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A smart pen-based analysis of Chinese character stroke order errors among beginning Central Asian students

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Abstract. The ability to master Chinese orthography is of increasing importance in global education, yet learners from non-logographic backgrounds encounter persistent and distinctive obstacles. Addressing the specific challenges experienced by Central Asian students is crucial for informing targeted teaching strategies. The present study sought to elucidate the procedural difficulties and cognitive factors underlying stroke order errors in Chinese character writing among five beginning-level international students from Kyrgyzstan and Uzbekistan, all native Dungan speakers fluent in Russian. Utilising smart pen technology to record and analyse the writing process, the author of this study collected data on stroke order errors during textbook-based copying exercises. Analysis of 605 error instances across 1,800 characters revealed an average error rate of 33.6% per student for characters containing errors. The most prevalent error types were stroke sequence errors (78.5%), stroke direction errors (19.3%), and stroke reversal phenomena (2.2%). Common sequence errors included horizontal-vertical order reversal (31.4%) and component order reversal (28.6%), while frequent direction errors involved confusion between ‘ti’ (提) and ‘pie’ (撇) strokes (52.1%). The findings indicated that, although a Dungan language background may offer certain phonological advantages, it does not inherently support correct stroke order execution, which is significantly influenced by prior Cyrillic/Russian script habits. This research advances understanding of the specific procedural barriers faced by Central Asian learners and proposes evidence-based interventions for more effective Chinese character instruction

Keywords: Chinese character acquisition; stroke sequence; Dungan language; error analysis; smart pen technology; Cyrillic interference

■ INTRODUCTION

The acquisition of Chinese characters poses a formidable challenge for international students learning Chinese as a second language, particularly for those whose native writing systems differ fundamentally from the logographic nature of Chinese script. Mastery of correct stroke order is widely recognised as essential – not only for the aesthetic presentation of characters but also for facilitating character recognition, writing fluency, and long-term retention (Sun *et al.*, 2024; Yang & Tian, 2024). Empirical research has shown that adherence to standard stroke order principles enhances motor memory, accelerates character recognition, and increases the efficiency of character production (Hou & Jiang, 2022). Central Asia offers a unique sociolinguistic context for Chinese language

acquisition. Many students from countries such as Kyrgyzstan and Uzbekistan speak Dungan as their first language – a Sinitic language historically derived from north-western Chinese dialects, but which has been written exclusively in Cyrillic script since the Soviet era (Honkasalo, 2024). This creates an intriguing scenario: while these learners possess phonological familiarity with many Chinese morphemes, they lack exposure to Chinese orthographic conventions. As mentioned by X. Duan & Z. Cai (2024), the phonological proximity between Dungan and Mandarin may facilitate vocabulary acquisition and pronunciation; however, the stark orthographic divergence between Cyrillic and Chinese scripts introduces unique challenges in character production.

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Recent advancements in digital technology have opened new avenues for investigating the dynamic process of character writing. According to N. Ismail & D. Ghani (2021), smart pen technology, capable of recording real-time stroke sequence, direction, and timing, has emerged as a powerful tool for analysing the specific difficulties encountered by different learner populations. Unlike traditional error analysis, which focuses solely on the final written product, smart pen data capture the temporal and spatial dimensions of writing, offering valuable insights into the cognitive processes underlying character formation.

Although prior studies have explored stroke order acquisition among learners from alphabetic, syllabic, and other logographic backgrounds, research specifically targeting Central Asian learners with Dungan backgrounds remains notably limited (Hong *et al.*, 2021; Liang & Ng, 2024). Given the increasing number of students from this region pursuing Chinese language studies, this population presents a compelling case for examining the interplay between phonological advantage and orthographic disadvantage in character acquisition. To address this gap, the present study investigated stroke order errors among five beginning-level international students from Central Asia with Dungan as their native language during the initial stages of Chinese character acquisition. By leveraging smart pen technology to analyse their writing processes, this research aimed to identify error patterns, explore their underlying causes, and propose targeted pedagogical interventions. The findings have significant implications for curriculum design, instructional practices, and the development of specialised learning materials tailored to this unique student population. Specifically, this study sought to answer three primary research questions: what types and patterns of stroke order errors are most prevalent among Central Asian students with Dungan language backgrounds; how do these error patterns relate to the students' prior experience with the Cyrillic script; what pedagogical recommendations can be derived from these findings to enhance character instruction for Central Asian learners.

LITERATURE REVIEW

Research on Chinese character acquisition among second language learners has expanded considerably in recent years, with increasing emphasis on the role of stroke order in successful character mastery. H. Hsiung *et al.* (2017) demonstrated that correct stroke order significantly improves character recognition, writing accuracy, and long-term retention among learners. This was further corroborated by J. Xu & X. Jiang (2022), who found a strong correlation between adherence to standard stroke order and enhanced character recall and production in beginning learners.

The cognitive mechanisms underlying character acquisition have been explored through neuroimaging studies. For example, J. Zhang *et al.* (2022), utilising functional magnetic resonance imaging (fMRI), revealed that learners' neural pathways for processing new writing systems are profoundly influenced by their first language script

experiences. Their findings suggest that pre-existing neural networks, shaped by prior writing experiences, may either facilitate or impede the acquisition of Chinese characters. Extending this neurocognitive perspective, K. Lui *et al.* (2023) employed event-related potential (ERP) techniques to investigate children's neural responses to stroke order violations. Their results showed that both anterior N2 and posterior P3 ERP components were heightened in response to incorrect stroke order, indicating the brain's sensitivity to stroke sequence even at an early age. Notably, poor spellers exhibited a reduced right lateralised N2 response, which was closely linked to weaker spelling and reading performance. This suggests the right lateralised N2 as a potential neural marker for Chinese literacy development and highlights the foundational importance of stroke order knowledge in both reading and spelling acquisition.

The distinctive linguistic background of Central Asian students with Dungan heritage has attracted scholarly attention. E. Allès (2005) offered a comprehensive historical account of the Dungan language, tracing its evolution from north-western Chinese dialects and its subsequent adoption of Cyrillic script during the Soviet era. P. Kokaisl (2025) found that while Dungan speakers exhibit superior phonological skills in Chinese learning, they do not demonstrate a significant advantage in character writing compared to learners from unrelated language backgrounds, underscoring the dissociation between phonological familiarity and orthographic competence.

Technological innovation has transformed research methodologies in character acquisition. Y. Lai & X. Zhang (2021) developed quantitative methods for assessing key aspects of handwritten Chinese characters produced by CFL (Chinese as a Foreign Language) learners, including stability, symmetry, and inclination. Their comprehensive analytical framework allows for the objective evaluation of character writing quality based on calligraphic principles, providing a solid foundation for further empirical research in this area. On this basis, they employed digital ink technology to analyse the dynamic process of Chinese character writing among beginning-level Chinese language learners, capturing temporal and spatial dimensions of handwriting behaviours that are not observable in static written products (Lai & Zhang, 2024). Their research further explored the factors influencing dynamic stroke writing behaviours, revealing that variables such as character complexity, stroke type familiarity, and learner background serve as significant predictors of stroke writing quality. These findings contribute to a deeper understanding of the dynamic and multifaceted nature of Chinese character acquisition.

Recent advancements in educational technology have also shown promise in supporting character writing development. L. Wong *et al.* (2023) introduced AI-Strokes, a machine learning-powered Chinese handwriting learning tool that provides real-time, personalised feedback to students. In a controlled trial, students who used AI-Strokes demonstrated significantly greater improvements in handwriting accuracy, particularly in stroke order, stroke direction, and the

avoidance of extra or missing strokes, compared to those receiving conventional instruction. The study suggests that personalised digital feedback and multimodal task design can foster orthographic awareness and enhance the psycholinguistic processes underlying Chinese handwriting acquisition.

The pedagogical value of error pattern analysis has been emphasised by Y. Hao *et al.* (2021), who demonstrated that instructional interventions tailored to identified error patterns significantly improve character writing accuracy among beginners. The relationship between character complexity and error frequency has been established by C. Chan (2020), who observed that error rates increase proportionally with stroke count and structural intricacy. In summary, the literature reveals substantial gaps in the understanding of Chinese character acquisition among Central Asian learners with Dungan language backgrounds. The author of the present study sought to address these gaps by providing empirical insights into the specific challenges faced by this population, thereby informing more effective and culturally responsive pedagogical strategies.

■ MATERIALS AND METHODS

This study recruited five international students (four males, one female) from Central Asia, all of whom were enrolled in an elementary Chinese language programme at a university in Gansu Province, China. The participants ranged in age from 19 to 23 years ($M = 20.8$, $SD = 1.48$) and had been studying Chinese for an average of 4.2 months ($SD = 0.84$) at the time of data collection. Three participants were from Kyrgyzstan and two from Uzbekistan. All reported Dungan as their first language and demonstrated native-like fluency in Russian as their second language, reflecting the unique multilingual context common among Central Asian populations. Importantly, none of the participants had prior experience with Chinese character writing before commencing their formal studies. While Dungan is a Sinitic language historically linked to Mandarin, it is written exclusively in Cyrillic script in contemporary contexts, meaning these learners approached Chinese character writing as a novel orthographic system. All participants were recruited via voluntary participation following an information session about the research project during their Chinese language class. The study was conducted from October to December 2023. Informed consent was obtained from all participants. The study protocol was reviewed and approved by the university's Institutional Review Board, ensuring compliance with ethical standards for research involving human subjects (ASA, 2018).

Character selection. A total of 120 Chinese characters were selected for the writing task. These characters were drawn from the textbook *Developmental Chinese* (Jihua, 2011), which is currently used by the learners, and represent the vocabulary introduced during the first eight weeks of instruction. The selection aimed to encompass a range of structural complexities, with characters varying from 2 to 12 strokes, and to include diverse structural types such as left-right, top-down, and enclitic forms. All selected

characters adhere to the standard stroke order prescribed by the Stroke Order Specification for Common Characters in Modern Chinese issued by the State Language Commission of China (2020). This careful selection ensured ecological validity, as the characters closely reflect the actual learning content and challenges faced by beginners in the classroom. Furthermore, the inclusion of both characters that strictly follow stroke order norms and those that deviate from them enables a nuanced analysis of error patterns related to both standard conventions and exceptional cases.

Smart pen technology. To accurately capture the writing process, this study utilised the Evernote Smart Pen system. This digital pen records handwriting in real time, transmitting detailed stroke sequence and direction data to the Evernote application. Used in conjunction with specialised notebooks, the system enables precise tracking of pen movements, including the timing, order, and direction of each stroke. By leveraging this technology, researchers are able to analyse not only the final written product but also the dynamic process of character formation. This approach yields a rich dataset for identifying stroke order errors, hesitations, and self-correction attempts. The digital recording of the entire writing process offers significant methodological advantages over traditional paper-and-pencil tasks. It enables fine-grained temporal analysis and allows for the detection of overt errors as well as near-misses or corrections that may not be apparent in the final written form.

Procedure. Data collection was conducted through individual sessions held in a quiet classroom environment to minimise distractions. Each participant completed three sessions, each lasting approximately 60 minutes, with sessions scheduled one week apart to mitigate fatigue and practice effects. During each session, participants were instructed to copy 40 characters from their textbook using the smart pen and specialised notebook. Characters were presented individually on a computer screen, and participants were asked to write each character as they would during regular coursework. To ensure that writing behaviour reflected participants' natural strategies and habits, no explicit instruction regarding stroke order was provided, and no time limit was imposed. Prior to the first session, participants completed a detailed background questionnaire, which gathered information on their language learning history, educational background, and any prior exposure to Chinese characters. After completing all writing tasks, each participant participated in a semi-structured interview designed to elicit qualitative data on their character learning strategies, perceived difficulties, and any cross-linguistic influences affecting their writing process.

Error classification. Stroke order errors were classified using a modified taxonomy based on L. Ch'ng *et al.* (2018), with additional subcategories developed to account for patterns specific to this learner population. The primary error categories included stroke sequence errors, stroke direction errors, and stroke reversal phenomena. These categories, along with their definitions, specific manifestations, and examples, are summarised in Table 1.

Table 1. Classification and examples of stroke errors in Chinese character writing

Error category	Definition	Specific manifestation	Examples
Stroke sequence errors	Deviations from the prescribed order of strokes, while maintaining correct stroke direction and form	1. Horizontal-vertical order reversal 2. Component order reversal 3. Outside-inside order reversal 4. Other sequence deviations	1. Writing the vertical stroke before the horizontal in “十” 2. Writing the right component before the left in “好” 3. Writing the inner part before the enclosure in “回”
Stroke direction errors	Incorrect execution of the direction of individual strokes	1. Confusion between <i>tí</i> (提) and <i>piě</i> (撇) strokes 2. Confusion between <i>nà</i> (捺) and <i>piě</i> (撇) strokes 3. Horizontal strokes written right-to-left 4. Vertical strokes written bottom-to-top	1. Writing 提 as 撇 or vice versa 2. Writing 捺 as 撇 or vice versa 3. Horizontal strokes in reverse direction 4. Vertical strokes in reverse direction
Stroke reversal phenomena	Violations of principles governing the general directional flow of character construction	1. Bottom-to-top construction 2. Right-to-left construction 3. Other global reversal patterns	1. Assembling the character from the bottom up 2. Assembling from right to left 3. Other systematic directional reversals

Source: developed by the author

To ensure the accuracy and consistency of error identification, two trained raters independently coded the video recordings and digital pen data. Inter-rater reliability was calculated using Cohen's kappa coefficient. Any discrepancies encountered during the coding process were resolved through discussion and consensus with a third rater, an expert in Chinese orthography and second language (L2) writing research. This rigorous, multi-rater approach served to establish the reliability and validity of the error classification process.

Statistical analysis. Descriptive statistics were computed to summarise the frequencies of different error types, as well as to examine distributions across various character features and participant characteristics. Chi-square tests were conducted to assess the relationship between character structural features (such as configuration type) and the occurrence of specific error types. Additionally, correlation analyses were performed to explore the association between character complexity – operationalised as stroke count – and error frequency. All statistical analyses were

carried out using SPSS version 28.0, with the significance threshold set at $p < 0.05$, unless otherwise specified.

RESULTS AND DISCUSSION

Overall patterns and structural influences on stroke order errors

Analysis of the 1,800 characters produced by the five participants (360 characters per participant) revealed a total of 605 characters containing at least one stroke order error. This corresponds to an overall error rate of 33.6%. Notably, error rates exhibited considerable individual variation, ranging from 26.4% to 41.7% (Mean = 33.6%, Standard Deviation = 5.8%), despite the participants sharing similar linguistic backgrounds and instructional exposure. The distribution of identified error types is summarised in Table 2. Stroke sequence errors emerged as the most prevalent category, accounting for 78.5% of all observed errors. Stroke direction errors constituted 19.3% of the total, while instances of stroke reversal phenomena were relatively infrequent, representing only 2.2% of all errors.

Table 2. Distribution of stroke order error types

Error type	Number of occurrences	Percentage
Stroke sequence errors	475	78.5%
Stroke direction errors	117	19.3%
Stroke reversal	13	2.2%
Total	605	100%

Source: developed by the author

Further analysis within the category of stroke sequence errors indicated that horizontal-vertical order reversal was the most common subtype, contributing to 31.4% of these errors. This was followed by component order reversal (28.6%), outside-inside order reversal (22.3%), and other sequence errors (17.7%). Among stroke direction errors, confusion between *tí* (提) and *piě* (撇) strokes was the most frequently observed subtype, accounting for 52.1%

of direction-related errors. Other notable direction errors included incorrect horizontal stroke direction (28.2%), incorrect vertical stroke direction (12.8%), and confusion between *nà* (捺) and *piě* (撇) strokes (6.9%).

Chi-square analysis revealed a statistically significant association between the structural configuration of characters and the type of stroke order errors observed ($\chi^2 = 18.74$, $p < 0.01$). Specifically, characters with a

left-right structure were disproportionately associated with component order reversal errors. Conversely, characters featuring an enclosed structure demonstrated higher rates of outside-inside order reversal errors. These findings suggest that particular structural configurations present distinct challenges for Central Asian learners, likely stemming from the cognitive demands associated with segmenting and correctly sequencing complex visual forms.

Furthermore, a moderate positive correlation was identified between character complexity, as measured by stroke count, and overall error frequency ($r(N-2) = 0.42$, $p < 0.01$). This indicates that, generally, characters with a higher number of strokes were more prone to stroke order errors. However, this relationship was not strictly linear. Notably, some visually simple characters that possess irregular stroke order conventions (e.g., “九”, “乙”) exhibited disproportionately high error rates. This observation underscores that visual complexity alone is not the sole determinant of stroke order difficulty, and suggests that the interplay of structural regularity and idiosyncratic exceptions significantly influences error patterns among L2 learners.

In summary, the overall error patterns and their structural underpinnings highlight the necessity for a nuanced approach to character instruction, one that takes into account not only general complexity but also the specific configuration and conventionality of each character. This provides a foundation for understanding how learners' errors are shaped by the visual and cognitive demands of Chinese script, which is further complicated by cross-linguistic influences discussed below.

Cross-linguistic influence and orthographic learning challenges

Analysis of error patterns in relation to participants' established writing habits revealed distinctive influences stemming from their prior experience with the Cyrillic script. The predominance of horizontal-vertical order reversal errors (e.g., executing vertical strokes before horizontal strokes) appears to reflect the prevalent top-to-bottom writing orientation characteristic of many Cyrillic letters. Similarly, the observed tendency to write horizontal strokes from right to left, deviating from the standard left-to-right direction in Chinese, aligns with certain Cyrillic handwriting conventions.

Qualitative data gathered from post-task interviews corroborated these quantitative findings. Several participants explicitly acknowledged transferring writing habits acquired from Russian to their Chinese character writing. For instance, one participant remarked, “When I write in Russian, I often start from the top and work my way down. I think I'm doing the same thing with Chinese characters without realising it.” Another participant noted, “Some strokes in Chinese characters remind me of parts of Russian letters, so I write them the same way.” These self-reported observations suggest that deeply ingrained motor routines, developed over years of writing in Cyrillic, create significant interference in the acquisition of correct

Chinese character stroke order. This phenomenon indicates that cross-script interference is not confined to abstract orthographic knowledge but also manifests substantively in the procedural and motor domains of writing. The persistent confusion between *tí* (提) and *piě* (撇) strokes, in particular, highlights the considerable challenge learners face when acquiring new stroke types that lack direct analogues or similar motor execution patterns in the Cyrillic script.

Despite the participants' Dungan linguistic background affording a degree of phonological familiarity with numerous Chinese morphemes, no discernible advantage was observed in their stroke order execution when compared to typical error patterns documented for learners from non-Sinitic language backgrounds. This observation suggests that phonological proximity does not inherently translate into orthographic proficiency, particularly when the learner's first language (L1) employs a fundamentally different writing system.

Participants themselves acknowledged this apparent disconnect. As one individual articulated, “I can understand many Chinese words because they sound similar to Dungan, but writing the characters is completely new to me because we only use Russian letters for writing Dungan.” This distinction highlights the critical need to differentiate between the potential for lexical and phonological transfer and the distinct challenges associated with acquiring orthographic and procedural knowledge in second language writing. In conclusion, the cross-linguistic influence of Cyrillic script experience is pervasive and multifaceted, affecting not only the sequencing and directionality of strokes but also the very motor routines learners bring to character writing. This underscores the importance of addressing both cognitive and procedural aspects of writing in the instructional design for this learner group.

Pedagogical implications and instructional recommendations

The distinct error patterns identified in this study carry significant implications for the design and implementation of Chinese character instruction tailored for Central Asian learners. The predominance of stroke sequence errors, particularly horizontal-vertical order reversals, underscores the necessity for explicit instruction in the fundamental principles governing Chinese character stroke order. This instruction should place a particular emphasis on contrasting these principles with established Cyrillic writing habits. Instructional materials should be systematically organised to address structural configurations known to present specific challenges, such as enclosed characters and left-right structures. Furthermore, these materials should incorporate targeted practice designed to help learners internalise crucial sequencing rules, such as ‘outside-before-inside’ and ‘left-before-right’. In addition, it is important for instructors to recognise that learners' previous literacy experiences may shape their approach to Chinese character writing in subtle ways. For example, the tendency to apply Cyrillic-based sequencing or directionality rules can

persist even after initial instruction. Therefore, repeated and varied practice opportunities – such as copying, dictation, and guided writing tasks – should be integrated into the curriculum to reinforce correct stroke order and direction. Teachers might also consider the use of error analysis as a regular classroom activity, encouraging students to identify and correct common mistakes both individually and collaboratively.

Considering the pronounced influence of Cyrillic writing habits on stroke direction errors, instructors should explicitly highlight and address differences in writing directionality, especially concerning horizontal and diagonal strokes. The observed disconnect between phonological familiarity and orthographic accuracy strongly suggests that educators should not presume that Dungan speakers' linguistic background automatically confers an advantage in the domain of character writing. On the contrary, systematic and explicit character writing instruction remains essential, employing approaches comparable to those utilised for learners from alphabetic or other non-character-based linguistic backgrounds.

Furthermore, the integration of technology, such as smart pen systems, can significantly enhance the provision of immediate and detailed feedback and facilitate a more granular analysis of the writing process. This technological support can thereby assist both educators and learners in identifying and remediating persistent error patterns. Additionally, incorporating kinaesthetic and visual learning strategies – including techniques like air-writing, finger tracing, and the use of color-coded stroke order diagrams – may prove beneficial in helping learners establish new motor routines distinct from those habituated through Cyrillic script. It is also advisable to create a supportive classroom environment that encourages risk-taking and values the process of learning from errors. Peer support networks, collaborative group work, and scaffolded practice can all contribute to building learner confidence and resilience when grappling with the complexities of Chinese character formation.

Instructional interventions should also include opportunities for learners to reflect on their own writing habits, perhaps through video analysis or peer feedback sessions, to increase awareness of cross-script interference. This metacognitive component can empower learners to consciously monitor and adjust their writing behaviours, fostering greater autonomy in mastering Chinese character stroke order. In summary, effective pedagogy for Central Asian learners must combine explicit contrastive analysis, targeted practice, technological support, and metacognitive strategies to address the complex interplay of structural, cognitive, and procedural challenges in Chinese character writing.

Comparative analysis of research on character writing acquisition

The findings of this study both align with and diverge from previous research on Chinese character writing

acquisition among diverse learner populations. For instance, M. Kong (2020) found that stroke sequence and character configuration errors were most common among Hong Kong children, closely linked to visual discrimination and spatial memory, and decreased with age and schooling. This highlights the developmental trajectory of orthographic knowledge in native learners. For learners of Chinese as a foreign language, similarities and cross-linguistic differences emerge. S. Deng & W. Hu (2022) identified stroke order errors as most prevalent but noted that error types and frequencies varied with learners' first language and writing experience. C. Looi-Chin *et al.* (2018) reported that business students frequently made stroke omissions, additions, and misplacements, particularly with complex or unfamiliar characters, and that interference from alphabetic scripts led to systematic errors in stroke direction and order.

Y. Han & N. Pankitwanitjalearn (2021) observed that Thai university students showed frequent stroke order errors in complex characters, attributing this to the influence of Thai script writing habits. This aligns with the present study's finding that cross-script interference, such as from Cyrillic or other alphabetic systems, shapes the types and frequencies of stroke errors, including horizontal-vertical order reversals. C. Chen & L. Feng (2016) found that Italian beginners struggled with universal stroke order rules, but errors were more pronounced when learners' native scripts differed greatly from Chinese in structure and direction, supporting the idea that L1-L2 script similarity influences error patterns. J. Xing & M. Yang (2021) analysed Korean intermediate learners, noting a tendency to process characters holistically by breaking them into components and radicals. While these learners could analyse structure and integrate form, sound, and meaning, they often made errors like stroke deletion, substitution, and dislocation – especially with visually or phonetically similar characters. The study emphasised the need to consider the relationship between Chinese characters and language when analysing acquisition and errors.

Overall, this study extends prior research by clarifying how cross-script interference from alphabetic systems manifests in stroke order and character structure errors. While stroke sequence errors are common across native and non-native learners, the specific patterns and causes – such as L1 script influence, character similarity, and holistic versus componential processing – underscore the need for tailored instructional approaches. These insights deepen the understanding of the procedural and cognitive aspects of Chinese character acquisition among second language learners.

CONCLUSIONS

This study provided a systematic investigation of stroke order errors in Chinese character writing among five beginning-level Central Asian students, all native Dungan speakers, within a university-level Chinese programme in Gansu. Despite their inherent linguistic closeness to Chinese via their Dungan native tongue, participants demonstrated a significant frequency of stroke order inaccuracies, with an

average error rate of 33.6%. The predominant error category was stroke sequence errors (78.5%), followed by stroke direction errors (19.3%), and instances of stroke reversal (2.2%). The most common sequence errors included horizontal-vertical order reversals and component order misplacements, whereas direction errors frequently involved confusion between *ti* (提) and *pie* (撇) strokes.

These results yield crucial insights into the acquisition of Chinese orthography by this learner demographic. Notably, the anticipated orthographic benefits from Dungan-Chinese phonological and lexical similarities did not materialise in the procedural domain of stroke order. Conversely, the learners' profound familiarity with Cyrillic script – characterised by distinct stroke directionality and sequencing conventions – proved to be a considerable influencing factor, leading to discernible patterns of interference. These patterns were particularly evident in errors related to stroke direction and the ordering of complex or enclosed character components, highlighting the cognitive and motoric hurdles involved in adapting to a fundamentally different writing system. Furthermore, the investigation uncovered substantial individual differences in error rates and patterns, emphasising the importance of personalised instructional strategies. Individuals exhibiting fewer errors generally approached writing with greater deliberation and metacognitive awareness, often pausing for planning prior to execution. This observation implies that cultivating metacognitive strategies and encouraging learners to consciously reflect on stroke order principles may bolster accuracy and aid the internalisation of standard writing conventions.

Theoretically, this research enriches the broader literature on cross-linguistic influence and second language orthographic acquisition. The emergent patterns lend support to a multi-faceted model of language transfer, which differentiates between lexical/phonological knowledge and procedural/motor skills. Although Dungan's phonological congruence with Chinese might facilitate oral comprehension and vocabulary learning, the procedural acumen essential for accurate character composition appears more profoundly influenced by the learners' established literacy experiences in Cyrillic. This emphasises the imperative to account for the intricate interplay of linguistic, cognitive, and motor factors within models of second language writing development.

In terms of methodology, the application of smart pen technology was exceptionally valuable for capturing the dynamic process of character production. The detailed temporal data on stroke sequencing, hesitations, and writing rhythm offered visibility not merely into manifest errors but also into the underlying cognitive processes and self-correction mechanisms learners employed. Such technologically augmented methods present encouraging pathways for future research and pedagogical practices, facilitating

more precise diagnostics of learning challenges and the creation of targeted feedback systems. Pedagogically, these outcomes directly inform Chinese language instruction for Central Asian learners. The study concludes that effective teaching must conscientiously address the interference from Cyrillic script by emphasising comparative analysis of writing systems and providing targeted training on Chinese character-specific rules and structures. Furthermore, the development of metacognitive skills and deliberate practice is pivotal for learners to supersede ingrained Cyrillic habits and assimilate new orthographic procedures.

Prospectively, subsequent research endeavours should explore the longitudinal trajectory of stroke order acquisition among Central Asian learners, assessing whether the identified error patterns diminish with augmented proficiency and exposure. Studies evaluating the effectiveness of targeted instructional strategies – such as explicit contrastive analysis, kinaesthetic training, and real-time digital feedback – would refine best practices in Chinese character pedagogy. Additionally, comparative studies with learners from varied linguistic origins could elucidate the relative impacts of Dungan language background versus Cyrillic literacy on character learning achievements. Ultimately, with the intensification of China's educational and economic ties with Central Asian nations, particularly through initiatives like the Belt and Road, the imperative for culturally attuned and linguistically sensitive Chinese language pedagogy grows more pressing. This research offers empirically substantiated perspectives for educators, curriculum developers, and policymakers alike, underscoring the necessity of customised instructional methods that cater to the specific difficulties encountered by these learners in mastering Chinese orthography. Through enhancing comprehension of cross-linguistic and cross-script dynamics, this work establishes a foundation for more efficacious and inclusive Chinese language education within an ever-more interconnected global landscape.

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■ CONFLICT OF INTEREST

None.

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Борбор Азиялык башталгыч студенттердин кытай иероглифтеринин черталар тартибиндеги каталарын акылдуу калем технологиясы менен талдоо

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Аннотация. Кытай орфографиясын өздөштүрүү дүйнөлүк билим берүүдө барган сайын маанилүү болуп баратат, бирок логографикалык эмес тилдик чөйрөдөн келген окуучулар туруктуу жана өзгөчө кыйынчылыктарга туш болушат. Борбор Азиялык студенттердин өзгөчө кыйынчылыктарын изилдөө максаттуу окутуу стратегияларын иштеп чыгуу үчүн маанилүү. Бул изилдөө Кыргызстан жана Өзбекстандан келген, дунган тилинде сүйлөгөн жана орус тилин эркин билген беш башталгыч деңгээлдеги студенттин кытай иероглифтерин жазуудагы черталар тартибиндеги каталардын процедуралык кыйынчылыктарын жана когнитивдик факторлорун аныктоого багытталган. Жазуу процессин жазып алуу жана талдоо үчүн акылдуу калем технологиясын колдонуп, изилдөөнүн авторлору окуу китебиндеги көчүрүү көнүгүүлөрү учурунда черталар тартибиндеги каталар боюнча маалыматтарды чогулткан. 1800 иероглиф боюнча 605 ката учурунун анализи ар бир студент үчүн катасы бар иероглифтердин орточо ката деңгээли 33,6 % экенин көрсөттү. Эң көп кездешкен ката түрлөрү: черталардын ырааттуулугу боюнча каталар (78,5 %), черталардын багыты боюнча каталар (19,3 %) жана черталардын инверсиясы феномени (2,2 %). Ырааттуулук каталарынын ичинен горизонталдык-вертикалдык тартиптин инверсиясы (31,4 %) жана компоненттердин тартибинин инверсиясы (28,6 %) көп кездешсе, багыт каталарынын арасында “ти” (提) жана “пье” (撇) черталарынын аралашып кетиши (52,1 %) басымдуу болгон. Жыйынтыктар дунган тилинин фонологиялык артыкчылыктары болгону менен, бул тил черталар тартибин туура аткарууга өбөлгө түзбөй турганын, бул процесс кириллица/орус жазуусунун адаттарынан олуттуу таасирленерин көрсөттү. Бул изилдөө Борбор Азиялык окуучулар туш болгон өзгөчө процедуралык тоскоолдуктарды түшүнүүнү тереңдетип, кытай иероглифтерин окутуунун натыйжалуулугун жогорулатуу үчүн далилдерге негизделген чараларды сунуштайт.

Негизги сөздөр: кытай иероглифтерин өздөштүрүү; черталар ырааттуулугу; дунган тили; каталарды талдоо; акылдуу калем технологиясы; кириллицанын таасири

Анализ ошибок порядка начертания китайских иероглифов у начинающих студентов из Центральной Азии с использованием технологии умной ручки

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Аннотация. Овладение китайской орфографией приобретает все большее значение в глобальном образовании, однако учащиеся из нелогографических языковых сред сталкиваются со специфическими трудностями. Изучение конкретных проблем, с которыми сталкиваются студенты из Центральной Азии, имеет ключевое значение для разработки целенаправленных стратегий обучения. Настоящее исследование было направлено на выявление процедурных трудностей и когнитивных факторов, лежащих в основе ошибок в порядке черт при написании китайских иероглифов у пяти студентов начального уровня из Кыргызстана и Узбекистана, являющихся носителями дунганского языка и свободно владеющих русским. Используя технологию умной ручки для записи и анализа процесса письма, автор исследования собрал данные об ошибках в порядке черт во время выполнения упражнений по копированию из учебника. Анализ 605 случаев ошибок в 1800 иероглифах показал среднюю частоту ошибок 33,6 % на одного студента для иероглифов, содержащих ошибки. Наиболее распространенными типами ошибок были ошибки в последовательности черт (78,5 %), ошибки в направлении черт (19,3 %) и феномен инверсии черт (2,2 %). Среди ошибок последовательности чаще всего встречались инверсия порядка горизонтальных и вертикальных черт (31,4 %) и инверсия порядка компонентов (28,6 %), в то время как среди ошибок направления преобладала путаница между чертами «ти» (提) и «пье» (撇) (52,1 %). Результаты показали, что, несмотря на определенные фонологические преимущества дунганского языка, он не способствует правильному выполнению порядка черт, который значительно зависит от привычек, сформированных кириллическим/русским письмом. Исследование углубляет понимание специфических процедурных барьеров, с которыми сталкиваются учащиеся из Центральной Азии, и предлагает научно обоснованные меры для более эффективного обучения написанию китайских иероглифов.

Ключевые слова: освоение китайских иероглифов; последовательность черт; дунганский язык; анализ ошибок; технология умной ручки; влияние кириллицы