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Comparison studies of typing and handwriting in Chinese language learning: A synthetic review

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ABSTRACT

The differential effects of typing and handwriting on language performance have attracted much research attention, including literature reviews and meta-analyses in the field of English-language education. However, how these two modes of language production interact with the unique characteristics of Chinese characters and the various dimensions of Chinese language learning and performance remains an open question. The present study therefore presents a synthetic review of empirical studies examining the effects of typing and handwriting on Chinese language performance. The study found that typing has a greater effect on Chinese learners' phonology recognition and phonology-orthography mapping than handwriting, and this advantage was more salient in Chinese than in English. Unlike in English, where it only benefited orthographic recognition of letters, handwriting had positive effects on Chinese learners' orthography recognition and orthography-semantic mapping at both the character and lexical levels. Moreover, in contrast with consistent findings concerning the positive effect of typing on English writing performance, the effects of typing on Chinese writing performance were mixed. The findings suggest that the effects of typing and handwriting might manifest differently in the two languages, calling for differential theorization of the cognitive impact of typing on English and Chinese language processing.

1. Introduction

Handwriting is an important way to enhance letter recognition and learn new words (Graham & Weintraub, 1996; Hsiung, Chang, Chen, & Sung, 2017). However, as information and communication technology (ICT) becomes ever more pervasive in daily life, children are learning typing simultaneously with or even prior to handwriting in school, or even before entering school (Amez & Baert, 2020; Mangen & Balsvik, 2016; Verhoeven, Voeten, van Setten, & Segers, 2020). As the proportion of time students spend typing increases, it is worth examining how this mode of written communication might affect language learning.

Numerous studies have examined the effects of typing and handwriting on English language learning. Meta-analyses and reviews of these studies have revealed a stronger and more lasting impact of handwriting on letter recognition (e.g. Longcamp, Zerbato-Poudou, & Velay, 2005; Wollscheid, Sjaastad, & Tømte, 2016), but a greater positive effect of typing on writing quantity, quality, and motivation (e.g. Goldberg, Russell, & Cook, 2003; Wollscheid, Sjaastad, Tømte et al., 2016; Wollscheid, Sjaastad, Tømte, & Løver, 2016).

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These findings suggest that typing and handwriting may activate different cognitive and neurological processes (Purcell, Turkeltaub, Eden, & Rapp, 2011).

However, it remains unclear whether similar results would hold for languages with different writing systems, such as Chinese (Wong, Boticki, Sun, & Looi, 2011). Chinese characters are the smallest unit in Chinese. As 80 % of Chinese characters comprise both a phonetic radical and a semantic one (Feldman & Siok, 1999; Ho, Ng, & Ng, 2003), the phonetic, semantic, and orthographic associations within Chinese characters are much closer than those within English letters and words (Dang, Zhang, Wang, & Yang, 2019; Tan & Perfetti, 1998). Therefore, the cognitive processes involved in retrieving appropriate characters and the likelihood of retaining them in memory induced by typing and handwriting might show up differently in Chinese than in English. To what extent should handwriting and(or) typewriting practice be involved in the classrooms is a controversial issue in Chinese language learning and has drawn much attention in the Chinese language education field (both as L1 and L2) (see Chen, 2018; Di, 2014; Lu, Ostrow, & Heffernan, 2019; Xu, 2011). Some scholars argue that typewriting may hinder Chinese language acquisition as lacking handwriting practice results in poor character retention and even hinder reading performance (Chen, 2018; Di, 2014; Tan, Xu, Chang, & Siok, 2013; Xu, 2011). Others, however, argue that handwriting is the most time-consuming activity in the class, and typewriting training can decrease the difficulties of character learning, especially for beginning learners (Allen, 2008; Xie, 2010). Some empirical studies have been conducted to compare the effects of typing and handwriting on different language components, including Chinese characters (Guan, Perfetti, & Meng, 2015; Guan & Wang, 2017; Guan, Liu, Chan, Ye, & Perfetti, 2011; Tan et al., 2013) and essay production (Chai, Wong, Sim, & Deng, 2012; Zhu, Shum, Tse, & Liu, 2016). However, inconsistent findings are reported, and a holistic picture of current findings on the issue is essential to guiding Chinese language teachers' pedagogical practices. Thus, a synthetic review is needed, but currently lacking, to provide such a holistic view and allow for a comparison of the findings from Chinese-language studies with those from English-language studies (Gong, Gao, & Lyu, 2020; Gong, Lai, & Gao, 2020; Gong, Lyu, & Gao, 2018; Ma, Gong, Gao, & Xiang, 2017). The present work aims to fill this research gap and develop a comparative model of the cognitive processes involved in typing and handwriting in Chinese and in English. Such a comparative model will provide nuanced insights into the impact of these two modes of writing on language learning and performance.

2. Literature review

2.1. Cognitive processes involved in typing and handwriting

Typing and handwriting involve separate cognitive processes. Summarizing research findings from cognitive psychology, Mangen and Velay (2010) identified four primary differences between these two modes of writing. First, typewriting is a bimanual activity, which may involve interhemispheric activity, whereas handwriting is unimanual and relates to "cerebral lateralization of language and motor processes" (p. 396). Considering that the left hemisphere is mainly responsible for linguistic processes in most cases, handwriting thus may induce greater brain activation in terms of letter production. Second, producing the same word by handwriting takes more time than by typing. According to Gentner (1983), it takes an average of 100 ms to draw a stroke or a letter, but on a computer screen these shapes appear almost instantaneously. The longer processing time thus may facilitate the retention of words in writers' brains.

Third, during handwriting, writers focus on a limited space—a small subsection of piece of paper and the endpoint of the pen. The spatiotemporal contiguity between sensory and motor action and (audio-)visual output may contribute to enriched cognitive processing (see also Higashiyama, Takeda, Someya, Kuroiwa, & Tanaka, 2015; Mangen, Anda, Oxborough, & Brønnick, 2015). In contrast, during typing, attention is split between the motor space (the keyboard) and the visual space (the screen), which may reduce the intensity of cognitive processing (Mangen & Velay, 2010). Fourth, handwriting involves the processing of both the shape and position of individual letters within a word, whereas typing processes the position of letters within a word only. Thus, intensive handwriting practice may be beneficial to the memorization of graphic forms (see also Naka & Naoi, 1995). Mangen and Velay (2010) argue that these fundamental differences suggest that handwriting has cognitive advantages in written language processing. Purcell et al. (2011) further added that differences in the cognitive architecture of typewriting and handwriting are also rooted in peripheral processes regarding motor actions for producing letters/words. To be specific, the production of a word through handwriting involves both allographic/letter-shape conversion and graphic-motor planning, whereas the production of a word through typing involves graphic-motor planning only.

The above conceptualizations of the different cognitive processes involved in typing and handwriting have also been verified in various functional magnetic resonance imaging (fMRI) studies. For instance, Longcamp et al. (2008) found that when participants processed handwritten input, activation was detected in multiple brain regions—specifically, the brain regions that are responsible for execution (e.g., same-different discrimination), visual-spatial processing (e.g., visual processing of graphic shapes), and motor activity (e.g., motor action). However, when participants processed printed input, activation was only observed in the brain region that is responsible for execution. Thus, as handwriting activates more brain regions that are in charge of different aspects of letter identification, handwritten input may induce better performance on recognition tasks than typewritten input.

Similarly, Higashiyama et al. (2015) also found that production tasks using both modes of writing activated the left anterior superior parietal lobule (involved in visuospatial processing), the left supramarginal gyrus (involved in motor representations), and the posterior end of the left middle frontal gyrus/superior frontal gyrus (involved in spatially oriented working memory). However, the typing task primarily activated the left posteromedial intraparietal cortex, which is associated with spelling knowledge (see Buchwald & Rapp, 2009). Moreover, activity in the left premotor cortex was found to be more rostral during a typing task than during a handwriting task. They speculated that this could be due to the greater spatial attention involved in, or the greater sensory demands of,

the former. Higashiyama et al. (2015, p. 15) thus concluded that there were "higher orthographic working memory demands in typewriting than in handwriting", suggesting that more working load is needed in typewriting tasks.

Thus, psychological and neuroscience studies have consistently indicated that distinct cognitive architecture and processes are involved in typewriting and handwriting. These differences may influence character/letter processing in two writing modes, suggesting the advantages of handwriting. However, it is under-explored whether similar cognitive processes are applicable to graphic languages such as Chinese. The associations between phonetics, semantics, and orthography are much closer in Chinese than in English (Feldman & Siok, 1999; Ho et al., 2003), and typing Chinese characters via Pinyin implies an extra phoneme-grapheme conversion that is not needed in English typing (Chen, Luo, & Liu, 2017; Guan et al., 2011). The differences in Chinese and English suggest that the cognitive processes might be different in typing and handwriting, and thus might further exert differential effects. Understanding the differential effects of typing and handwriting on these two languages, which represent non-alphabetic and alphabetic languages, could develop a comparative cognitive model to inform general language processing rules, as well as having implications for language education (Gong, Ma, Hsiang, & Wang, 2020).

2.2. Impact of typing and handwriting on English

Existing studies in the English language education field have revealed that typing and handwriting have differential effects on both orthographic learning and writing performance. It has been found that handwriting has a stronger and more lasting impact on orthographic learning among both L1 and L2 English students. For example, Longcamp et al. (2005) conducted a three-week letter-learning intervention in a preschool context, with one group of three- to five-year-olds learning letters via typing and another learning them via handwriting. The five-year-old children in the handwriting group performed better on immediate and delayed letter-recognition tests both immediately after the intervention's learning sessions and one to two weeks later. Similar findings are reported in the adult L2 English learner context. Longcamp, Boucard, Gilhodes, and Velay (2006) taught 12 adult participants 20 pseudo-words modified from the Bengali and Gujarati alphabets through either typing or handwriting. Word-recognition tests were conducted immediately after the three-week intervention, and at one-week and three-week intervals after it ended. The participants in the handwriting learning mode were found to perform significantly better both in immediate and delayed tests. The researchers attributed the observed advantage of handwriting to motor effects, i.e. that writing by hand involves more motor memory than writing by typing. The stronger motor memory led to greater orthographic memory (Mangen & Balsvik, 2016). However, notwithstanding consistent findings on the greater advantage of handwriting in letter recognition, investigations into the writing modality effect on lexical-orthography learning have yielded inconsistent findings. Some studies showed that handwriting led to greater performance in lexical recognition (Cunningham & Stanovich, 1990), whereas others revealed no significant differences between handwriting and typing (Stainthorp, 1997; Vaughn, Schumm, & Gordon, 1992).

With regard to writing performance, meta-analyses on the effects of writing modality have consistently reported that students performed better when typing their compositions. Based on their review of 26 studies of English-speaking K-12 students published between 1992 and 2002, Goldberg et al. (2003) found that typing led to greater motivation and better performance in both writing quantity ($d = .05$) and quality ($d = .50$) than did paper-and-pencil writing. Looking beyond the overall quality of the essay, Wollscheid, Sjaastad, Tømte et al. (2016) and Wollscheid, Sjaastad, Tømte, Løver et al. (2016) reviewed 10 studies from 2005 to 2015 that compared the impact of typing and handwriting on primary school students' letter/alphabet transcription, writing of simple words and sentences, writing enjoyment, and writing experience. The researchers found that handwriting helped enhance writing fluency, letter recognition, and reproduction, whereas typing improved students' attitudes toward writing. Focusing specifically on weaker K-12 writers and readers, Morphy and Graham's (2012) review of 27 studies found that typing had positive effects on writing quality ($d = .52$), length ($d = .48$), textual development/organization ($d = .66$), mechanical correctness ($d = .61$), motivation to write ($d = 1.42$), and attitudes towards word processing ($d = .64$). Similarly, in the context of English L2 learning, studies have reported that typing has a significantly more positive effect than handwriting on students' writing quantity and quality, as well as their writing motivation (Li & Cumming, 2001; Wollscheid, Sjaastad, Tømte et al., 2016). Researchers have attributed the observed advantages of typing for writing performance to its facilitation of more frequent revision (Bangert-Drowns, 1993; Chadwick & Bruce, 1989; Sarbakhshian & Saeidi, 2016). This body of literature has further revealed that the effects of typing on writing performance might be stronger for older learners than for younger learners. For example, Goldberg et al.' (2003) meta-analysis showed that middle- and high-school students performed better than primary schoolers when composing through typing, after controlling for individuals' keyboarding experience and academic achievement. This is further corroborated in Berninger, Abbott, Augsburger, and Garcia' (2009) longitudinal study where students were found to produce longer sentences and essays via handwriting when they were in second grade, but via typing when they progressed to fourth grade and above.

Thus, literature from the English language education context suggests a consistently stronger effect of handwriting on letter recognition, but not on lexical recognition. It further reveals an advantage of typing over handwriting on the motivation and quality of student's writing performance.

2.3. Characteristics of written-word production in Chinese

The production of written words in Chinese is influenced primarily by the characteristics of the basic unit in the Chinese writing system, the Chinese character (Zhu, Liu, Ding, & Peng, 2009). Chinese orthography is morpho-syllabic, with each character representing both a syllable and a morpheme (DeFrancis, 1989). Broadly square in shape, these characters can be divided into two main types: integrated (consisting of inseparable crossed strokes), and compound (typically involving two or more separable

subcomponents). More than 80 % of the most commonly used Chinese characters are semantic-phonetic compounds, that is, they include both semantic and phonetic radicals (Zhou, 1978). Semantic radicals provide cues to the meanings of characters, while phonetic radicals provide pronunciation cues (for an example, see Table 1). Thus, unlike in English, knowing how to pronounce a word in Chinese does not automatically imply being able to transcribe it into an understandable written form. Pinyin is used to denote the pronunciation of Chinese characters, but the probability of a given Chinese character sharing the same syllable with another is about 9 % (Tan & Perfetti, 1998). Therefore, a person must be able to recognize Chinese characters after typing Pinyin on a digital device (for an example, see Fig. 1), meaning that such typing involves a different input process from typing of English and other alphabetic languages.

The most commonly used Chinese typing system, Pinyin input (Zhu et al., 2009), involves typing Pinyin without tone marks and then selecting the appropriate character from a list that then appears below it (see Fig. 1). This review examined Pinyin typing, on the grounds of its greater popularity than any other such system.[1]

Considering the unique characteristics of the Chinese writing system and its inputting mechanism, the question remains of whether the two writing modes might impose similar effects on Chinese written language processing as those revealed in the English language education literature. Although quite a number of studies have investigated the effects of handwriting and typing on various dimensions of Chinese-language learning (e.g., Chai et al., 2012; Guan et al., 2011; Tan et al., 2013; Zhu et al., 2016), there is no synthetic review of the literature that could yield a holistic picture of the issue, to support a systematic comparison of the findings with those from the English language education field. A comparison of the findings from the Chinese- and English-language education contexts may shed considerable light on the cognitive architecture and processes of typing and handwriting across the two languages. Such a review could also yield useful pedagogical recommendations regarding keyboarding and handwriting in Chinese language teaching and learning, which is a controversial issue in the field. The study was guided by the following research question:

RQ: How do typing[2] and handwriting affect different aspects of Chinese language learning and performance?

3. Methods

3.1. Literature search

To locate studies for inclusion in this paper, keyword searches were conducted using the Educational Resources Information Center (ERIC) database, Web of Science, and the China National Knowledge Infrastructure database (CNKI). The search string used in the two English-language databases was "handwriting or writing by hand" + "typing or typewriting or keyboarding" + "Chinese or Chinese character", along with the Chinese-language equivalents (手写 + "认打 or 打字 or 键盘" + "中文 or 汉语 or 汉字"). Publication types were limited to journal articles, conference proceedings, doctoral dissertations, and Master's theses in the literature search, on the grounds that these four types of publications have all undergone formal review processes. The reference sections of each article were also checked to help identify any further relevant literature, generating an additional 3 articles in Chinese. 129 studies written in English and 4,060 written in Chinese were generated after duplicates removed. Following this procedure, the abstracts of 4,189 articles were read to determine whether they were comparative studies on typing vs. handwriting (Cohen's Kappa = 1.000). 43 publications remained after this screening.

3.2. Inclusion criteria

The following criteria were used to determine whether the remaining 43 publications were suitable to be included in the review:

1) the study compared typing and handwriting (or orthography-based typing), or frequent and less-frequent typists;
2) the study was empirical (i.e., an experimental or quasi-experimental, single-case, or questionnaire-survey design); and
3) the study reported quantitative findings on the impact of writing modes on students' Chinese language learning.

To establish whether these criteria had been met, the abstract of each article was reviewed by two members of the research team. As a result of this process, a total of 27 articles (13 in English and 14 in Chinese, published between 2009 and 2019) were deemed to meet all the criteria and were thus included in the present synthetic review. The article screening and selection process is presented in a Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram in Fig. 2.

3.3. Coding and analysis

The included articles were coded along the dimensions of research context, research design, and learning outcome and its measurement (see Table 2). Four researchers independently coded each study. The results of Cohen's kappa coefficient of all indicators

[1] It should be pointed out some other typing engines, such as Wubi and Cangie, are orthography-based and therefore require their users to analyze the components of each character and remember the corresponding keys. Taking the character 妈 (mā, mother) as an example, the two subcomponents are 女 and 马, with 女 being in key v, and 马 in key c. Thus, to type 妈, learners need to strike v and c in turn.

[2] In the remainder of this article, except where otherwise stated, "typing" refers to Pinyin typing. Orthography-based typing is considered as handwriting.

Table 1
An example of Chinese character components.

Chinese Character	妈
Pinyin (pronunciation)	mā
Meaning	mother
Strokes	
Semantic radical	女 (meaning: woman)
Phonetic radical	马 (pronunciation: mǎ)

Chinese Character	妈
Pinyin (pronunciation)	mā
Meaning	mother
Strokes	〈 丿 一 冂 ·
Semantic radical	女 (meaning: woman)
Phonetic radical	马 (pronunciation: mǎ)

Fig. 1. An example of typing a Chinese character via Pinyin input.

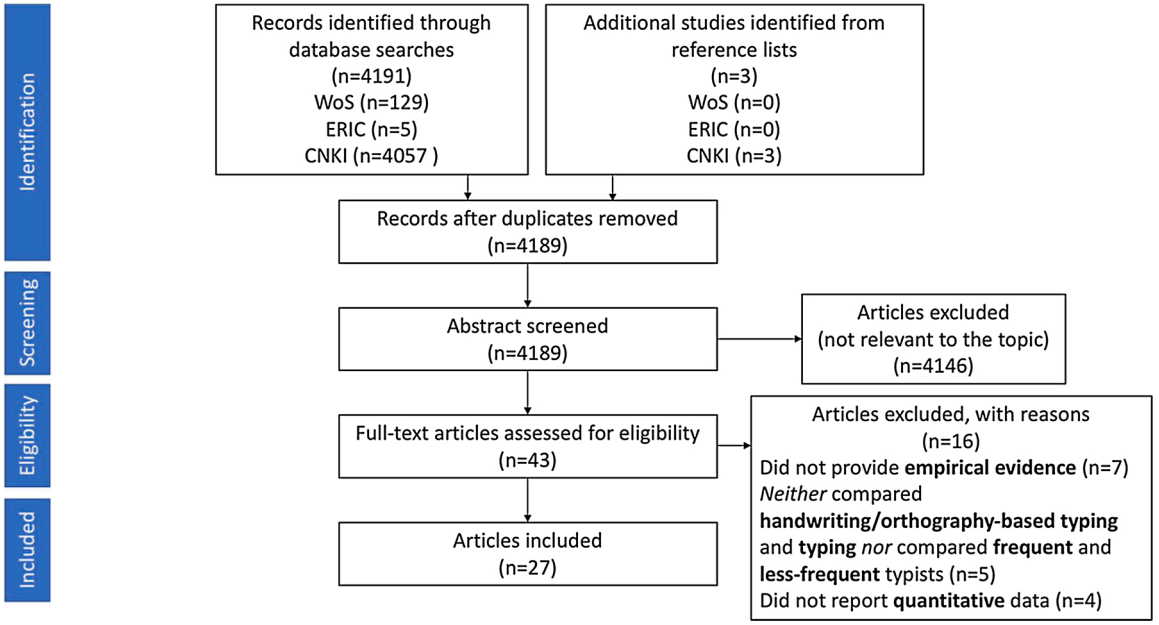

Fig. 2. PRISMA flow diagram.

were 1.000, suggesting a good inter-coder reliability. For open coded categories (Mother tongue backgrounds, Intervention duration, Specific research design, Validity measure, and Reliability measure), different expressions were used in the coding process, and therefore the four researchers double-checked the coding together to ensure accuracy.

4. Results

An overall information of the included studies is listed in Table 3. 11 studies were conducted in the teaching Chinese as a native language context. Among the 16 studies that were conducted in the teaching Chinese as a second/foreign language context, 10 were conducted in CSL context and 6 were in CFL context. The quality of the studies concerning measurement were noted. Only 11 studies provided validity and(or) reliability of the measurement. The other 15 studies either did not control for confounding variables such as students' academic performance when testing characters from textbooks (e.g., Tan et al., 2013), and frequency of characters trained (e.g., Chen, Xu, Cheng, & Liu, 2016; Zhu et al., 2009), or did not provide inter-rater reliability when assessing participants' writing (e.g.,

Table 2
Description of coding scheme.

Dimension	Subcategory	Code	Description
Research context	Grade level of participants	Kindergarten	Participants were in kindergarten
		Primary	Participants were in primary school
		Secondary	Participants were in secondary school
		Higher education	Participants were in higher education
		Adult	Participants were graduated from higher education
		Missing	The study did not report grade level of participants
	Language context	L1	Participants learned Chinese as their first language
		CSL	Participants learned Chinese as a second language
		CFL	Participants learned Chinese as a foreign language
		Missing	The study did not report language context
	Mother tongue backgrounds of participants if they were not Chinese native speakers (only applicable to CSL and CFL learner)	Open coded	CSL and CFL learner's native language
	Chinese language proficiency level of Chinese language learners (only applicable to CSL and CFL learner)	Beginning	The study reported the Chinese language learners were at beginning level
		Intermediate	The study reported the Chinese language learners were at intermediate level
		Advanced	The study reported the Chinese language learners were at advanced level
		Missing	The study did not report language proficiency level
Research design	Nature of research design	Quantitative	The study conducted quantitative research design
		Qualitative	The study conducted qualitative research design
		Mixed	The study conducted mix research design
	Sample size	Open coded	The study reported the number of participants
	Typing engine	Pinyin/Zhuyin	The study adopted Pinyin (orthography-based) typing system.
		Wubi/Cangie	The study adopted Wubi or Cangie (orthography-based) typing system.
	Times of experiment	One-shot	The study conducted once experiment/test
		Longitudinal	The study conducted experiment/test more than once
	Intervention duration (only applicable to the study conducted experiment/test more than once).	Open coded	The duration of the experiment/test if the study was coded as "longitudinal"
	Specific research design	Open coded	The specific research design of the study (such as pre-post design; AB-BA design)
	Validity measure	Open coded	The study reported any measurement to address validity of the results (e.g., any variables were controlled)
	Reliability measure	Open coded	The study reported any measurement to address reliability of the results (e.g., reliability analysis of questionnaire items)
Outcome & Measurement	Target outcome	Reading	The study targeted reading ability
		Writing	The study targeted writing ability
		Listening	The study targeted listening ability
		Speaking	The study targeted speaking ability
		Characters	The study targeted Chinese characters learning
		Perceptions	The study targeted participants' perceptions toward typing
		Other	The study targeted other language skills or linguistic elements
	Measurement	Questionnaire	The study performed questionnaire in relation to the target outcome
		Interview	The study performed interview in relation to the target outcome
		Test/task	The study performed test/task in relation to the target outcome
		Other	The study performed other measurement in relation to the target outcome

Note: Missing indicated the indicator was not reported in the study.

Chen, 2013). None of the survey studies reported the reliability of the questionnaire. Among the 27 selected articles, 14 were primarily about character learning, 7 about students' perceptions, 5 about writing performance and 1 about word learning.

4.1. Effects of typing and handwriting on Chinese character and word learning

The 15 studies that examined the influence of typing and handwriting on Chinese character and word learning primarily assessed students' performance in phonological-orthographic-semantic mapping, character retention and word recognition. Among the 15 studies, four were conducted in the Chinese L2 context and 11 were conducted in the Chinese L1 context. Table 4 provides a summary

Table 3
An overview of the reviewed studies (n = 27).

Dimension	Subcategory	Number (Percentage)
Research context	L1	11 (41 %)
	CSL	10 (37 %)
	CFL	6 (22 %)
Grade level of participants[a]	Kindergarten	0 (0 %)
	Primary	7 (26 %)
	Secondary	3 (11 %)
	Higher education	18 (67 %)
	Adult	0 (0 %)
Language proficiency (L2, n = 16)[b]	Beginning	10 (63 %)
	Intermediate	7 (44 %)
	Advanced	5 (31 %)
	Missing	4 (25 %)
Nature of research design	Quantitative	21 (78 %)
	Qualitative	3 (11 %)
	Mixed	3 (11 %)
Length of study	One-shot	22 (81 %)
	Longitudinal	5 (19 %)
Typing engine[c]	Pinyin/Zhuyin	27 (100 %)
	Wubi/Cangie	6 (22 %)
Research design	Included validity measure	8 (30 %)
	Included reliability measure	3 (11 %)
Target outcome	Character learning	14 (52 %)
	Word learning	1 (4 %)
	Student perceptions	7 (26 %)
	Writing performance	5 (19 %)

[a] One study included participants both from primary and secondary schools.
[b] Five studies included participants with more than one language proficiency levels.
[c] Six studies compared effects of phonology-based with orthography-based typing engine.

of the typing and handwriting effects on Chinese character and word learning. The research suggests that typing had a greater effect on phonological recognition and phonological-semantic mapping whereas handwriting had a greater positive effect on orthographic recognition and orthographic-semantic mapping for L2 learners. However, the results varied among native Chinese speakers, depending on the research context and material selection. Only one study compared the effects of typing and handwriting on word recognition (Lu et al., 2019). The participants in the study learnt the target words online, and half of them were required to practice the words by hands after online instruction. An immediate posttest and two delay posttests were conducted, after 3 and 8 days, online and on paper, respectively. Results found that the CFL participants with handwriting practice significantly outperformed those without handwriting practice in the immediate posttest both online and on-paper, and significantly outperformed in the 3-day-delay posttest only on paper. To be noted, there was no significant difference between word recognition performance and handwriting practicing in the 8-day-delay posttest, both online and on-paper. Thus, more evidences need to argue the effects of handwriting on word retention in a long-term period.

Guan et al. (2011, 2015) conducted a series of studies of Chinese as a foreign language (CFL) learners' character acquisition via typing versus handwriting. The participants in their studies were undergraduate students. Guan et al. (2011) suggested that students who received training via typing for one day and training via handwriting for another day performed better on a dictation task, whereas the students who received training via handwriting for both days performed better on a lexical decision task, a partial-cue-based recognition task, and an English-translation task. The findings suggested that typing provided more support for phonological identification and phonological-semantic mapping, but handwriting supported orthographic recognition and orthographic-semantic mapping instead. In a subsequent study, Guan et al. (2015) extended the training to five days to explore the effects over a longer period and used a repeated-measures design. The research context was also Chinese L2 undergraduate students. The study found that handwriting improved these Chinese L2 adult learners' character-recognition ability on the phonological, orthographic, and semantic levels, whereas typing enhanced their pronunciation recognition.

While Guan and colleagues' studies were conducted among Chinese L2 learners, 11 studies examined the effects of typing and handwriting on Chinese character recognition and production among native Chinese speakers. However, the findings varied, depending on the research context and material selection. For instance, the effect of typing on phonological-semantic associations was not found to be obvious among hearing-impaired children (Guan & Wang, 2017). At the same time, results from Zhu et al. (2009) and Chen et al. (2016) did not support the role of handwriting in strengthening orthographic recognition. Among the studies that reported non-significant handwriting effects on orthographic recognition, low-frequency characters were often used as learning material (Chen et al., 2016; Zhu et al., 2009). Tan et al. (2013) even reported a significant negative correlation between primary school students' character-reading scores and the time they spent on typing. However, their findings could have been biased by the research design (e.g., failure to control for factors such as students' pre-intervention reading ability, student's academic performance, and the time they spent on schoolwork other than typing, and the materials used were mostly selected from textbooks; for an extended critique, see Chen et al., 2017). In another study conducted by Siok and Liu (2018), daily handwriting time did not show significant correlation with

Table 4
Summary of typing and handwriting on character and word learning (n = 15).

Study	Research context	Grade	Language Proficiency	Major findings
Guan et al. (2011)	CFL	Higher education	Beginning level	Participants in handwriting training group were found to outperform in orthographic recognition and orthographic-semantic mapping tasks than those in typewriting training group. However, participants in typewriting training group performed better in phonological recognition and phonological-semantic mapping tasks comparing to handwriting training group.
Guan et al. (2015)	CFL	Higher education	Beginning level	Participants in handwriting training group were found to outperform those in typewriting training group in orthographic recognition, orthographic production, and orthographic-semantic mapping tasks. However, participants in typewriting training group performed better in phonological recognition and phonological-orthographic mapping tasks comparing to handwriting training group.
Chen (2018)	CSL	Higher education	Intermediate level	The time spent on handwriting every day was positively related to participants' dictation scores.
Lu et al. (2019)	CFL	Higher education	Beginning - Advanced level	Participants with handwriting training showed better word recognition performance than those without handwriting training in the immediate posttest and 3-day-delay posttest only when assessing on paper.
Chen et al. (2016)	L1	Primary	Native speakers	No significant difference was found between writing condition and character recall (recognition) performance. For the participants with lower performance in pertest, handwriting training was found to benefit Character recall (production) than typewriting training.
Chen et al. (2017)	L1	Secondary	Native speakers	High-experienced typing users were found to performed better than low-experienced typing users in phonological-semantic mapping task. No significant correlation was found between typing experiences and orthographic-semantic mapping performance.
Chen and Chuang (2008)	L1	Higher education	Native speakers	Cangie (Orthography-based) typing users were found to performed better in orthographic recognition task than Zhuyin (Phonology-based) typing users, whereas Zhuyin (Phonology-based) typing users performed better in phonological recognition task.
Guan and Wang (2017)	L1	Primary	Native speakers	Handwriting training benefited orthographic recognition and orthographic-semantic mapping performance than typewriting training. Typewriting training benefited phonological- orthographic mapping and phonological-semantic mapping performance only for hearing normal children.
Lin (2007)	L1	Higher education	Native speakers	Handwriting group performed better than typing group in paragraph recall tasks.
Siok and Liu (2018)	L1	Higher education	Native speakers	Time spent on handwriting every day did not significantly correlate with character reading or dictation performance for both orthography-based typing (include Cangjie, Quick and Stroke) group and phonology-based typing (include Pinyin or Jyutping) group. Phonology-based typing (include Pinyin or Jyutping) experiences were positively correlated with English word spelling and reading performances.
Tan et al. (2013)	L1	Primary	NA	Time spent on handwriting everyday was found to be positively associated with character reading scores.
Qian and Feng (2004)	L1	Primary	NA	Zongheng (Orthography-based) typing users outperformed than Pinyin (Phonology-based) typing users in orthographic recognition task, whereas Pinyin (Phonology-based) typing users performed better in phonological recognition task than Zongheng (Orthography-based) typing users.
Zhang and Li (2010)	L1	Higher education	NA	Wubi (Orthography-based) typing users were found to performed better than Pinyin (Phonology-based) typing users in orthographic-semantic mapping task. Pinyin (Phonology-based) typing users performed better than Wubi (Orthography-based) typing users in phonological-semantic mapping task.
Zhou and Xu (2013)	L1	Higher education	NA	Wubi (Orthography-based) typing users were found to performed better than Pinyin (Phonology-based) typing users in orthographic production task. Pinyin (Phonology-based) typing users performed better than Wubi (Orthography-based) typing users in phonological-orthographic mapping task.
Zhu et al. (2009)	L1	Higher education	NA	Both phonological recognition and orthographic recognition performance were found to be positively related to typing experiences.

character reading performance among undergraduate students, regardless of the specific type engines. The discrepancy in the research findings suggests that the frequency of the characters and the demographic backgrounds of participants both require careful consideration when examining the effects of typing and handwriting.

In summary, the 15 studies on the effects of writing modes on orthography learning revealed a beneficial effect of learning via handwriting on orthographic recognition and orthographic-semantic mapping, and a beneficial effect of learning via typing on phonological recognition and phonological-semantic mapping, for both L1 Chinese speakers and adult L2 Chinese learners. However, the typing effect was not salient for hearing-impaired L1 children, and the handwriting effect was not salient when low-frequency characters were involved.

4.2. Effects of typing and handwriting on writing performance

Four studies examined the effects of typing and handwriting on writing performance among Chinese as a second language (CSL) or foreign language (CFL) learners, and reported mixed findings (see Table 5).

In Chai et al.' (2012) exploratory study of 419 15-year-old CSL students from three secondary schools in Singapore, the participants composed two essays on different topics, one with pen and paper and the other using a computer. The essays were graded by experienced teachers, and an overall score was given to each. After the students' pre-existing language-proficiency levels and typing speeds were controlled for, no significant differences in writing scores were found across the two modes. Adopting a similar design (AB-BA design), Zhu et al. (2016) studied 32 beginning-level CFL learners. Although the students' essays were marked across three dimensions—ideas and content organization, linguistic expression, and cohesion and coherence—only an overall score was reported, but these scores were significantly higher for essays that had been word-processed.

Kang (2011) recruited 16 beginner and 12 intermediate CFL learners at a university in the US, and delved deeper into the effects of the input medium on two dimensions of their writing: clarity (i.e., character, vocabulary, and grammar errors) and organization (i.e., style of writing and use of linking words). Analysis of a dictation task completed by both groups of students and an essay task completed by the intermediate students revealed that essays produced via typing were subject to a smaller range of error types than those produced via handwriting. However, intermediate-level students who wrote using paper and pen(cil) performed better in both writing clarity and organization than the student who wrote on a keyboard. In contrast, Chen (2013) compared the accuracy of characters in essays typed vs. handwritten by 12 beginner and eight intermediate CSL university learners in China, and found that typing was associated with both higher character accuracy and greater writing speed, but only among the beginning group.

In summary, these four studies reported mixed findings regarding the effects of typing and handwriting on CFL and CSL learners' writing performance. However, these research studies were rather limited in both the research methodology and research foci: these studies generally focused narrowly on writing outcomes, and used overall scoring for the essays. The narrow research foci, without examining the composition process, mean that they are unable to shed light on how/why composition was helped or hindered by the two writing modes. The use of overall scores to measure writing outcomes means that the studies are also unable to provide important insights into what dimensions of writing these two writing modes might affect.

4.3. Students' perceptions of typing and handwriting

Seven studies used survey questionnaires to examine Chinese L2 learners' perceptions of typing and handwriting. Table 6 summarizes the research findings in this body of literature. According to Table 6, Chinese L2 learners were generally in favor of writing by typing. The participants believed that typing helped them memorize the pronunciation, meaning of characters (Jiang & Zheng, 2015) and character recognition (Lee, 2019), improved their writing speed and character accuracy (Wu, 2010), and boosted their learning autonomy (Wang, 2012). Nonetheless, the participants believed that writing Chinese characters by hand was also very important, especially if they were studying or living in China (Jiang & Zheng, 2015), and helped in character retention and stroke learning (Lee, 2019). Lee (2019) investigated Chinese L2 learners' perceptions toward different mobile inputting methods.[3] Comparing to handwriting input, more participants tended to use Pinyin input (6.67 % over 91.67 %). However, when coming across a new character, 98.33 % participants reported looking up the character with the use of handwriting input method. Studies also found that students' perceptions of typing in Chinese have been found to be influenced largely by their Pinyin knowledge and technical issues (Li, 2016; Wong, Boticki et al., 2011; Wong, Chai, & Gao, 2009; Wong, Chai, & Gao, 2011; Wu, 2010). Wong, Boticki et al. (2011) and Wong, Chai et al. (2011) found that secondary-school students had a stronger preference for Pinyin-input while writing than did their primary-school counterparts, a difference that was attributed to differences in typing competency between the two groups. Similarly, Wu (2010) found that L2 Chinese learners who lacked a certain threshold of Pinyin knowledge tended to report their frustration with writing via typing, and to exhibit negative attitudes towards learning characters through typing them (Li, 2016; Wong et al., 2009; Wong, Boticki et al., 2011; Wong, Chai et al., 2011).

5. Discussion

5.1. Major findings related to typing and handwriting effects on Chinese language learning

A review of the studies on the effects of typing and handwriting on Chinese-language learning and performance resulted in three major findings: 1) typing appears to enhance phonology recognition and the phonologic-semantic mapping of characters; 2) handwriting appears to enhance orthography recognition and the orthographic-semantic mapping of characters; and 3) although students expressed a preference for writing by typing, its effects on their writing performance are mixed. Table 7 summarizes the comparison of the major findings from the Chinese-language studies with those from the English-language studies.

The finding that handwriting had a stronger and longer-lasting positive impact on the recognition of characters/letters among both young native speakers and L2 learners (e.g., Chen et al., 2016; Guan et al., 2011, 2015; Qian & Feng, 2004; Zhou & Xu, 2013) is consistent with those from the English-language studies. However, unlike the inconsistent findings on the impact of handwriting on

[3] This review study did not include findings on voice inputting of mobile phones.

Table 5
Summary of typing and handwriting on writing performance (n = 5).

Study	Context	Grade of learner	Language proficiency	Major findings
Chai et al. (2012)	CSL	Secondary	Missing	No significant correlation was found between writing modality and writing scores.
Chen (2013)	CSL	Higher education	Beginning level Intermediate level	The character accuracy and composing speed measure was better in typewriting modality than handwriting modality, only for beginning level students though.
Kang (2011)	CFL	Higher education	Beginning level Intermediate level	Writing by typing significantly improved character accuracy than writing by hand. For intermediate level students, writing clarity and organization were also measured, and were found to be better in handwriting modality.
Zhu et al. (2016)	CSL	Higher education	Beginning level	Participants gained significant higher scores when writing by typing than by hand.
Zhang and Min (2019)	CFL	Higher education	Intermediate level	Participants gained significant higher scores when writing by typing than by hand.

Table 6
Chinese L2 learners' perceptions toward typing and handwriting (n = 7).

Study	Context	Grade	Proficiency	Major findings
Jiang and Zheng (2015)	CSL	Higher Education	Beginning Intermediate Advanced	Typing helps memorize pronunciation and meaning of characters while handwriting help memorize orthography knowledge. Handwriting is necessary especially if study or live in China. No relationship was found between the perceptions and their cultural background.
Lee (2019)	CSL	Higher Education	Beginning Intermediate Advanced	Student reported preference of Pinyin inputting over handwriting inputting when using mobile devices. Pinyin typing was believed to be helpful in character recognition whereas handwriting input was believed to be helpful in character retention.
Li (2016)	CFL	Higher Education	Beginning	Students showed more positive attitudes toward handwriting than typing. Their negative attitudes toward typing might because of technical issues they encountered while typing.
Wang (2012)	CSL	Higher Education	Beginning Advanced	Students believed handwriting is necessary and it helps memorization of vocabulary. Beginning level students showed more positive attitudes toward typing than advanced students and believed typing could improve their learning autonomy.
Wong et al. (2009)	CSL	Primary	Missing	When composting on tablet, students felt frustrated if lack Pinyin knowledge and then turned to finger-writing mode.
Wong, Boticki et al. (2011) and Wong, Chai et al. (2011)	CSL	Primary Secondary	Missing	Students' perceptions of writing modes related to their technical competency and linguistic knowledge.
Wu (2010)	CSL	Higher Education	Missing	Students lacked Pinyin knowledge tended to report their frustration with writing via typing, and to exhibit negative attitudes towards learning characters through typing.

Note: Missing indicated the indicator was not reported in the study.

Table 7
Comparison of findings between English- and Chinese-language studies.

	Effects of handwriting			Effects of typing		
	Recognition of letters/ characters	Production of letters/ characters	Orthographic-semantic mapping	Phonology	Phonologic-semantic mapping	Writing performance
Consistent findings	E & C	E & C	C	C	C	E
Possible explanation	Writing-motor effects		Handwriting experience involve semantic representations	Pinyin-input experience activates auditory	Pinyin-input experience involve semantic representations	Pinyin-input may decrease cognitive loads of retrieving characters and thus support higher processing such as constructing words, phrases, concepts and ideas. However, this advantage may be only evident among beginning level students, who suffer from orthography production at the early periods of Chinese character learning.

Note: E: Consistent findings were identified in English-language studies.
C: Consistent findings were identified in Chinese-language studies.

lexical orthography in the English-language studies (see Cunningham & Stanovich, 1990; Stainthorp, 1997; Vaughn et al., 1992), the Chinese-language literature yielded rather robust findings regarding handwriting's capacity to boost orthographic-semantic mapping ability (e.g., Guan & Wang, 2017; Guan et al., 2011, 2015; Zhang & Li, 2010). The consistent finding of the positive effects of handwriting on Chinese character recognition is understandable. The production of written language through handwriting involves both allographic/letter-shape conversion and graphic-motor planning, but production through typing only involves graphic-motor planning (Purcell et al., 2011). Since characters consist of a series of strokes that do not correspond to phonemes, allographic/letter-shape conversion is especially important to Chinese character production (Guan et al., 2011). Thus, handwriting helps to strengthen the visual representation of characters and enhances character recognition, a phenomenon conceptualized as writing-motor effects (James, 2010). The consistent finding on the effects of handwriting on orthographic-semantic mapping could be attributable to the greater activation of brain areas related to semantic processing in Chinese character handwriting training, as compared to Pinyin-typing training (Cao et al., 2013). In English the effects of typing and handwriting on lexical semantics remain unknown due to inconsistent findings related to activation in the left angular gyrus, the region related to sematic processing, in both handwriting and typewriting modes (Purcell et al., 2011). As such, the greater activation of semantic processing during Chinese character handwriting might explain the consistent findings regarding the impact of handwriting on orthographic-semantic mapping in Chinese but not in English.

In addition, typing was found to exhibit a greater effect on phonology recognition and phonologic-semantic mapping among both Chinese L1 children and adult L2 Chinese learners (e.g., Chen et al., 2016; Guan et al., 2011, 2015; Qian & Feng, 2004; Zhou & Xu, 2013). This was not observed in the English-language studies (Berninger, Cartwright, Yates, Swanson, & Abbott, 1994). The stronger impact of typing on phonology recognition in Chinese might be due to the input system, as typing Chinese characters—unlike writing them by hand—activates auditory representations, and therefore phonology recognition might be strengthened by intensive typing experience in Chinese. In English, on the other hand, both typing and handwriting activate auditory representations (Purcell et al., 2011). Moreover, as the association between phonetics, semantics, and orthography is much closer in a Chinese character than in an English letter or word (Feldman & Siok, 1999; Ho et al., 2003), individuals engage in semantic processing when choosing characters from the list they are presented with during typing (Cao et al., 2013). Thus, typing in Chinese involves phonological-orthographic mapping and semantic activation, which may lend to the observed beneficial effects of typing on phonological recognition and phonological-semantic mapping in the Chinese-language studies.

This review also revealed that, in contrast to the robust findings of previous studies regarding typing's quantitative and qualitative enhancement of English essay writing (see Goldberg et al., 2003; Morphy & Graham, 2012; Wollscheid, Sjaastad, Tømte et al., 2016; Wollscheid, Sjaastad, Tømte, Løver et al., 2016), its impact on Chinese essay writing was mixed, depending on students' language proficiency and their ages. Current studies suggest that beginning level students from university may benefit more from typing, especially in writing quality and character accuracy (Chen, 2013; Zhang & Min, 2019; Zhu et al., 2016). According to Van Galen (1991), composition involves multi-level processing including strokes, allographs, and graphemes at the lower levels, and words, phrases, concepts, and ideas at higher levels. Buffer storage at lower levels of processing could provide support for the higher levels. It follows that if cognitive loads at lower levels (e.g., strokes, allographs) can be reduced, learners will have more cognitive resources available for phrasal and word choices and the formulation of concepts and ideas at higher levels. When typing in Chinese, learners must attend to phoneme-grapheme conversion rather than to orthographical retrieval as when writing by hand. However, in English, typing and handwriting involve the same levels of processing. This difference could explain the differential effects of typing on learners of different proficiency levels. Typing has a stronger effect for beginning-level students because these students' lexical orthographical retrieval ability is still developing, and thus typing might help them more by reducing the cognitive load at lower levels of processing, so that they have more cognitive resources for higher level processing. As learners' Chinese-language proficiency levels rise, their orthographic-retrieval abilities also increase, which might be why the typing effects reduce for higher-level students (Shen, 2005). Given the reviewed literature's overwhelming research focus on writing outcomes, as opposed to writing processes, future research may need to include a deeper examination of which subcomponents of writing activity these two writing modes affect, and how they do so.

5.2. *Comparative model of written language processing in typing vs. handwriting across English and Chinese*

The findings of the review identified some differences between the Chinese-language studies and the English-language studies. Table 8 illustrates the cognitive processing model for Chinese written language and compares it with the processing model for English.

According to Purcell et al. (2011), the processing of English words via handwriting activates phoneme-grapheme conversion first, then orthographic working memory, and finally allographic/letter-shape conversion and the concomitant graphic-motor planning. The processing of English words via typing, on the other hand, activates phonological memory first, and then orthographic memory. When typing, writers of English proceed directly to graphic-motor planning, skipping allographic/letter-shape conversion. Thus, the cognitive difference between handwriting and typing in English lies in the activation of phoneme-grapheme conversion and allographic/letter-shape conversion, or the lack thereof. However, this review revealed that handwriting training enhanced orthographic recognition (Chen et al., 2016; Guan et al., 2011, 2015) and production (Chen et al., 2016), which suggest that, similar to English handwriting (Purcell et al., 2011; Van Galen, 1991), when writing Chinese characters by hand, individuals rely heavily on central processes such as orthographic memory as well as peripheral ones such as allographic/letter-shape conversion and graphic-motor planning. However, when producing a Chinese character via typing, phonological knowledge (i.e., the writer's process phoneme-grapheme conversion when selecting the appropriate character from a list) is involved (Guan et al., 2015). Semantic representations are involved in both handwriting and typing the Chinese language (Cao et al., 2013; Guan et al., 2015). In addition,

Table 8
Comparative model of language processing in typing vs. handwriting.

	English handwriting	typing	Chinese handwriting	typing
Cognitive process	phoneme-grapheme conversion orthographic memory allographic/letter-shape conversion graphic-motor planning	phonological memory orthographic memory graphic-motor planning	orthographic memory semantic representations allographic/letter-shape conversion graphic-motor planning	phonological memory semantic representations orthographic memory graphic-motor planning
Synthesizing the differences in cognitive processes				
Comparison between handwriting and typing	Compared to handwriting English, typing English lacks activation of phoneme-grapheme conversion and allographic/letter-shape conversion		Compared to handwriting, typing Chinese lacks activation of allographic/letter-shape conversion but involves phonological memory	
Comparison between handwriting English and Chinese	Compared to handwriting English, handwriting Chinese lacks activation of phoneme-grapheme conversion but involves semantic representations.			
Comparison between typing English and Chinese	Compared to typing English, typing Chinese involves activation of semantic representations.			

although orthographic memory is needed for both writing modes, it should be noted that the cognitive load of typing is likely to be lower than writing Chinese characters by hand, because typists only need to recognize characters, not accurately produce their shapes. Based on the empirical evidences, we argue that the major differences in the cognitive processing models for the two languages may lie in the fact that phonology processing is activated in both the handwriting and typing modes in English, while it is more activated in the typing mode in Chinese. These differences suggest that the cognitive models of Chinese written language processing via typing and handwriting probably differ from those for English written language processing.

This comparative model of the cognitive processing involved in written language processing in Chinese and English, derived from the existing literature, may provide a theoretical framework to predict and explain potential variations in the effects of different writing modes in English and Chinese across different contexts. Studies of different learning contexts and neuroscience studies will be needed to test and refine this model.

5.3. Recommendations for pedagogical practices and research concerning typing and handwriting in Chinese language education

Whether to type or handwrite is a hotly debated issue in Chinese character education. This debate comes from the oft-reported difficulty in and frustration related to learning Chinese characters, and from concerns over students' inability to write Chinese characters by hand. This review found that typing and handwriting strengthen different aspects of Chinese character learning and retrieval, and that typing enhances the quality of writing performance for beginners. Thus, it is important to integrate these two modes of writing in Chinese education (Guan et al., 2015). Although scholars in English language education argue in favor of the importance of handwriting in building a strong foundation in literacy development regarding orthography recognition and production in the early stages of language learning (Mangen & Balsvik, 2016), the distinct effects of typing in Chinese and English written language processing suggest a clear role for typing in the Chinese language education context.

Considering the concerns that typewriting may hinder Chinese language acquisition (see Chen, 2018; Di, 2014; Xu, 2011), this synthetic review study found that while handwriting enhances orthography recognition and production, typewriting enhances phonology and phonologic-semantic mapping (e.g., Chen et al., 2016; Guan et al., 2011, 2015; Guan & Wang, 2017), and thus may benefit semantic-phonetic-compound characters acquisition, which is the most common category in Chinese characters but the most difficult one to Chinese L2 learners (Wang, 2019; Zhou, 1978). Some previous studies also suggested that for beginning learners of Chinese and primary school children of Chinese native speakers, typing facilitates character recognition and pronunciation (Allan, 2008; Lee, 2019; Ren, 2014; Zhou, 2012). Wang (2012) found that the early introduction of typing would enable beginners to circumvent the frustration of Chinese character production and assume the identity of language users, enhancing their learning autonomy early on. Thus, this synthetic review study suggests that Chinese language teacher should capitalize on the unique strength of typewriting for Chinese character acquisition and consider strengthening typewriting training in and outside the classroom. Given that handwriting strengthens orthographic knowledge and orthographic-semantic mapping and typewriting enhances phonological knowledge and phonologic-semantic mapping, a multimodal, flexible plans for writing tasks could be adopted and adjusted to facilitate the different aspects of Chinese character acquisition. This synthetic review further found that in the writing classroom, typewriting facilitates the holistic writing quality and improve character accuracy, especially for beginning students. Thus, typewriting may be considered according to the instructional purpose and students' language ability. In summary, based on the current literature, typing should be introduced in beginning level classrooms, and an integration of both typing and handwriting training is recommended.

This review has found that the existing research is limited in its research foci and in the measurements used. The reviewed studies were limited to learning outcomes such as character learning, writing, and perceptions. Thus, future research may need to expand the target outcomes. For instance, the effects of typing and handwriting on other cognitive language skills such as listening, reading, and speaking, and on metacognitive skills such as learning autonomy need to be explored. As for examining students' writing, more

dimensions—including but not limited to length, speed, grammar, content, structure, ideas—could be considered, and therefore, the use of writing rubrics rather than holistic scoring is recommended. Perhaps most importantly, researchers may wish to consider examining the writing process across different writing modalities, as informed by the work of Berninger et al. (2002), and Goldberg et al. (2003). Additional variables will also be critically important to research targeting distinct learning skills. For example, students' writing outcomes may differ across writing genres. The characteristics of each character, including its frequency of use and whether it is a homophone, homograph, or phonogram, may also have an impact on typing and writing effects. Crucially, future comparisons of typing and handwriting in Chinese language learning should also consider individual-level variables such as the participants' access to technology, and their technology-use habits. Moreover, most of/all the reviewed studies compared handwriting with keyboarding. However, the omnipresence of technologies in daily life brings new input methods (e.g., pinyin input; handwriting input; voice input) and thus introduces new dimensions to the issue (Lee, 2019). How might different mobile input method influence character acquisition and retention, as compared to paper-and-pencil writing, and how might the influence differ for different input methods on mobile devices versus on computer screens are open questions that deserve much research attention.

6. Conclusion

This review of 27 empirical studies on the effects of typing and handwriting on Chinese language learning is believed to be the first of its kind. In addition, the current study compared the findings of the reviewed body of literature with those of broadly similar studies focused on English-language learning, yielding important fresh insights into patterns of similarity and difference across these two languages and how they are taught and learned. The review suggests that given the differences in the cognitive processing of Chinese and English written language in the two writing modes, the direct application of findings from studies on English is questionable. More research on this issue is needed in the Chinese language education context, given its particularity, in order to yield language-specific and appropriate recommendations concerning the use of typing and handwriting in Chinese language education (Gong, Gao, Li, & Lai, 2020; Gong, Guo, Li, Lai, & Wang, 2021).

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