Effects of Orthographic Depth on Chinese Character Word Naming in Han and Uyghur University Students: Postprint

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Abstract

The abundance and complexity of polyphonic characters in Chinese present considerable challenges for Uyghur students learning the language. Through two experiments, this study examined the impact of orthographic depth on Chinese character naming among Han and Uyghur university students. Results indicated that Uyghur students exhibited significantly longer reaction times than Han students when naming both monosyllabic and disyllabic words. For monosyllabic words, naming latencies for participants from both ethnic groups were influenced by orthographic depth and word frequency; specifically, naming polyphonic characters took significantly longer than naming monophonic characters, and naming low-frequency characters took significantly longer than naming high-frequency characters. For disyllabic words, an interaction between word frequency and orthographic depth was observed in the naming latencies of both groups: for high-frequency words, the reaction time difference between words composed of polyphonic versus monophonic characters was not significant for Han students, whereas Uyghur students showed significantly longer reaction times for words composed of polyphonic characters; for low-frequency words, Han students demonstrated significantly longer reaction times for words composed of polyphonic characters compared to those composed of monophonic characters, while this difference was not significant for Uyghur students. Overall, the study reveals that orthographic depth influences Chinese character naming differently across the two ethnic groups, a pattern attributable to variations in native language characteristics, age of vocabulary acquisition, language proficiency, and language processing modes.

Full Text

Effects of Orthographic Depth on Chinese Word Naming for Han and Uyghur University Students

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Abstract

Chinese contains numerous polyphonic characters with complex pronunciation patterns, posing significant challenges for Uyghur students learning Chinese. Through two experiments, this study examined how orthographic depth influences Chinese character naming among Han and Uyghur university students. The results showed that Uyghur students exhibited significantly longer naming latencies than Han students for both monosyllabic and disyllabic words. For monosyllabic words, naming times for both groups were affected by orthographic depth and word frequency: polyphonic characters were named significantly slower than monophonic characters, and low-frequency characters were named significantly slower than high-frequency characters. For disyllabic words, an interaction emerged between word frequency and orthographic depth: for high-frequency words, Han students showed no significant difference in response times between words composed of polyphonic versus monophonic characters, whereas Uyghur students were significantly slower for words containing polyphonic characters; for low-frequency words, Han students were significantly slower for words with polyphonic characters, while Uyghur students showed no significant difference between the two word types. These findings demonstrate that orthographic depth affects Chinese word naming differently across the two ethnic groups, a pattern attributable to differences in native language characteristics, age of vocabulary acquisition, language proficiency, and language processing styles.

Keywords: orthographic depth; word frequency; context; Uyghur

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Introduction

China is a multi-ethnic nation where different ethnic groups speak different languages. Language compatibility constitutes a fundamental condition for interethnic communication and an important prerequisite for national identity. Consequently, bilingual education represents a special pedagogical form through which ethnic minorities inherit their linguistic and cultural heritage while gaining proficiency in the national standard language and script. As Mackey and Siguan (1989) noted, "In terms of global scope, bilingual education represents the most valuable contribution we can make toward strengthening mutual understanding among ethnic groups; at the national level, it constitutes the optimal pathway for promoting peaceful coexistence among various racial groups." To enhance exchanges among ethnic groups and strengthen the cohesion of the Chinese nation, China' s constitution has established "the state promotes the use of Putonghua and the implementation of standardized Chinese characters" as a fundamental national policy. With increasing interethnic interaction, ethnic compatriots have deeply recognized the urgency and importance of mastering Putonghua and standardized Chinese characters (Li Xulian, 2015). While bilingual education has achieved tremendous success, numerous pressing problems remain, and the task of accelerating its development remains formidable (Chen Lipeng, 2016).

Xinjiang represents a distinctive bilingual education region in China. With a large ethnic minority population—nearly 9.83 million Uyghurs alone—living in sizable, stable communities with high regional cultural homogeneity, Xinjiang' s bilingual education system is particularly significant. By 2012, the number of minority students in bilingual classes and "min kao han" programs at the preschool and primary-secondary levels reached 1.6786 million, accounting for 66.6% of total minority student enrollment, and minority students' Chinese proficiency has improved markedly. However, behind these achievements lies an awkward reality: despite nearly two decades of effort, Chinese language instruction for Xinjiang' s ethnic minorities has yet to achieve the autonomous region government' s goal of "proficiency in both ethnic and Han languages."

According to a 2009 survey by Xinjiang University' s Academic Affairs Office, only 76.37% of incoming minority students could understand Chinese-medium instruction, 56.83% could articulate learning content in Chinese, 61.24% could read Chinese textbooks, and merely 38.72% could write academic papers in Chinese. Even among Chinese majors, reading and writing abilities were concerning: only 34.61% of 2013 Chinese language graduates from Xinjiang University' s College of Humanities could read Chinese literature, and only 42.71% could write graduation theses in Chinese (Zhao Jiangmin & Fu Dongmei, 2013). These difficulties are substantially related to differences in orthographic depth between Chinese characters and Uyghur script.

Orthographic depth refers to the degree of consistency or transparency between a word' s morphological structure and its phonological structure—in other words, how directly form maps onto sound. Orthographic depth significantly impacts word recognition (Zhang Jijia, 1998). Across different languages, orthographic depth influences the types of encoding readers employ for lexical access. Shallow orthographies encourage phonological strategies based on surface-level phonemic information, while deep orthographies promote visual coding strategies (Katz & Feldman, 1981). Within a single language, when one graphic form corresponds to two or more pronunciations, learning and application difficulty increases (Daal & Wass, 2016). Compared to monophonic characters, polyphonic characters have greater orthographic depth and longer naming latencies (Zhang Jijia & Wang Huiping, 1996).

Scripts can be classified as phonographic or logographic (Saussure, 1995). Uyghur belongs to the Turkic branch of the Altaic language family and is an agglutinative language typologically. The Uyghur script is an alphabetic writing system based on Arabic script that runs right-to-left, featuring strict grapheme-phoneme correspondence that facilitates reading through form-to-sound mapping. Chinese, by contrast, uses characters that are primarily logographic and secondarily phonographic, constituting a morphosyllabic script. Each word is represented by a single symbol that can convey meaning directly through form, even without reliance on phonology. In the earliest stages of character creation, Chinese employed a one-form-one-meaning-one-sound principle to represent objects, actions, or properties. As stated in *Shuowen Jiezi*, "When Cangjie first created writing, he modeled it on pictographic representations of categories, hence called them 'wen' (patterns)··· 'Wen' are the root forms of objects; 'zi' (characters) are what multiply through reproduction." From oracle bone and bronze inscriptions, the "root forms of objects" evolved from simple to complex. However, the development of phonetic loan characters and derivative characters broke the one-form-one-meaning-one-sound rule, leading to characters with multiple meanings, multiple sounds, or both multiple meanings and sounds (Xu Shirong, 1988). As homophony increased, the pictophonetic principle emerged, combining semantic radicals with phonetic components to create phono-semantic compounds. These compounds' pronunciations follow their phonetic components, making grapheme-sound correspondences less arbitrary (Zhang Xuexin, 2011).

For a period, character creation through the pictophonetic principle effectively expressed new concepts without requiring new syllables. Since adding characters did not increase syllable inventory, Chinese characters became increasingly complex, accumulating numerous homophones and making polyphony inevitable. Graphically similar characters developed different pronunciations, and even identical forms acquired multiple pronunciations—polyphonic characters. With Chinese characters' forms becoming fixed and rigid, different pronunciations corresponded to different meanings. Statistics show that among the *Modern Chinese Commonly Used Characters List*, 544 characters are polyphonic, with 2–5 pronunciations each; the more pronunciations a character has, the fewer characters share that pattern. Among these, 467 characters (85.85%) have two pronunciations, and 65 (11.95%) have three (Zhu Li, 2012). Polyphonic variations in Chinese serve to distinguish meanings, parts of speech, and stylistic registers. For example, "喝" (hē) means "to drink," while "喝" (hè) means "to shout" (as in "喝彩" —to applaud) (Wang Quanlan, 2014). Consequently, Uyghur script has shallower orthographic depth than Chinese characters.

Chinese polyphonic characters arise from six main types: (1) dialectal variations, such as "弄" (lòng) in dialectal usage meaning "alley" ; (2) literary versus colloquial readings, such as "剥" (bāo) meaning "to peel" versus (bō) used in compounds like "剥夺" (deprive); (3) written versus oral language differences with identical initials and finals but different tones, such as "绷" (bēng) meaning "to stretch" versus (běng) meaning "to keep a straight face"; (4) transliteration, such as "刹" (shā) versus (chà) from Sanskrit "ksetra" meaning Buddhist temple; (5) pragmatic contexts, such as "啊" with five pronunciations corresponding to different intonations; and (6) phonetic changes for new grammatical functions, such as "称" (chēng) meaning "to weigh" versus (chèng) as a noun meaning "scale" (Chen Yangwen, 2015). Xu Shirong (1988) summarized polyphonic character origins into two categories: meaning differentiation and functional differentiation. Meaning differentiation includes: (1) part-of-speech conversion (e.g., 担 dān "to carry" vs. dàn "burden"); (2) semantic extension (e.g., 奇 qí "strange" vs. jī "odd number"); (3) fine-grained distinctions (e.g., 吐 tǔ "to spit out" vs. tù "to vomit"); (4) successive borrowing where original characters were borrowed for other meanings, requiring modified pronunciations (e.g., 荷 hé "lotus" vs. hè "to carry"); (5) archaic readings preserved in classical texts (e.g., 骑 qí "to ride" vs. jì "mount"); (6) historical sound changes (e.g., 曲 qū "bent" vs. qǔ "song"); and (7) complex etymologies (e.g., 臊 sāo "fishy smell" vs. sào "bashful"). Functional differentiation includes: (1) literary versus colloquial readings; (2) specialized terminology; (3) proper names with special pronunciations; (4) foreign transliterations; and (5) conventional variations. In summary, Chinese polyphonic characters are numerous and complex, creating substantial learning difficulties. Mastering them requires following the principle of "determining pronunciation according to word context," clarifying meanings, distinguishing properties, analyzing structures, and combining contextual information to produce the appropriate pronunciation.

The Sapir-Whorf hypothesis posits that language influences cognition (Wolff & Holmes, 2011; Zhang Jijia, 2016). Humboldt (2001) argued that "each language contains a complete system of concepts and modes of imagination belonging to a particular human group." Uyghur and Chinese belong to different language families, which affects processing styles. Uyghur is a typical agglutinative language and low-context language that emphasizes formal linguistic structure, characterized by the absence of internal inflection and the principle that each morpheme represents only one grammatical meaning. Because roots and affixes combine loosely, they can be assembled arbitrarily. This associative method of combining grammatical meanings through affixes makes Uyghur structure rigorous. Uyghur word formation follows a "prefix + root + suffix + suffix···" pattern (Guljamal et al., 2013), with rich grammatical information embedded in affixes, fixed and clear parts of speech, and clearly demarcated conceptual expression. Language influence makes Uyghur language processing analytical, abstract, logical, and deterministic (Peng Feng, Jin Yan, & Han Tao, 2013). Chinese is a high-context language where meaning and pronunciation at the discourse, sentence, and lexical levels depend heavily on context. Influenced by Chinese, Han language processing tends to be holistic, imagistic, paratactic, and fuzzy (Ma

Yan, 2011). Compared to some other ethnic minorities in China, Uyghur culture is relatively mature and developed, with powerful social functions for the native language and substantial differences from Chinese, resulting in markedly different language processing styles between Uyghur and Han individuals and creating numerous difficulties for Uyghur students learning and using Chinese.

In summary, Uyghur's strict grapheme-phoneme correspondence, rigorous structural forms, and low-context nature, combined with Uyghur people' s analytical, abstract, logical, and deterministic language processing style, jointly create substantial difficulties in learning and using Chinese. Chinese polyphonic characters are numerous, with complex pronunciation rules, ambiguous grapheme-phoneme correspondences featuring one-to-two or one-to-many mappings, where context plays a crucial role in determining which pronunciation corresponds to a given form. This creates processing difficulties for Uyghur students with polyphonic characters. This study hypothesized that compared to Han students, Uyghur students would show significantly longer naming latencies for Chinese polyphonic characters and significantly weaker ability to utilize contextual information when naming them. Moreover, research indicates that native Chinese speakers employ different extraction methods for high- and low-frequency words: high-frequency words tend toward whole-word representation and retrieval, while low-frequency words tend toward morphemic representation and retrieval (Andrews, 1989; Coney, 2005; Ding Guosheng & Peng Danling, 2006; Grainger & Whitney, 2004). Therefore, we predicted that when naming disyllabic words with polyphonic initial characters, native Chinese speakers would be less aware of the polyphonic nature of high-frequency words but more aware for low-frequency words. Due to native language processing influences, Uyghur participants would be aware of the polyphonic nature for both high- and low-frequency words, though their recognition of polyphony would be weaker than that of native Chinese speakers. This study comprises two experiments: Experiment 1 examines Han and Uyghur students' naming of monosyllabic Chinese words to reveal orthographic depth effects on character naming across both groups; Experiment 2 investigates naming of disyllabic Chinese words to examine how context and word frequency moderate orthographic depth effects. The findings provide psychological evidence for improving Chinese language instruction for Uyghur students.

Experiment 1: Naming of Monosyllabic Chinese Words

Method

Participants. Sixty university students from Minzu University of China participated: 30 Han students and 30 Uyghur students, with equal gender distribution. Most Uyghur participants had received Chinese-medium education before university and were "min kao han" students[1]. Some were "bilingual" students who began learning Chinese in kindergarten or first grade, grew up in bilingual family environments, completed two years of preparatory studies before major declaration, and demonstrated proficient Chinese skills, having passed both the MHK (Chinese Proficiency Test for Ethnic Minorities) Level 4 and the Putonghua Proficiency Test.

Design. A 2 (ethnicity: Han/Uyghur) × 2 (orthographic depth: polyphonic/monophonic) × 2 (word frequency: high/low) mixed design was employed, with ethnicity as a between-subjects factor and orthographic depth and word frequency as within-subjects factors.

Materials. Eighty monosyllabic Chinese words were selected, comprising 40 polyphonic and 40 monophonic characters. From the *Modern Chinese Frequency Dictionary* (Beijing Language Institute Language Teaching Research Institute, 1986), we selected 20 high-frequency polyphonic words (frequency range: 338.5–3912.9 per million) and 20 low-frequency polyphonic words (frequency range: 7.7-281.5 per million), along with 20 high-frequency monophonic words (frequency range: 343.3–3869.8 per million) and 20 low-frequency monophonic words (frequency range: 7.2–237.8 per million). Statistical analysis revealed no significant difference in average frequency between high-frequency polyphonic (M = 1785.45 per million) and monophonic words (M = 1773.62 per million), $t(38) = 0.46$, $p > 0.05$, nor between low-frequency polyphonic (M = 92.89 per million) and monophonic words (M = 94.42 per million), $t(38) = -0.79$, $p > 0.05$. Stroke counts ranged from 3 to 15, with average stroke counts of 7.55, 8.80, 8.10, and 7.20 for high-frequency polyphonic, low-frequency polyphonic, high-frequency monophonic, and low-frequency monophonic words, respectively, $F(3, 76) = 1.43$, $p > 0.05$, indicating no significant differences. Prior to the formal experiment, 30 Uyghur students who did not participate in the main study were asked to provide pronunciations for the selected characters, writing all possible pronunciations for polyphonic characters to ensure the experimental materials were familiar to participants.

Procedure. After the experiment, participants were asked to identify which characters were monophonic and which were polyphonic, achieving 99% accuracy, confirming the validity of the materials.

Apparatus and Procedure. The experiment used a PET-SRBOX response box, microphone, and PIII-667 computer. Stimuli were presented centrally on the computer screen in 72-point Song font. Responses were recorded via a microphone connected to the response box. E-Prime software controlled stimulus presentation. Participants sat approximately 60 cm from the screen. Each trial began with a 500 ms fixation cross, followed by a 500 ms blank screen, then presentation of the character for a maximum of 1000 ms. Participants named the character into the microphone, after which the character disappeared. After a 1000 ms interval, the next trial began. The computer automatically recorded response times and accuracy with millisecond precision (±1 ms). The experimenter recorded pronunciation accuracy. Data were analyzed using SPSS 19.0.

Results and Analysis

Response times were analyzed after excluding incorrect responses, responses shorter than 300 ms or longer than 2500 ms, and data beyond M $\pm$ 2.5 SD, accounting for 7.46% of trials. Results are presented in Table 1 .

Table 1 Mean Response Times (ms) and Error Rates (%) for Chinese Character Naming by Han and Uyghur Students

Group	High-Frequency Polyphonic	High-Frequency Monophonic	Low-Frequency Polyphonic	Low-Frequency Monophonic
Han	522 (54) 0.00 (0.00)	547 (64) 0.00 (0.00)	759 (206) 2.50 (4.04)	885 (221) 2.83 (4.64)
Uyghur	546 (67) 0.00 (0.00)	579 (72) 0.00 (0.00)	804 (213) 2.50 (4.09)	916 (204) 2.96 (4.78)

Note: Values in parentheses are standard deviations.

ANOVA on response times revealed significant main effects of ethnicity, F (1, 58) = 56.95, $p < 0.001$, $p^2 = 0.50$; F (1, 76) = 1693.07, $p < 0.001$, $p^2 = 0.96$. Han students' response times (M = 548.50 ms) were significantly shorter than Uyghur students' (M = 841 ms), a difference of 292.5 ms. Orthographic depth also showed a significant main effect, F (1, 58) = 35.23, $p < 0.001$, $p^2 = 0.38$; F (1, 76) = 33.52, $p < 0.001$, $p^2 = 0.31$. Monophonic characters (M = 678.25 ms) were named significantly faster than polyphonic characters (M = 711.25 ms), a difference of 33 ms. Word frequency yielded a significant main effect, F (1, 58) = 81.11, $p < 0.001$, $p^2 = 0.58$; F (1, 76) = 6.79, $p < 0.01$, $p^2 = 0.08$. High-frequency words (M = 657.75 ms) were named significantly faster than low-frequency words (M = 732.25 ms), a difference of 74.5 ms. The ethnicity $\times$ word frequency interaction was significant in subject analysis, F (1, 58) = 29.86, $p < 0.001$, $p^2 = 0.34$, but not in item analysis, F (1, 76) = 1.15, $p > 0.05$. Simple effects analysis showed that Han students named high-frequency words (M = 534 ms) significantly faster than low-frequency words (M = 563 ms), $p < 0.001$, a 29 ms difference, while Uyghur students also named high-frequency words (M = 782 ms) significantly faster than low-frequency words (M = 901 ms), $p < 0.001$, a 119 ms difference. The word frequency effect was thus more pronounced among Uyghur students. No other interactions were significant (ps > 0.05).

ANOVA on error rates revealed only a significant main effect of ethnicity, F (1, 58) = 52.77, $p < 0.05$, $p^2 = 0.48$; F (1, 152) = 20.08, $p < 0.001$, $p^2 = 0.12$. Uyghur students' error rates were significantly higher than Han students' ($p < 0.001$). No other main effects or interactions were significant (ps > 0.05).

For polyphonic character responses, pronouncing the higher-frequency reading (e.g., reading "便" as "biàn") was considered a "dominant response," while pronouncing the lower-frequency reading (e.g., "pián") was a "non-dominant response" (Zhang Jijia et al., 1996). The proportions and response times for dominant and non-dominant responses are shown in Table 2 .

Table 2 Proportions and Mean Response Times (ms) for Dominant and Non-dominant Responses to Polyphonic Characters

Group	Dominant Response RT	Non-dominant Response RT	Dominant Response %	Non-dominant Response %
Han	553 (116)	614 (138)	83.3	16.7
Uyghur	830 (292)	907 (312)	80.0	20.0

Analysis revealed that Han students'dominant responses were significantly faster than non-dominant responses, $t(29) = -6.13$, $p < 0.001$, $d = 0.47$, a 61 ms difference. Uyghur students also showed significantly faster dominant responses, $t(29) = -3.37$, $p < 0.005$, $d = 0.25$, a 77 ms difference. However, the proportion of non-dominant responses did not differ significantly between groups, $U = 0.77$, $p > 0.05$.

Experiment 1 revealed consistent patterns across both groups: (1) Both showed polyphonic character effects, with significantly longer naming times for orthographically deep polyphonic characters than shallow monophonic characters, consistent with previous research (Lukatela et al., 1980; Bentin et al., 1984; Zhang Jijia et al., 1996). (2) Both exhibited word frequency effects, with high-frequency characters named significantly faster than low-frequency characters. (3) Both groups produced predominantly dominant responses to polyphonic characters, with no significant difference in non-dominant response rates. These findings reflect universal aspects of Chinese character cognition, as both groups' naming was influenced by orthographic depth, word frequency, and dominant/non-dominant pronunciation ratios. However, clear ethnic differences emerged: (1) Uyghur students showed significantly longer response times than Han students for both polyphonic and monophonic characters; (2) The word frequency effect was more pronounced among Uyghur students, with a larger difference between high- and low-frequency characters.

Experiment 1 examined naming of isolated monosyllabic words. Would polyphonic effects persist when polyphonic characters appeared in context? If all pronunciations of a polyphonic character are activated, response competition should produce polyphonic effects even with contextual information. If only context-appropriate pronunciations are activated, polyphonic effects should disappear in context, yielding equivalent recognition times for words with polyphonic versus monophonic characters. Additionally, because Chinese characters emphasize holistic, imagistic, paratactic, and fuzzy processing, their recognition is highly context-dependent. Polyphonic characters emerged partly because single characters could not express multiple meanings, necessitating pronunciation changes to differentiate semantics. Thus, polyphonic characters simultaneously carry different semantic information. Placing polyphonic characters in disyllabic words constrains both semantics and pronunciation. Unlike Chinese, Uyghur words inherently carry substantial phonological and grammatical information, making their recognition less context-dependent. Do these native language differences lead to different processing modes for polyphonic characters across the two groups?

Experiment 2: Naming of Disyllabic Chinese Words

Method

Participants. Sixty students from Minzu University of China participated: 30 Uyghur and 30 Han students, with equal gender distribution. The Uyghur students' background information was similar to that in Experiment 1.

Design. A 2 (ethnicity: Uyghur/Han) × 2 (orthographic depth: polyphonic/monophonic) × 2 (word frequency: high/low) mixed design was employed, with ethnicity as a between-subjects factor and orthographic depth and word frequency as within-subjects factors.

Materials. Eighty disyllabic Chinese words were selected, with 40 words containing one polyphonic character (positioned as the first character) and 40 words composed of monophonic characters. The 80 words were divided into four groups: 20 high-frequency polyphonic words (frequency range: 285.7–2565.4 per million), 20 low-frequency polyphonic words (frequency range: 2.3–47.6 per million), 20 high-frequency monophonic words (frequency range: 222.2–732.4 per million), and 20 low-frequency monophonic words (frequency range: 2.3–25.7 per million). No significant frequency difference existed between high-frequency polyphonic (M = 472.4 per million) and monophonic words (M = 409.45 per million), $t(38) = 0.55$, $p > 0.05$, nor between low-frequency polyphonic (M = 9.75 per million) and monophonic words (M = 5.86 per million), $t(38) = 1.50$, $p > 0.05$. Stroke counts ranged from 7 to 27, with average stroke counts of 14.35, 16.90, 13.90, and 16.45 for the four conditions, respectively, $F(3, 76) = 2.42$, $p > 0.05$. As in Experiment 1, pre-testing confirmed that Uyghur students could identify the polyphonic characters when presented in isolation.

Apparatus and Procedure. E-Prime controlled stimulus presentation on a PIII-667 computer. Disyllabic words were presented centrally at 280×167 pixels. Responses were recorded via microphone connected to the PET-SRBOX response box. The procedure mirrored Experiment 1: 500 ms fixation cross, 500 ms blank screen, then stimulus presentation for a maximum of 1000 ms, with participants naming the disyllabic word into the microphone.

Results and Analysis

Response times were analyzed after excluding incorrect responses, responses shorter than 300 ms or longer than 2500 ms, and data beyond M ± 2.5 SD, accounting for 4.92% of trials. Error rates were extremely low (<1% across conditions) and were not analyzed further. Results are presented in Table 3 .

Table 3 Mean Response Times (ms) for Disyllabic Word Naming by Han and Uyghur Participants

Group	High-Frequency Polyphonic	High-Frequency Monophonic	Low-Frequency Polyphonic	Low-Frequency Monophonic
Han	516 (56)	513 (67)	545 (52)	561 (54)
Uyghur	702 (153)	845 (185)	736 (186)	854 (168)

ANOVA on response times revealed significant main effects of ethnicity, F (1, 58) = 60.00, $p < 0.001$, $p^2 = 0.51$; F (1, 76) = 1269.70, $p < 0.001$, $p^2 = 0.94$. Han students' response times (M = 536.25 ms) were significantly shorter than Uyghur students' (M = 784.25 ms), a 248 ms difference. Orthographic depth showed a significant main effect in subject analysis, F (1, 58) = 9.74, $p < 0.01$, $p^2 = 0.14$, but not in item analysis, F (1, 76) = 0.14, $p > 0.05$. Words with monophonic characters (M = 652 ms) were named significantly faster than words with polyphonic characters (M = 666 ms), a 14 ms difference. Word frequency yielded a significant main effect in subject analysis, F (1, 58) = 283.14, $p < 0.001$, $p^2 = 0.59$, but not in item analysis, F (1, 76) = 1.51, $p > 0.05$. High-frequency words (M = 616.75 ms) were named significantly faster than low-frequency words (M = 701.25 ms), an 84.5 ms difference. The ethnicity × word frequency interaction was significant in subject analysis, F (1, 58) = 83.91, $p < 0.001$, $p^2 = 0.59$, but not in item analysis, F (1, 76) = 1.51, $p > 0.05$. Simple effects analysis showed that Han students named high-frequency words (M = 514.5 ms) significantly faster than low-frequency words (M = 553 ms), $p < 0.05$, a 38.5 ms difference, while Uyghur students also named high-frequency words (M = 719 ms) significantly faster than low-frequency words (M = 849.5 ms), $p < 0.001$, a 125.5 ms difference. The word frequency effect was again more pronounced among Uyghur students. Critically, the three-way interaction among ethnicity, word frequency, and orthographic depth was significant, F (1, 58) = 8.52, $p = 0.005$, $p^2 = 0.13$; F (1, 76) = 37.66, $p < 0.001$, $p^2 = 0.33$.

Further analysis revealed that for high-frequency words, the ethnicity × orthographic depth interaction was significant, F (1, 58) = 4.08, $p < 0.05$, $p^2 = 0.07$; F (1, 38) = 25.79, $p < 0.001$, $p^2 = 0.97$. Mean comparisons showed no significant difference for Han participants between words with polyphonic (M = 513 ms) and monophonic (M = 516 ms) initial characters, $p > 0.05$, whereas Uyghur participants were significantly slower for words with polyphonic initials (M = 736 ms) than monophonic initials (M = 702 ms), $p = 0.001$. For low-frequency words, the ethnicity × orthographic depth interaction was also significant, F (1, 58) = 9.67, $p < 0.01$, $p^2 = 0.14$; F (1, 38) = 15.66, $p < 0.001$, $p^2 = 0.92$. Han participants were significantly slower for words with polyphonic initials (M = 561 ms) than monophonic initials (M = 545 ms), $p < 0.01$, while Uyghur participants showed no significant difference between monophonic (M = 845 ms) and polyphonic (M = 854 ms) conditions, $p > 0.05$.

Experiment 2 demonstrated that both groups showed word frequency effects for both monophonic and polyphonic disyllabic words, with high-frequency words named significantly faster than low-frequency words, and this effect was more pronounced among Uyghur students, consistent with Experiment 1. However, polyphonic effects in context differed across groups, revealing word frequency' s moderating role: For high-frequency words, Han participants showed no polyphonic effect (no difference between polyphonic and monophonic conditions), whereas Uyghur participants exhibited a significant polyphonic effect. For low-frequency words, Han participants showed a polyphonic effect, while Uyghur participants did not. Word frequency thus moderated polyphonic effects differently across ethnic groups, a phenomenon warranting careful attention.

Combined Analysis of Experiments 1 and 2

Because Experiments 1 and 2 used homogeneous participant samples, we combined response time data for a 2 (ethnicity: Uyghur/Han) × 2 (word frequency: high/low) × 2 (orthographic depth: polyphonic/monophonic) × 2 (context: present/absent) mixed ANOVA, with ethnicity and context as between-subjects factors and word frequency and orthographic depth as within-subjects factors.

ANOVA revealed significant main effects of ethnicity, $F(1, 116) = 116.50$, $p < 0.001$, $p^2 = 0.50$; word frequency, $F(1, 116) = 271.02$, $p < 0.001$, $p^2 = 0.70$; and orthographic depth, $F(1, 116) = 44.96$, $p < 0.001$, $p^2 = 0.28$. Polyphonic characters and words containing them yielded significantly longer response times than monophonic counterparts. The ethnicity × word frequency interaction was significant, $F(1, 116) = 89.13$, $p < 0.001$, $p^2 = 0.44$, with larger word frequency effects for Uyghur participants. The orthographic depth × context interaction was significant, $F(1, 116) = 13.68$, $p < 0.001$, $p^2 = 0.11$, with larger polyphonic effects in the no-context condition. The ethnicity × word frequency × orthographic depth interaction was significant, $F(1, 116) = 9.00$, $p < 0.01$, $p^2 = 0.07$. The four-way interaction among ethnicity, word frequency, orthographic depth, and context was also significant, $F(1, 116) = 4.07$, $p < 0.05$, $p^2 = 0.02$. No other effects were significant ($ps > 0.05$).

To examine ethnic differences in polyphonic effects across context conditions, we compared polyphonic effect magnitudes. For Han students, context significantly reduced polyphonic effects for both high-frequency words (no-context effect = 24 ms vs. context effect = −3 ms), $t(29) = 4.56$, $p < 0.001$, $d = 0.84$, and low-frequency words (no-context effect = 32 ms vs. context effect = 16 ms), $t(29) = 2.22$, $p < 0.05$, $d = 0.40$. Han students thus demonstrated robust context utilization, with smaller polyphonic effects in context. Uyghur students' polyphonic effects were influenced by both context and whole-word frequency. For high-frequency words, polyphonic effects did not differ significantly between no-context (45 ms) and context (34 ms) conditions, $t(29) = 0.79$, $p > 0.05$. For low-frequency words, context significantly reduced polyphonic effects (no-context = 31 ms vs. context = 9 ms), $t(29) = 2.22$, $p < 0.05$, $d = 0.41$. Uyghur participants were aware of polyphonic characters' multiple pronunciations for high-frequency words regardless of context, but for low-frequency words, they recognized polyphony only in the no-context condition.

General Discussion

Word naming is a lexical retrieval process wherein graphic information first activates orthographic representations in the mental lexicon, which then activate phonological and semantic representations, ultimately initiating articulation (Fang Yanhong & Zhang Jijia, 2009). This study demonstrates that objective variables such as orthographic depth, word frequency, and context, along with subjective variables including age of acquisition, language proficiency, character usage frequency, and language processing style, all influence Chinese word naming times for both groups.

Ethnic Differences in Chinese Word Naming: Effects of Language Proficiency and Age of Acquisition

Han students demonstrated significantly shorter naming latencies than Uyghur students for both monosyllabic and disyllabic Chinese words. This reflects that Chinese is the native language for Han students but a second language for Uyghur students, and characters are native script for Han students but second-language script for Uyghur students. Although Uyghur students were quite proficient in Chinese, it remained their second language, and their character proficiency could not match that of native speakers. Bilingual research indicates that age of acquisition (AoA) and second-language proficiency are crucial factors (Nichols & Joanisse, 2016). AoA refers to the age at which a word is first encountered and understood in spoken or written form; earlier AoA predicts faster lexical processing (Chen Jun, Lin Shaohui, & Zhang Jijia, 2011; Saito, 2015; Zhang Jijia, Chen Suiqing, Zhang Guangyan, & Dai Donghong, 2012). Chen Baoguo, Wang Lixin, Wang Lulu, and Peng Danling (2004) found that AoA and frequency independently affect Chinese disyllabic word identification. Uyghur students acquired Chinese vocabulary much later than Han students, after already acquiring their native language, resulting in slower processing. Compared to AoA, second-language proficiency has greater impact on bilingual representation and neural structure. Research shows that when bilinguals' two languages are equally proficient, processing speeds are comparable; when proficiency differs, the dominant language is processed faster with fewer errors. In lexical decision tasks, English-French bilinguals respond faster and more accurately to their proficient language (English) than their less proficient language (French) (Thomas & Allport, 2000). Studies of Greek-English bilinguals reveal interactions between language and proficiency: when English is relatively proficient, English word decisions are faster than Greek; when English is less proficient, Greek decisions are faster (Orfanidou & Sumner, 2005). Research on Chinese-English bilinguals, Chinese-Japanese-English trilinguals, and Tibetan-Chinese-English trilinguals similarly identifies proficiency as a key factor (Cui Zhanling & Zhang Jijia, 2009; Li Li, Mo Lei, & Wang Ruiming, 2008; Wang

Yue, Sun Erhong, & Zhang Jijia, 2016; Wang Yue & Zhang Jijia, 2014).

According to the weaker links hypothesis, bilinguals' connections between phonological, semantic, and lexical representations are weaker than those of monolinguals (Gollan, Rosa, Montoya, Cera, & Sandoval, 2007; Zhang Jijia & Zhang Fengling, 2010; Yang Chen & Zhang Jijia, 2011). Uyghur students' use of both Uyghur and Chinese in daily life results in lower Chinese character usage frequency than Han native speakers, yielding lower character proficiency and consequently longer naming times.

Both experiments revealed word frequency effects, with high-frequency Chinese words named faster than low-frequency words for both groups. However, the word frequency effect was more pronounced for Uyghur students. While word frequency effects on lexical processing are well-established (Chen Baoguo et al., 2004; Tan Lihai & Peng Danling, 1989; Zhang Jijia, Zhang Houcan, & Peng Danling, 1990; Brysbaert, Mandera, & Keuleers, 2018), the exaggerated effect for Uyghur students requires explanation. One possibility relates to Chinese character usage patterns. Zhou Youguang' s "character utility decrement law" shows that the top 1000 most frequent characters cover approximately 90% of usage, with each additional 1000 characters increasing coverage by only about 10% (Zhou Xiaowen & Li Yong, 2009). According to Tsinghua University' s frequency table of 6763 common characters, knowing 500 characters covers 78.53% of usage, 1000 characters covers 91.92%, 2000 characters covers 98.39%, and 3000 characters covers 99.63%. All Uyghur participants had passed MHK Level 4, which targets learners with 1600–2000 hours of formal Chinese education approaching native-like proficiency. Under 2011 compulsory education standards, Chinese middle school graduates should know approximately 3500 common characters. Since Chinese is not their native language, Uyghur university students' character knowledge likely does not exceed 3500 characters. Moreover, among these 3500 characters, Uyghur students probably use high-frequency characters more and low-frequency characters less than Han students, further widening the familiarity gap between high- and low-frequency words and amplifying the word frequency effect. Another possibility involves AoA. Uyghur students' later AoA for Chinese words may be even later for low-frequency words, further increasing the response time difference between high- and low-frequency character naming.

Differential Polyphonic Effects: Interactions Among Orthographic Depth, Context, Word Frequency, and Language Processing Style

This study' s central concern is how orthographic depth differentially affects Chinese word naming across the two ethnic groups. Results demonstrate that ethnic differences in polyphonic effects reflect interactions among orthographic depth, context, word frequency, and language processing style. In Experiment 1, both groups named polyphonic characters significantly slower than monophonic characters, indicating orthographic depth effects on isolated character naming. This occurs because monophonic characters have one-to-one grapheme-phoneme mappings with transparent relationships, allowing direct activation of phonological representations from orthographic representations, yielding fast responses. Polyphonic characters' one-to-many grapheme-phoneme mappings create ambiguity, activating multiple pronunciations that compete during naming, requiring selection and lengthening response times. Thus, polyphonic effects in isolated character naming primarily reflect orthographic depth. Zhang Jijia et al. (1996) previously identified polyphonic effects in monosyllabic naming; this study replicates and extends this finding across ethnic groups. Moreover, these polyphonic effects occurred without contextual support, and the absence of an ethnicity × orthographic depth interaction indicates both groups recognized polyphonic characters' multiple pronunciations when presented in isolation, reflecting universal aspects of character cognition.

Experiment 2 revealed ethnic differences in contextual polyphonic effects: Han students showed significant context effects, with smaller polyphonic effects in context than in isolation, demonstrating effective context utilization. Uyghur students showed weaker context effects, with no context effect for high-frequency words (polyphonic effect magnitude did not differ between context conditions). Furthermore, ethnic differences manifested in different interaction patterns with word frequency. In context (Experiment 2), Han students' polyphonic effects appeared only for low-frequency words, not high-frequency words, suggesting their polyphonic effects were modulated by whole-word frequency. Two explanations are possible: (1) In high-frequency word contexts, Han students may activate only the context-appropriate phonological representation, which in fixed compounds functions similarly to monophonic character representations, making them insensitive to polyphonic characters' complex phonological structure. In low-frequency contexts, where contextual support is weaker, both pronunciations are activated, increasing sensitivity to the polyphonic character' s bidirectional phonological structure and requiring contextual resolution, thereby lengthening response times. (2) Native Chinese speakers may have different phonological representations and retrieval methods for high- versus low-frequency words. High-frequency words may have holistic phonological representations, with naming based on integrated whole-word representations that leave little opportunity for polyphonic morpheme effects. Low-frequency words may have decomposed phonological representations, with retrieval of individual morpheme phonology followed by integration, allowing multiple pronunciations to be activated and compete, complicating integration and lengthening response times.

In contrast, Uyghur students' polyphonic effects in context appeared only for high-frequency words, not low-frequency words. The dual-route model posits two word recognition pathways: a lexical route where orthographic representations activate phonological representations directly or via semantic representations, and a nonlexical route where sublexical grapheme-phoneme conversion rules construct phonology without lexical involvement (Coltheart et al., 2001). Uyghur is an alphabetic script with shallow orthographic depth (Mahpiret · Kanji, Liu Xiangping, & Zhang Wei, 2011). In Uyghur reading, individuals use phonological decoding strategies based on grapheme-phoneme correspondence. Each successful decoding provides orthographic information about specific words. Mahpiret • Kanji (2016) found that sublexical phonological decoding is the fundamental strategy in Uyghur word recognition. Uyghur students'slower naming of high-frequency disyllabic words with polyphonic initials suggests they employed nonlexical grapheme-phoneme correspondence strategies, activating both pronunciations and creating competition that prolonged responses. For low-frequency words, unfamiliarity with both the whole word and the polyphonic character may have prevented activation of all phonological representations, activating only the dominant pronunciation and eliminating response time differences between polyphonic and monophonic conditions. However, Uyghur students' awareness of Chinese polyphonic characters is developing: combined analysis showed that context significantly reduced polyphonic effects for low-frequency words, indicating context began modulating their polyphonic word naming.

Ethnic differences in disyllabic word polyphonic effects also relate to linguistic representation of compound words. Three main perspectives exist: (1) Morpheme Access Model (MA), which posits decomposed morphemic storage with morpheme activation preceding whole-word access (Taft & Forster, 1975). Morpheme priming and frequency effects support this model (Bien, Levelt, & Baayen, 2005; Wang Juan, Zhang Jijia, & Xu Jinyu, 2014). (2) Word Access Model (WA), which proposes whole-word storage with direct whole-word activation (Manelis & Tharp, 1977). Whole-word frequency effects in Chinese normal and brain-damaged participants support this view (Bi, Han, & Shu, 2007; Janssen, Bi, & Caramazza, 2008). (3) Combined Access Model (CA), which posits both morpheme and whole-word representations with interactive activation (Caramazza, Laudanna, & Romani, 1988). Both morpheme and whole-word representations contribute to compound word recognition, with dual representation patterns emerging early in visual processing (Chen Xi & Zhang Jijia, 2005; Fang Jie, 2009).

For Han students, high-frequency words have both high-frequency whole-word and lower-frequency morpheme representations, leading to whole-word-based naming with minimal morpheme influence. Low-frequency words also have both representation types, but whole-word representations are weaker while morpheme representations are relatively stronger, making morpheme activation likely and polyphonic effects more apparent. For Uyghur students, native language processing influences may prevent or weaken formation of whole-word representations for compounds. For both high- and low-frequency words, they may primarily activate morpheme representations and integrate them into whole-word representations, employing decompositional processing. High-frequency words' morpheme representations activate easily, enabling activation of all corresponding phonology and revealing polyphonic effects. Low-frequency words' morpheme representations activate poorly, activating only dominant phonology and eliminating polyphonic effects.

In summary, ethnic differences in polyphonic effects reflect interactions among orthographic depth, context, and word frequency, underpinned by differences in language processing style. Chinese character cognition involves coexisting whole-word and morpheme representations, with both holistic retrieval and decompositional processing, leading Han participants to process high-frequency words holistically and low-frequency words decompositionally. Uyghur script cognition' s decompositional representations and serial processing lead Uyghur participants to apply similar decompositional strategies to both high- and low-frequency Chinese words. Their familiarity with polyphonic characters in high-frequency words enables awareness of dual pronunciations, activating both and slowing responses. Their unfamiliarity with polyphonic characters in low-frequency words prevents awareness of dual pronunciations, activating only dominant phonology and eliminating response time differences.

These findings have important implications for Chinese language instruction for Uyghur students. Instruction should emphasize word-based rather than character-based teaching, as words are the basic linguistic unit. Word-based instruction facilitates mastery of polyphonic characters' different pronunciations and promotes formation of whole-word representations for polymorphemic words, fostering Chinese-appropriate processing styles. Additionally, bilingual education should begin early, with systematic programs to improve parents' Chinese proficiency, enabling Uyghur families to become bilingual, advancing Uyghur students' Chinese AoA, increasing Chinese usage frequency in Uyghur families, and facilitating Uyghur students' development into proficient Uyghur-Chinese bilinguals.

Conclusions

1. Both Han and Uyghur students exhibited polyphonic and word frequency effects in monosyllabic character naming, with word frequency effects more pronounced among Uyghur students.
2. Polyphonic effects in disyllabic word naming for both groups reflected interactions among orthographic depth, word frequency, context, and native language processing style.

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[1] *Min kao han* refers to ethnic minority students who take the National College Entrance Examination using Chinese-language answer sheets and primarily apply to Chinese-medium institutions. These students represent the highest Chinese proficiency among Uyghur students, having received Chinese-medium education from childhood with school experiences nearly identical to Han students, enabling fluent Chinese communication, writing, and reading.

Note: Figure translations are in progress. See original paper for figures.