Flow Experience in Foreign Language Digital Reading: An Eye-Tracking Approach—A Critical Analysis and Future Directions

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Abstract： As the foreign language acquisition era unfolds, learners’ flow during English learning has drawn increasing attention—a core construct that reflects optimal cognitive engagement and efficient processing in second language (L2) digital reading. Yet prior research on flow suffers from three key limitations: an overreliance on subjective self-reports, a lack of sufficient objective behavioral evidence, and inadequate validation in controlled L2 digital reading environments. To overcome these gaps, Teng and Zhang (2025) employed a mixed-methods approach, combining eye-tracking technology with psychological scales, to examine the flow experiences of Chinese college students engaged in L2 digital reading. Specifically, their study centered on three fundamental questions: what subjective perceptual and objective behavioral features define flow, which factors influence it, and how it relates to reading performance.This research advances flow measurement by developing a dual-dimensional framework that integrates subjective scales and objective eye-movement indicators. Empirically, it confirms the applicability of the “challenge-skill balance” principle (Fong et al., 2015) in L2 digital reading contexts, identifies language proficiency, perceived text difficulty, and interest as key predictors of flow, and uncovers unique eye-movement patterns associated with flow states. Building on these empirical findings, the present paper critically evaluates the contextual appropriateness and methodological rigor of Teng and Zhang’s (2025) study, clarifies its theoretical and empirical contributions to both L2 digital reading and flow research, and proposes context-specific, methodologically sound directions for future research—all aimed at enhancing the reliability, validity, and generalizability of flow studies in this domain.

Keywords: second language acquisition; flow; foreign language digital reading; eye-tracking

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1 Outline

1.1 Research Questions

Teng and Zhang (2025) formulated three core research questions to address the gaps in existing flow research in foreign language digital reading:

(1)What are the subjective perceptual and behavioral characteristics of learners’ flow experience during foreign language digital reading?

(2)How do learners’ individual factors (e.g., foreign language proficiency, reading interest, perceived text difficulty) influence flow experience?

(3) Is there an association between flow experience (encompassing subjective perceptual and objective behavioral dimensions) and reading performance (including accuracy, speed, and efficiency)?

1.2 Methodology

This study employed a quantitative-dominant mixed-methods design, with methodological rigor and innovations that address key gaps in prior flow research in foreign language digital reading.

The sample included 66 first-year non-English major undergraduates from a top Chinese university (32 females, 34 males; average age = 18). Their English proficiency, measured by college entrance exam scores ($M = 134.77$, $SD = 8.02$), matched the CEFR B2 level—an intermediate stage important for studying flow in foreign language reading (Huang et al., 2017). All participants had normal or corrected-to-normal vision. This control step, often missing in earlier studies (e.g., Kirchhoff, 2013; Zare-ee, 2013), improves the reliability of behavioral data.

The reading material was a 355-word brain-themed passage from past CET-4 exams, split into 8 paragraphs with 5 multiple-choice comprehension questions. Using this standardized text fixed a problem in prior research: unregulated texts with inconsistent difficulty (Gao et al., 2022). It ensured the task challenge was consistent for all participants and matched their B2 proficiency (Cho, 2018).

An Eyelink 1000Plus desktop eye-tracker (1000Hz sampling rate) recorded four key eye movement indicators: average fixation duration, average saccade amplitude, average gaze duration, and average regression path reading time. This tool is a major improvement. Earlier foreign language reading flow studies mostly used self-reported scales (e.g., Thissen et al., 2018’s RFSS) or retrospective interviews (Xu & Zhao, 2024), which have memory bias and cannot capture real-time behavior.

For psychological measurements: Adapted Reading Flow Short Scale (RFSS) with 9 items (Cronbach’s $\alpha = 0.74$) measuring two factors (absorption and smooth processing); a 3-item text perception questionnaire (7-point Likert scale) assessing familiarity, perceived difficulty, and reading interest; and college entrance examination English scores as an indicator of foreign language proficiency.

Data were collected in individual 35-minute sessions following a standard process: eye-tracker calibration (average error $<0.5°$) for precision, a practice reading phase to help participants adapt to digital reading and equipment, formal self-paced digital reading (controlled by space bar), completion of comprehension questions, and filling out the text perception questionnaire and adapted RFSS.

SPSS 22.0 was used for descriptive statistics (to characterize variables), Pearson correlation analysis (to explore relationships between variables), and multiple regression analysis (to identify predictors of flow and reading performance). Reading performance was operationalized as accuracy, speed (words per minute), and efficiency (accuracy × speed).

1.3 Findings

The study yielded four key findings: learners' overall subjective flow level was low (M=4.40 on a 7-point scale), with only 24.2% (n=16) entering a flow state (scale score ≥ 5). Flow-state learners exhibited distinct eye movement patterns: longer saccade amplitude (M = 3.92 vs. 3.70 for non-flow learners) and shorter regression path reading time (M = 745.83 ms vs. 852.92 ms for non-flow learners), indicating more fluent information processing. A significant positive correlation was found between smooth processing (subjective scale) and average saccade amplitude ($r = 0.25$, $p < 0.05$). While other correlations between subjective flow factors and eye-tracking indicators were weak ($r < 0.2$), they aligned with Cohen's (1988) criterion for small effect sizes, suggesting an interplay between perceptual and behavioral dimensions of flow.

Multiple regression analysis showed that foreign language proficiency ($\beta = 0.34$, $p = 0.003$), perceived text difficulty ($\beta = -0.31$, $p = 0.009$), and reading interest ($\beta = 0.28$, $p = 0.013$) were significant predictors of subjective flow experience, collectively explaining 26% of its variance ($F = 8.74$, $p < 0.001$). No significant correlations were found between individual factors and eye-tracking indicators. Subjective flow indicators showed no significant correlations with reading performance, except for a small positive correlation between smooth processing and reading accuracy ($r = 0.14$). In contrast, eye-tracking indicators (average fixation duration, average gaze duration, average regression path reading time) were significantly negatively correlated with reading speed and efficiency. Average gaze duration nearly significantly predicted reading efficiency ($\beta = -0.35$, $p = 0.059$), explaining 17% of its variance ($F = 5.28$, $p = 0.003$).

1.4 Implications

This study advances flow theory in second language acquisition by establishing a dual-dimensional measurement framework that integrates subjective psychological scales and objective eye-tracking indicators, thereby overcoming the long-standing limitation of over-reliance on single-dimensional self-report measures in prior flow research. It further validates the cross-contextual generalizability of the challenge-skill balance principle (Fong et al., 2015) within foreign language digital reading, confirming that language proficiency (skill), perceived text difficulty (challenge), and reading interest (motivation) collectively shape learners' flow experience. In addition, the findings enrich the cognitive processing theory of second language reading (Reichle et al., 2006), revealing that objective eye-tracking metrics are more sensitive to real-time cognitive dynamics than subjective self-perceptions in digital reading environments.

For foreign language digital reading instruction, the study recommends: (1) Matching text difficulty to learners' proficiency (e.g., CET-4 level texts for B2 learners) to maintain challenge-skill balance; (2) Enhancing reading interest through topic relevance to promote flow; (3) Using eye-tracking-derived insights (e.g., reducing regression frequency) to design targeted training for fluent reading; (4) Simplifying eye-tracking technology for classroom use (e.g., mobile-based tools) to enable personalized feedback.

2 Evaluation

2.1 Context Evaluation

This study addresses a critical contextual void in flow research within foreign language reading. Existing literature has predominantly centered on paper-based reading environments (Noorbakhsh et al., 2018; Zare-ee, 2013) or unstructured informal digital reading (Gao et al., 2022), while neglecting controlled formal digital reading settings—the prevailing instructional modality in contemporary foreign language education (Ma, 2024). By investigating flow experience among Chinese university learners during English digital reading, the study responds to the call for context-sensitive flow inquiry, given that cultural and educational factors (e.g., examination-oriented learning) may yield distinct flow patterns compared with Western educational contexts (Egbert, 2003; Kirchhoff, 2013). Nevertheless, the generalizability of its findings is constrained by a homogeneous sample limited to high-proficiency (CEFR B2) students from a single elite university. Consequently, the conclusions may not apply to heterogeneous learner populations (e.g., vocational college students, adult learners) or other foreign language learning contexts (e.g., Chinese as a second language, other less commonly taught languages).

2.2 Methodological Evaluation

The study's methodology represents a significant advancement by integrating eye-tracking technology with psychological scales, addressing key limitations of previous flow research in foreign language education: Traditional flow research in foreign language reading relied heavily on self-reported scales (e.g., RFSS; Thissen et al., 2018) or retrospective interviews (Kirchhoff, 2013; Zare-ee, 2013), which are prone to memory bias and unable to capture real-time flow dynamics (Xu & Zhao, 2024). By incorporating eye-tracking technology—a tool validated in reading cognitive research (Yan et al., 2013)—the study provides objective behavioral evidence of flow, complementing subjective perceptions. This dual-dimensional approach aligns with Barthelmäs and Keller's (2021) call for integrating perceptual and behavioral indicators to capture flow's multidimensional nature, a gap identified in Xu and Zhao's (2024) review of foreign language learner flow research.

The use of a standardized CET-4 passage (consistent difficulty, unfamiliar to participants) and controlled experimental conditions (fixed eye-screen distance, head stabilization via chin rest) minimizes confounding variables, enhancing internal validity. This addresses the criticism that previous digital reading studies lacked control over text characteristics and environmental distractions (Sweller, 1994). The adoption of college entrance examination scores as a proficiency measure (rather than self-report) also ensures objective assessment of learners' skill levels, consistent with Huang et al.'s (2017) emphasis on valid proficiency measurement in flow research.

Furthermore, the combination of correlation analysis (reporting effect sizes alongside p-values) and multiple regression (controlling for

multicollinearity, VIF < 10) adheres to rigorous quantitative research standards (Cohen, 1988; Kline, 2010). The introduction of "reading efficiency" (accuracy × speed) as a comprehensive performance indicator also advances previous research, which often relied on single metrics (e.g., accuracy alone; Noorbakhsh et al., 2018) or speed alone (Gao et al., 2022).

However, the methodology has limitations supported by literature. With only 66 participants (16 in the flow group), the study lacks statistical power for reliable group comparisons (e.g., t-tests between flow and non-flow groups), as noted by Kline (2010) who recommends a minimum of 30 participants per group for group-level analyses. This contrasts with larger-scale flow studies (e.g., Liu & Song, 2021, n = 203; Wang & Huang, 2022, n = 358), which enhance result generalizability.

As for flow Measurement, the adapted RFSS scale only measures cognitive dimensions (absorption, smooth processing), omitting emotional (pleasure) and motivational (intrinsic drive) dimensions of flow—core components of Csikszentmihalyi's (1990) original theory and Nakamura and Csikszentmihalyi's (2002) conceptualization. This aligns with Xu and Zhao's (2024) critique that many foreign language flow studies narrow flow's multidimensional nature, reducing construct validity. The study does not include a paper-based reading control group, preventing comparisons between digital and paper-based flow experiences—a key research gap identified by Gao et al. (2022) and Zare-ee (2013). Without this comparison, it is difficult to determine whether the low flow rate (24.2%) is inherent to digital reading or specific to the experimental context.

Compared to earlier studies, this methodology has three key contributions: firstly, combining the adapted RFSS (subjective) with eye-tracking (objective) solves the limitations of single-dimensional measurement (Xu & Zhao, 2024). It aligns with Barthelmäs and Keller's (2021) call for multidimensional flow assessment; Standardized text difficulty, controlled testing conditions, and objective proficiency measurement fix the lack of rigor in earlier digital reading flow research (Sweller, 1994; Kirchhoff et al., 2024); The three-part reading performance indicator captures detailed effects of flow on reading, overcoming the oversimplification of outcomes in prior studies (Zare-ee, 2013; Gao et al., 2022).

3 Directions for Future Relevant Research

To address the limitations identified in Teng and Zhang's (2025) study and further enhance the reliability, validity, and generalizability of flow inquiry in foreign language digital reading, future research is recommended to pursue the following interrelated directions:

3.1 Expand Sample and Context Diversity

Teng and Zhang's sample was homogeneous—only students from a top university with CEFR B2 proficiency. This limits how widely the findings can be applied. Flow experiences may differ across proficiency levels (A2, C1, C2), educational settings (vocational colleges, adult education), and target languages (e.g., Chinese as a second language, Japanese).

Future studies should recruit a large, diverse sample (at least 200 participants) from different schools, proficiency levels, and age groups. They should also compare flow across languages (e.g., English vs. Chinese L2 digital reading) to see if language-specific cognitive demands (e.g., logographic vs. alphabetic writing) shape flow patterns. This follows Jia et al.'s (2024) suggestion to include diverse learners in flow research.

3.2 Adopt Longitudinal and Mixed-Methods Designs

Teng and Zhang's cross-sectional design cannot show cause and effect (e.g., does better flow lead to better reading performance, or vice versa?). It also fails to capture how flow changes over time. Qualitative data can explain learners' personal experiences of flow in digital reading, which quantitative data alone cannot.

Future studies should use a longitudinal design (1-2 semesters) to track changes in learners' flow, proficiency, and reading performance. Cross-lagged panel models can test causal links (Jia et al., 2024). They should also add semi-structured interviews (e.g., "What helps you focus deeply during digital reading?") and learning diaries to explore factors not captured by scales or eye-tracking. This mixed-methods approach, recommended by Xu and Zhao (2024), makes flow research deeper and richer.

3.3 Improve Flow Measurement Tools

Teng and Zhang's scale only measured cognitive aspects of flow (attention, smooth processing). It missed emotional (pleasure) and motivational (intrinsic drive) dimensions. Self-reported scales also have memory bias, making it hard to capture flow accurately.

Future studies should develop a comprehensive flow scale for foreign language digital reading. It should include cognitive, emotional, and motivational dimensions, building on Wang and Huang's (2022) blended learning scale and Nakamura and Csikszentmihalyi's (2002) definition of flow. They should combine eye-tracking with other physiological measures (e.g., EEG for brain activity, skin conductance for emotional arousal) to capture real-time flow. Lee and Stoodley (2024) note EEG can measure attention and relaxation—key parts of flow—for a more complete objective assessment. Using the Experience Sampling Method (ESM) to collect real-time subjective data (e.g., random phone surveys during reading) can avoid memory bias, as Xu and Zhao (2024) suggest.

3.4 Explore Multi-modal Digital Reading and Interactive Contexts

Teng and Zhang's study employed static, text-only digital materials, whereas authentic digital reading typically involves multi-modal inputs (text, images, audio) and interactive functions (annotations, hyperlinks, adjustable difficulty). These features shape cognitive load and learner control, both of which are central to flow (Csikszentmihalyi, 1990; Sweller, 1994; Ma, 2024).

Future research should compare flow experience across diverse multi-modal configurations (text-only, text + image, text + audio) to identify optimal design principles for flow induction. Empirical inquiry into how interactivity (e.g., learner control over difficulty, annotation tools) influences flow is urgently needed, addressing the understudied role of digital interactivity in flow research (Kirchhoff et al., 2024).

3.5 Conduct Contextualized and Comparative Studies

Teng and Zhang's laboratory setting may have reduced flow—eye-tracker calibration and head stabilization can increase cognitive load (Sweller, 1994). Natural settings (e.g., classroom digital reading, mobile reading) and comparisons between laboratory and natural contexts are needed to see how environment shapes flow.

Future studies should run naturalistic experiments in real-world digital reading environments (e.g., mobile apps) to collect more realistic data. Comparing flow between laboratory and natural contexts can show if the low flow rate in Teng and Zhang's study was due to the lab setting. Additionally, cross-cultural comparisons can explore if educational and cultural factors (e.g., exam pressure, learning beliefs) affect flow.

3.6 Use Advanced Statistical and Analytical Methods

Standard multiple regression as used by Teng and Zhang is limited in testing complex theoretical relationships, such as mediation and moderation, which are essential to unpacking the mechanisms linking flow to reading outcomes.

Future research should adopt structural equation modeling (SEM) to test hypothesized mediation paths (e.g., whether cognitive fluency mediates the flow–performance link) and moderation effects (e.g., whether digital reading experience moderates the effect of text difficulty on flow; Kline, 2010). In addition, machine-learning approaches (e.g., random forests) can be used to mine high-dimensional data (eye-tracking, self-reports, behavioral logs) and identify key, non-linear predictors of flow, enabling more robust, data-driven insights (Ma, 2024).

4 Conclusion

Teng and Zhang's (2025) study contributes meaningfully to flow research in foreign language digital reading. By combining eye-tracking and psychological scales, it identifies key factors leading to flow, their related behaviors, and builds a two-part measurement framework that fixes prior over-reliance on subjective reports. Based on flow theory and L2 reading cognition, it confirms the "challenge-skill balance" principle in digital reading and offers insights into real-time L2 reading cognition.

However, confined to its limited dimension of unrepresentative samples, incomplete flow measurement, and a lab-based design lacking real-world relevance, this study has left room for relevant studies from other flow experience, i.e., expand learner or context diversity, improve flow measurement tools, use long-term and mixed methods, and study flow in real digital settings. This will enhance flow research reliability and provide practical guidance for digital foreign language teaching.

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