adult university students. Two studies (Tong et al., 2017; Tseng et al., 2023) examined younger children or those with developing reading skills. Two studies examined L2 learners (Chen & Peng, 2017; Chen et al., 2015), whereas six other articles were only available as abstracts; among these, three did not specify the participant population and they were not included in this statistic. However, the impact of visual complexity is most pronounced during early literacy development, as readers rely more heavily on visual and structural cues. Recent studies outside this review have begun to address children and beginning learners. Yu et al. (2023) found that orthographic awareness, character recognition, and vocabulary knowledge jointly predict L1 children's reading fluency, and Chen (2022) tracked the non-synchronous development of radical awareness in L2 learners. However, neither has been linked to visual distinctiveness. Future research should systematically examine the interaction between visual features and reading experience in children and L2 learners.

Finally, the included studies primarily relied on behavioral measurement methods, such as naming and decision-making tasks. Neuroimaging and computational approaches offer additional methods to investigate how visual features are processed across different stages and brain regions. Early ERP and MEG findings by Yang et al. (2016) and Hsu et al. (2011) suggest that complexity effects can emerge within the first 200 milliseconds of processing. Future studies could extend this line of research by applying neuroimaging techniques to focus on time course and processing stages.

CONTRIBUTION

The scarcity of comparative studies between simplified and traditional Chinese characters may be attributed to the bias of database coverage towards simplified Chinese literature. Of the 29 included studies covering databases of English and Chinese, none directly compared the two scripts; the only study to include both scripts (Liu et al., 2018) used them as a tool to separate global structure from local component information, rather than as objects of comparison. Therefore, the gap is not a product of database bias, but a reflection of the state of the literature itself. It has been widely accepted that simplification may not directly improve recognition; however, this assertion lacks direct empirical support, and the gap is structural. This is not a matter of insufficient research, but rather that existing paradigms cannot address this question.

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LIMITATIONS

Several limitations of this review should be acknowledged. First, of the 29 articles, the full text could not be obtained for six, thus the data extraction was limited to the published abstracts; among these four did not report participant numbers, and three did not specify the participant population, which constrains the conclusion that can be drawn from this part of the evidence.

Second, only studies published in English or Chinese were included. Relevant research published in other languages (e.g., Japanese or Korean) may also address Chinese character processing, particularly in the context of native speakers or foreign language learners, and may have been missed.

Third, the search strategy relied on specific keywords related to visual features and character recognition. As a result, studies examining visual complexity as a secondary variable may not be included. Although CNKI and TCI-HSS provide access to Chinese-language studies of both simplified and traditional characters, the evaluation of Chinese and English literature may not be fully comparable due to differences in reporting conventions and interpretive demands. In addition, due to the large differences in participants, experimental tasks, and outcome measures included in the studies, a quantitative meta-analysis could not be conducted. Such analyses may become possible if reporting standards become more standardised.

Finally, the classification of studies into functional roles (i.e., core evidence, supporting evidence, or boundary/conditional evidence) was based on the judgment of the reviewers and should be understood as an organizational framework rather than a formal quality assessment. The lack of a standardized quality assessment tool applicable across diverse methodologies represents a limitation that future research in this field should aim to address.

CONCLUSION

This systematic literature review has examined how visual features of Chinese characters influence character recognition and identified methodological limitations in the existing evidence. In response to RO1, the review shows that visual distinctiveness in Chinese character recognition is multidimensional, encompassing stroke properties, component structure, spatial configuration, spatial transparency, and global form. These dimensions interact with character frequency, reader expertise, and task demands to determine recognition outcomes. In response to RO2, the existing evidence is insufficient to determine the direct effects of simplification; inferences based on single-dimension evidence suggest that stroke reduction may support early visual processing, while component merging may weaken distinctiveness; however, these inferences have not yet been tested. Because only one article (Liu et al., 2018) included both scripts and none used them to examine simplification itself, these conclusions remain inferential rather than empirically confirmed. In response to RO3, four major gaps were identified: First, most studies sample from only one script, which makes comparison across them unreliable. Second, visual complexity is measured mainly through stroke count, with little attention to relationships among visual dimensions or to the distinction between form and function. Third, the existing literature is heavily concentrated on adult university populations, with limited attention to developing readers and second-language learners. Finally, behavioral measures remain the primary means of assessment, offering limited insight into the processes underlying recognition.

To conclude, this review shows that the widely accepted assertion that simplification does not necessarily improve recognition has not been directly examined, and this gap is structural. Existing paradigms cannot answer a question about simultaneous multidimensional transformations. Future research should adopt comparative designs, broader participant samples, and richer measures of visual form. Such efforts would not only advance theoretical accounts of Chinese orthographic processing but also provide valuable insights for literacy development and educational practice in Chinese-speaking contexts.

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