

The Impact of Time-Space-Interest Factors, Renewal Intention, and Their Interaction on College Readers' Reading Behavior

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Abstract

This study explores how Time-Space-Interest (TSI) factors, renewal intention, and their interaction affect college reader's reading behavior, using Nanjing Normal University Library borrowing data (2016–2024). Covering undergraduates, postgraduates, faculty across 2016–2018, 2019–2021, 2022–2024, the dataset includes 78,947 borrowers and 1,633,673 borrowed volumes. Using PCA and Moderated Regression Analysis, the study extracts four types of factors: TSI, space-interest (SI), space (S), and interest (I), examining renewal as a moderator between TSI and borrowing volume, with logarithmic transformation handling extreme values. Key findings show TSI is a core positive driver of borrowing volume, with higher eigenvalues indicating greater impact. Renewal intention directly boosts borrowing volume but acts as an inhibitory moderator, making its interaction with TSI critical. Gender's with relevance varies by context. These insights guide decision-makers in strategy formulation to enhance reading behavior interventions.

Keywords: Time-Space-Interest (TSI) factor, Renewal Intention, PCA, Moderated Regression Analysis, Reading Behavior.

1. Introduction

Reading behaviors have evolved dynamically across human history, shaped by technological, generational, and societal shifts. From the elite, repetitive reading practices of ancient times to the popularization of reading following the printing press, and most recently, the decline in traditional reading interest amid easy access to compressed digital information, these changes underscore the long-term influence of technological development stages on how people engage with texts (Donskova & Kurilova, 2023). Time, in particular, acts as a critical mediator: adolescents' reading motivation declines with age, while their preferences for content and promotion methods evolve, reflecting how temporal patterns shape habits (Webber et al., 2025). Even literary interpretations shift over time—for example, translations of works like *Carmilla* adapt to changing societal values, altering readers' engagement with queer and horror elements and potentially influencing their renewal intention (Episkopou, 2024).

Spatial contexts, both physical and virtual, further mold reading behaviors. Urban layouts, for instance, shape how readers navigate and interpret historical cities, with well-connected spaces enhancing accessibility and legibility—paralleling how college libraries or digital platforms structure readers' focus and renewal intention (Leal E Silva & de Medeiros, 2019). Spaces infused with cultural meaning, such as “sacred” urban landscapes (Korshunova, 2020), deepen emotional connections to content, much like themed reading environments (e.g., heritage-focused spaces) boost engagement. Dedicated spaces like reading rooms and special interest clubs in urban housing estates foster collective reading practices, enhancing interaction with texts and peers and promoting renewal intention (Matysek-Imielińska, 2020).

Interest, as a driving force, intersects with both time and space to shape reading focus and behavior. Individuals' ideological tendencies, for example, influence their reading priorities: under feminist influences, men's engagement with gender-related topics in academia and daily life shifts, reflecting how interests mold post-reading behavior (Bizzaro, 2005). In library design, this interplay is tangible: aesthetically pleasing, themed spaces (space) arouse interest, while time-based material rotation (time) maintains novelty (Chang & Wang, 2016). For college readers, this translates to libraries updating displays (e.g., new psychology arrivals) in visually appealing zones, where interest in fresh content and spatial comfort together increase renewal intention.

The temporal, spatial, and interest-based attributes of readers' book borrowing behaviors constitute core dimensions for analyzing user behavior, with their interconnections providing a foundation for optimizing library services. Temporal attributes embody patterns in borrowing activities across time periods (intraday peaks, weekly/monthly/quarterly distributions), cycles (semester/holiday regularities), and special time nodes (examination periods, public holidays, social hotspots), reflecting readers' time usage habits and the timeliness of their needs. Research into such attributes can offer precise guidance for libraries to dynamically adjust their opening strategies. Spatial attributes encompass borrowing locations (branch libraries, online vs. offline channels), spatial mobility (cross-regional borrowing), and disparities in collection zoning, these attributes reveal the correlation between space and demand. Studies in this area can facilitate the efficient allocation of spatial resources in libraries and the rational expansion of service coverage. Interest attributes center on content preferences, these include themes (academic disciplines, trending fields), genres (novels, reference books, etc.), and personalized tags (e.g., “science fiction enthusiasts”, “postgraduate exam candidates”), which evolve dynamically in

response to group characteristics and social trends. Exploration of these attributes can provide clear orientations for the update of collection resources and the delivery of targeted services.

Book renewal intention refers to a borrower's premeditated psychological inclination or behavioral predisposition to initiate a formal request for extending the loan period of a borrowed library book, typically formed in anticipation of unmet usage needs (e.g., incomplete reading, ongoing research requirements) prior to the original due date. Book renewal intention holds significant research value as it helps libraries predict user demand persistence and optimize loan period management strategies.

Given the aforementioned research significance of investigating Time-Space-Interest Factors, their relationship with Renewal Intention, and the interaction mechanisms underlying these dynamics. To address this, the following research questions are proposed:

Q1: Compared with single - dimensional spatial or interest factors, what are the essential differences in the influence paths of TSI factors on lending volume?

Q2: How does the Time - Space - Interest (TSI) factor specifically exert its positive effect on the total number of books borrowed to become the core driving factor?

Q3: How does the interaction between the TSI factor and Renewal Intention affect the total number of books borrowed comprehensively?

Q4: In different user groups (Undergraduate Students, Graduate Students, and Faculty & Staff), how does the impact of the TSI factor on lending volume vary?

Q5: Why do the eigenvalues of frequently occurring SI factors have a relatively weaker impact on lending volume compared to TSI factors?

This study provides data-driven insights for university libraries to optimize resource allocation and service strategies. By clarifying how time patterns (e.g., seasonal borrowing trends), spatial factors (e.g., collection location accessibility), and readers' interest orientations (e.g., preferences for book categories) influence borrowing behavior—along with the moderating role of renewal intention—the study helps libraries adjust collection layouts, tailor book acquisitions to reader groups (Undergraduate Students, Graduate Students, and Faculty & Staff), and design targeted loan policies (e.g., flexible renewal terms) to enhance resource utilization efficiency. It

deepens understanding of heterogeneous reading behaviors across different reader types. The analysis of varying borrowing patterns among undergraduates, graduates, and faculty/staff over time (2016–2024) reveals evolving needs and constraints, enabling institutions to develop personalized reading promotion initiatives. For instance, interventions could address declining borrowing volumes by aligning services with specific groups' time availability, spatial preferences, or interest shifts. It offers theoretical and empirical support for refining library management systems. By quantifying how renewal intention moderates the effects of time-space-interest factors, the research highlights the importance of dynamic service adjustments—such as streamlining renewal processes or integrating digital resources to complement physical collections—thereby improving user satisfaction and sustaining engagement with library services amid changing reading habits (e.g., digital shift). The findings contribute to fostering a more reader-centric academic environment, where libraries can better support teaching, research, and lifelong learning by adapting to the complex interplay of factors shaping reading behavior.

This study's innovations lie in four aspects: integrating multi-dimensional factors via Principal Component Analysis (PCA) to extract common factors from variables like month, collection location, and major book categories, clarifying eigenvalues of time, space, interest, and their mixed factors to break single-factor analysis limitations; introducing renewal behavior as a moderator in moderated regression analysis, which reveals heterogeneity in TSI core factors' impact on borrowing volume by altering the relationship strength or direction rather than directly studying its own impact; quantifying the moderating effect through interaction terms between TSI factors and renewal behavior, refining the influence mechanism of borrowing volume to make conclusions more targeted; and log-transforming total borrowing volume to optimize the regression model, mitigating extreme value effects, approximating normal distribution for better model stability, and enabling coefficients to reflect relative change rates of borrowing volume.

2. Data and Methods

2.1 Research Sample

The research sample encompasses data on library borrowing behavior across three reader types (Undergraduate Students, Graduate Students, and Faculty & Staff) over three consecutive periods: 2016–2018, 2019–2021, and 2022–2024 in Nanjing Normal University (NNU) (see Table 1).

Table 1. Distribution by Reader Type.

Reader Type	Period	Borrowers	Book Volume
Undergraduate	2016-2018	18647	445673
	2019-2021	13631	198133
	2022-2024	10333	123128
Graduate	2016-2018	13350	402256
	2019-2021	11875	247967
	2022-2024	9833	157205
Faculty & Staff	2016-2018	1077	46984
	2019-2021	970	31209
	2022-2024	684	23011

Undergraduate students constitute the largest cohort of library users, followed by graduate students as the second-largest group, with faculty and staff representing the smallest user segment—their numbers being notably lower than those of the student populations. A consistent downward trajectory in user engagement is evident across all three groups. The sample data reveals a distinct shift in library usage patterns, characterized by a gradual decline in engagement across all user categories over the observed periods. This trend is particularly pronounced among undergraduates, manifesting in both the scale of users and the intensity of resource utilization. In contrast, faculty and staff, despite their smaller user base, maintain the highest level of per capita borrowing intensity throughout the timeframe.

2.2 Research Design

The temporal characteristics of book borrowing primarily pertain to monthly patterns. Specifically, the monthly average characteristics of book lending behavior denote the regularized patterns and statistical propensities that emerge from lending data when aggregated and averaged across monthly cycles.

The spatial characteristics of book borrowing denote the space-related regularities in readers' borrowing behaviors, encompassing both behavioral distribution within libraries' physical space (e.g., reading rooms) and the correlation between readers' origins and borrowing demands (cross-district readers show low borrowing frequency).

The interest characteristic in borrowing books refers to the regularity of readers' preferences for books in different fields, mainly reflected in the differences and distribution of borrowing volumes of various books identified by the Chinese Library Classification (CLC) numbers, such as high borrowing volumes in categories like "Literature" (Class I), "History and Geography" (Class K), "Natural Science" (Class N), and "Applied Technology" (Class T).

Taking readers' registration numbers as record identifiers, researcher collated the borrowing volume for each month, each lending room, each category of books, and the total borrowing volume respectively. These data formed the basis of the factor analysis table. Figure 1 illustrates the main steps of the research.

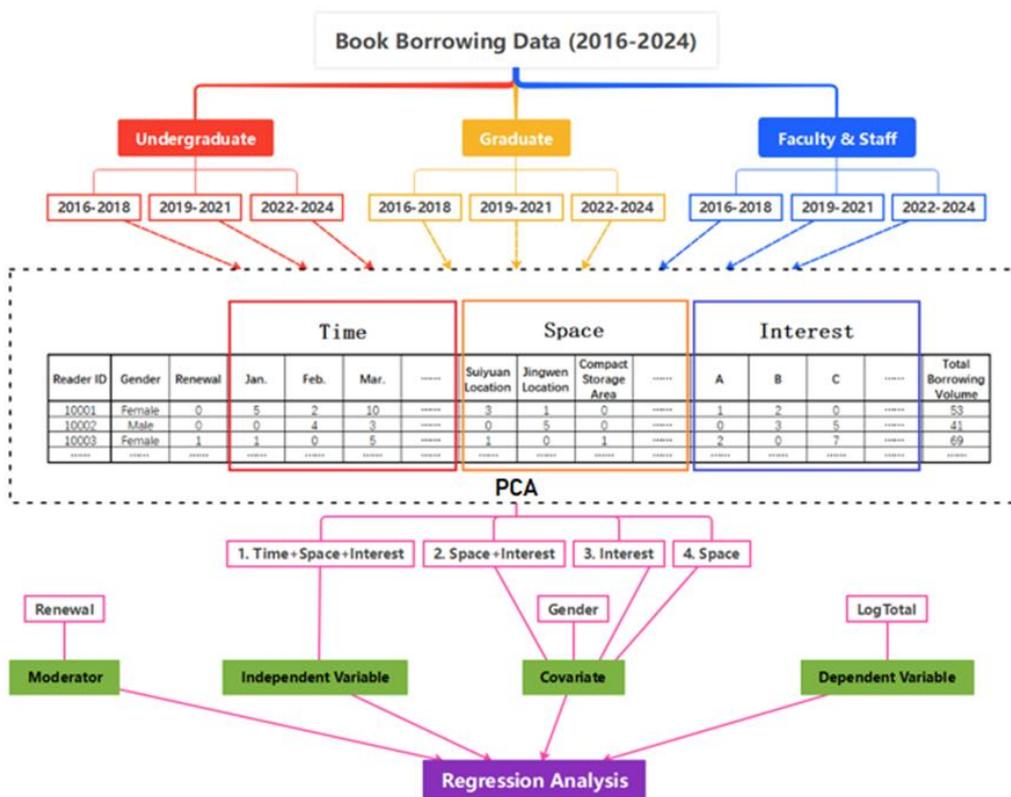


Figure 1. Research design

2.2.1 Principal Component Analysis (PCA)

The purpose of extracting common factors of readers' book borrowing behavior from variables such as month, collection location, and major book categories is to clarify the eigenvalue sizes of time, space, interest, and their mixed factors, and to explore the influence mechanism of these factors on readers' borrowing volume through moderated regression analysis that incorporates renewal as a moderator. The factor rotation method adopted is the maximum variance method, with items retaining those with factor loadings greater than 0.5.

2.2.2 Moderated Regression Analysis

In moderated regression analysis, the significance of renewal (i.e., book renewal behavior) as a moderator lies in that it does not directly affect readers' borrowing volume. Instead, it reveals the heterogeneity in the impact of these core factors (time, space, interest, and their mixed factors) on borrowing volume by altering the strength or direction of the relationship between the aforementioned core factors and borrowing volume. Examining whether renewal behavior constitutes a boundary condition for the impact of core factors on borrowing volume. For instance, whether the influence of Time-Space-Interest factors on borrowing volume is more significant among reader groups with

high renewal rates, or whether the effect of spatial factors (such as collection locations) is weakened due to the existence of renewal behavior. Quantifying the magnitude and significance of the moderating effect of renewal behavior in the aforementioned impact relationships by introducing interaction terms between TSI factors and renewal behavior, thereby revealing the influencing mechanism of borrowing volume in a more refined manner. The analytical tool employed is the MATRIX procedure within the PROCESS Procedure for SPSS Version 4.1.

2.2.3 Log-transforming Readers' Total Borrowing Volume and Using It as the Dependent Variable in Regression Analysis

Total borrowing volume typically exhibits a right-skewed distribution (i.e., most readers have low borrowing volumes, while a small number have extremely high ones), which may violate the regression model assumption that the dependent variable should approximate a normal distribution. Log transformation can mitigate the influence of extreme values, making the data distribution closer to normal and thereby enhancing the stability and accuracy of model estimation. Log transformation effectively reduces variance discrepancies, satisfying the homoscedasticity assumption. After log transformation, regression coefficients can be interpreted as the relative change ratio of the dependent variable (borrowing volume) per unit change in the independent variable (i.e., elasticity), rather than absolute changes. Total borrowing volume contains extreme high values (e.g., a small number of readers borrowing excessively), which can unduly influence regression results. The monotonicity of the logarithmic function

and its ability to compress large values can reduce the distortion of model parameter estimation caused by extreme values while preserving data trends.

3. Result

3.1 The Types of Extracted Factors

Factor analysis reveals a total of four composite factors (see Table 2):

Time - Space - Interest (TSI) factor: It integrates three dimensions, namely time, space, and readers' interests. Among the data of different types of readers in various time periods, it always has the largest eigenvalue. This comprehensive dimension exerts a prominent influence in the structure, and the pattern of its influence on reading behavior modes is relatively stable.

Space - Interest (SI) factor: It focuses on two dimensions, space and readers' interests. The description of "the most common" indicates that when analyzing the association between readers' reading behaviors, space-interest is an influence factor with a high occurrence frequency and is relatively typical

Space factor (S): It solely centers on the space dimension. Among the data of different types of readers in various time periods, the values of this factor are mostly 0, which shows that the independent influence of the pure space dimension on readers' reading behaviors is relatively weak.

Interest factor (I): Except for being identified in the 2016 - 2018 period for faculty and staff, its values are mostly 0 in other cases. This indicates that the independent influence of the interest factor on reading behaviors is limited and it often needs to rely on the joint action of dimensions such as space and time.

Table 2: The Types of Extracted Factors.

Reader Type	Period	Time-Space-Interest	Space-Interest	Space	Interest
Undergraduate	2016-2018	1	5	0	0
	2019-2021	1	3	0	0
	2022-2024	1	7	0	0
Graduate	2016-2018	1	7	1	0
	2019-2021	1	5	0	0
	2022-2024	1	3	0	0
Faculty & Staff	2016-2018	2	2	0	1
	2019-2021	2	3	0	0
	2022-2024	1	4	0	0

3.2 The Impact of the Moderating Effect on Borrowing Volume

3.2.1 Undergraduate Student

All the TSI factors are F1 with the largest eigenvalues. The models for all three periods passed the significance test (p = 0.0000), with an overall good fitting effect. The sample size of the Undergraduate Model shows a decreasing trend over time,

with model fitting first declining and then stabilizing. During 2016–2018, students' behaviors were more readily explainable by the model (e.g., stable reading habits). R-sq (Coefficient of Determination) peaked at 0.652 during 2016 - 2018, which means the model accounted for 65.2% of the variance in the dependent variable LogTotal. It declined slightly to 0.593 in 2019–2021 and then showed a marginal rebound to 0.604 in

2022–2024. Across these three periods, the model exhibited relatively strong explanatory power for the dependent variable. The Mean Squared Error (MSE) was smallest in the period

2022–2024, at 0.113, indicating that the model's prediction error was relatively low during this timeframe. In contrast, the MSE stood at 0.121 for both the 2016–2018 and 2019–2021 periods.

Table 3: Coefficient of Undergraduate Student Model (2016–2018).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	0.818	0.011	71.712	0.000	0.796	0.841
Z-score F1 (TSI)	0.595	0.005	130.767	0.000	0.586	0.604
Renewal	0.356	0.007	53.746	0.000	0.343	0.369
Int_1	-0.372	0.006	-65.081	0.000	-0.383	-0.361
Z-score F2 (SI)	0.066	0.003	25.717	0.000	0.061	0.071
Z-score F3 (SI)	0.062	0.003	24.094	0.000	0.057	0.067
Z-score F4 (SI)	0.038	0.003	14.891	0.000	0.033	0.043
Z-score F5 (SI)	0.010	0.003	3.807	0.000	0.005	0.015
Z-score F6 (SI)	0.025	0.003	9.807	0.000	0.020	0.030
Gender	0.092	0.006	14.825	0.000	0.080	0.104
Int_1 : Z-score F1 x Renewal						

Table 4. Coefficient of Undergraduate Student Model (2019–2021).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	0.718	0.014	53.055	0.000	0.692	0.745
Z-score F1 (TSI)	0.573	0.005	107.922	0.000	0.563	0.584
Renewal	0.434	0.010	45.566	0.000	0.416	0.453
Int_1	-0.409	0.007	-61.389	0.000	-0.422	-0.396
Z-score F2 (SI)	0.019	0.003	6.480	0.000	0.014	0.025
Z-score F3 (SI)	0.056	0.003	18.580	0.000	0.050	0.061
Z-score F4 (SI)	0.016	0.003	5.247	0.000	0.010	0.022
Gender	0.044	0.007	6.042	0.000	0.030	0.059
Int_1 : Z-score F1 x Renewal						

Table 5. Coefficient of Undergraduate Student Model (2022–2024).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	0.613	0.015	42.401	0.000	0.585	0.642
Z-score F1 (TSI)	0.538	0.007	81.954	0.000	0.525	0.550
Renewal	0.377	0.009	42.287	0.000	0.359	0.394
Int_1	-0.333	0.008	-42.492	0.000	-0.349	-0.318
Z-score F2 (SI)	0.022	0.003	6.519	0.000	0.015	0.028
Z-score F3 (SI)	0.011	0.003	3.344	0.001	0.005	0.018
Z-score F4 (SI)	0.050	0.003	15.043	0.000	0.043	0.056
Z-score F5 (SI)	0.021	0.003	6.431	0.000	0.015	0.028
Z-score F6 (SI)	0.050	0.003	14.925	0.000	0.043	0.056
Z-score F7 (SI)	0.026	0.003	7.756	0.000	0.019	0.032
Z-score F8 (SI)	0.025	0.003	7.480	0.000	0.018	0.031
Gender	0.040	0.008	5.069	0.000	0.025	0.056
Int_1 : Z-score F1 x Renewal						

Regression analysis results for the three periods indicate that the effects of Z-score F1, Renewal, and their interaction term on LogTotal are all significant. Specifically, the positive effect of Z-score F1 on LogTotal gradually weakened over time; the positive effect of Renewal on LogTotal was relatively strongest during 2019–2021 and weakest during 2016–2018; the negative interaction effect of Z-score F1 and Renewal on LogTotal was relatively strongest in 2019–2021 and weakest in 2022–2024. Additionally, across all three periods, Renewal attenuated the positive effect of Z-score F1 on LogTotal, with the strongest attenuation occurring in 2019–2021.

3.2.2 Graduate Student

The models for all three periods passed the significance test ($p = 0.0000$), with an overall good fitting effect. In the 2022–2024 period, the F-value of the Graduate Model is substantially higher than that of the Undergraduate Model, indicating that, despite a smaller sample size, the overall significance of the graduate model is stronger. Regarding the R-sq (Coefficient of Determination), the model explained 69.1% of the variance in LogTotal in 2016-2018, which was the highest among the three periods; it decreased to 60.5% in 2019-2021 and rebounded slightly to 63% in 2022-2024. For the MSE (Mean Squared Error), it was the smallest in 2016-2018 (0.108), indicating the highest prediction accuracy of the model during this period, while in 2019-2021, the MSE was the largest (0.128), with a relatively higher prediction error.

Table 6: Coefficient of Graduate Student Model (2016-2018).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	1.021	0.012	84.967	0.000	0.998	1.045
Z-score F1 (TSI)	0.665	0.007	97.894	0.000	0.652	0.678
Renewal	0.292	0.007	43.421	0.000	0.278	0.305
Int_1	-0.407	0.008	-53.097	0.000	-0.422	-0.392
Z-score F2 (SI)	0.068	0.003	23.446	0.000	0.062	0.073
Z-score F3 (SI)	0.052	0.003	18.128	0.000	0.046	0.057
Z-score F4 (S)	0.005	0.003	1.810	0.070	0.000	0.011
Z-score F5 (SI)	0.081	0.003	28.273	0.000	0.076	0.087
Z-score F6 (SI)	0.017	0.003	5.959	0.000	0.012	0.023
Z-score F7 (SI)	0.045	0.003	15.765	0.000	0.039	0.051
Z-score F8 (SI)	0.022	0.003	7.788	0.000	0.017	0.028
Z-score F9 (SI)	0.040	0.003	13.778	0.000	0.034	0.045
Gender	0.040	0.007	6.140	0.000	0.027	0.053
Int_1 : Z-score F1 x Renewal						

Table 7: Coefficient of Graduate Student Model (2019-2021).

Variable	Coefficient	se	t	p	LLCI	ULCI
constant	0.861	0.014	61.926	0.000	0.833	0.888
Z-score F1 (TSI)	0.595	0.008	79.237	0.000	0.580	0.610
Renewal	0.360	0.008	43.545	0.000	0.344	0.376
Int_1	-0.383	0.009	-44.777	0.000	-0.399	-0.366
Z-score F2 (SI)	0.068	0.003	20.488	0.000	0.061	0.074
Z-score F3 (SI)	0.064	0.003	19.316	0.000	0.057	0.070
Z-score F4 (SI)	0.071	0.003	21.410	0.000	0.064	0.077
Z-score F5 (SI)	0.024	0.003	7.283	0.000	0.018	0.031
Z-score F6 (SI)	0.013	0.003	3.856	0.000	0.006	0.019
Gender	0.040	0.008	5.196	0.000	0.025	0.054
Int_1 : Z-score F1 x Renewal						

Table 8: Coefficient of Graduate Student Model (2022-2024).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	0.814	0.014	56.426	0.000	0.786	0.843
Z-score F1 (TSI)	0.719	0.009	76.388	0.000	0.701	0.738
Renewal	0.310	0.008	38.789	0.000	0.295	0.326
Int_1	-0.502	0.010	-49.176	0.000	-0.522	-0.482
Z-score F2 (SI)	0.064	0.003	18.706	0.000	0.057	0.070
Z-score F3 (SI)	0.062	0.003	18.189	0.000	0.055	0.068
Z-score F4 (SI)	0.025	0.003	7.209	0.000	0.018	0.031
Gender	0.011	0.008	1.355	0.176	-0.005	0.026
Int_1 : Z-score F1 x Renewal						

The effects of Z-score F1, Renewal, and their interaction term on LogTotal are all significant. Specifically, the effect of Z-score F1 shows a trend of decreasing first and then increasing, with the strongest positive effect observed in 2022–2024; the effect of Renewal presents a trend of increasing first and then decreasing, with the strongest positive effect in 2019–2021 and the weakest in 2016–2018; regarding the interaction effect, in 2022–2024, the attenuating effect of Renewal on Z-score F1 is the strongest.

3.2.3 Faculty & Staff

The models for all three periods passed the significance test ($p = 0.0000$), with an overall good fitting effect. The sample size

of the Faculty & Staff Model is far smaller than that of student groups (less than 1/10) and showed a gradually decreasing trend (from 1077 to 970 to 684); however, the model still passed the significance test, and the results are statistically reliable. In terms of R-sq, the model accounted for 67.4% of the variance in LogTotal in 2016-2018, decreased to 60.6% in 2019-2021, and rebounded to 65.7% in 2022-2024, maintaining an overall high level. For the MSE, it was the smallest in 2022-2024 (0.14), indicating the highest prediction accuracy of the model during this period, while in 2019-2021, the MSE was the largest (0.169), with a relatively higher prediction error.

Table 9: Coefficient of Faculty & Staff Model (2016-2018).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	1.043	0.039	26.517	0.000	0.966	1.120
Z-score F1 (TSI)	0.721	0.032	22.295	0.000	0.657	0.784
Renewal	0.454	0.027	16.677	0.000	0.401	0.507
Int_1	-0.433	0.035	-12.273	0.000	-0.502	-0.364
Z-score F2 (TSI)	0.033	0.012	2.817	0.005	0.010	0.056
Z-score F3 (SI)	0.056	0.012	4.727	0.000	0.032	0.079
Z-score F4 (I)	0.040	0.012	3.352	0.001	0.017	0.063
Z-score F5 (SI)	0.041	0.012	3.478	0.001	0.018	0.064
Gender	0.011	0.023	0.468	0.640	-0.035	0.057
Int_1 : Z-score F1 x Renewal						

Table 10: Coefficient of Faculty & Staff Model (2019-2021).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	0.917	0.044	20.713	0.000	0.830	1.003
Z-score F1 (TSI)	0.778	0.052	14.972	0.000	0.676	0.880
Renewal	0.472	0.032	14.903	0.000	0.409	0.534
Int_1	-0.575	0.054	-10.618	0.000	-0.681	-0.469
Z-score F2 (TSI)	0.131	0.014	9.732	0.000	0.105	0.158
Z-score F3 (SI)	0.059	0.013	4.408	0.000	0.033	0.085
Z-score F4 (SI)	0.017	0.013	1.243	0.214	-0.010	0.043
Z-score F5 (SI)	0.036	0.013	2.725	0.007	0.010	0.062
Gender	0.028	0.027	1.067	0.286	-0.024	0.080
Int_1 : Z-score F1 x Renewal						

Table 11: Coefficient of Faculty & Staff Model (2022-2024).

Variable	Coefficient	se	t	p	LLCI	ULCI
Constant	1.102	0.052	21.015	0.000	0.999	1.205
Z-score F1 (TSI)	1.214	0.077	15.788	0.000	1.063	1.365
Renewal	0.278	0.038	7.342	0.000	0.204	0.353
Int_1	-0.961	0.079	-12.245	0.000	-1.115	-0.807
Z-score F2 (SI)	0.088	0.014	6.124	0.000	0.060	0.116
Z-score F3 (SI)	0.044	0.014	3.068	0.002	0.016	0.072
Z-score F4 (SI)	0.045	0.014	3.105	0.002	0.016	0.073
Z-score F5 (SI)	0.044	0.014	3.029	0.003	0.015	0.072
Gender	0.008	0.029	0.286	0.775	-0.049	0.065
Int_1 : Z-score F1 x Renewal						

Z-score F1's positive effect on LogTotal increased continuously, peaking in 2022–2024, which indicates its growing centrality in influencing LogTotal. The direct positive impact of Renewal was strongest in 2019–2021 but weakened significantly in 2022–2024; however, its moderating effect (via interaction) became increasingly inhibitory, suggesting a shift from a “direct positive influence” to a “negative moderation via interaction”. The attenuating effect of Renewal on Z-score F1, as part of the interaction effect, intensified over time, with particular prominence in 2022–2024, reflecting a structural change in their relationship. Among covariates, gender remained non-significant throughout.

4. Discussion

4.1 Comparative Analysis of TSI, SI, S, I Factors

A single-dimensional spatial or interest factor with a low eigenvalue has a negligible influence on lending volume. The eigenvalues of frequently occurring SI factors are lower than those of TSI factors. Also, SI factors reflect static or slow-changing spatial interest rate distribution, with an indirect impact and multi-link transmission that weakens the influence. In contrast, TSI factors integrate time-space-interest, reflect dynamic changes, and have a more direct and timely impact mechanism on lending volume.

This contrast in influence mechanisms is reinforced by insights into how time, space, and interest operate individually versus in concert to shape reading behavior and engagement. Single-dimensional factors—whether spatial, temporal, or interest-driven—exert limited impact due to their inability to capture the dynamic interplay that defines readers' real-world interactions with resources.

Spatial factors, when considered in isolation, rely on static or slow-changing distributions (e.g., fixed library locations or basic digital platforms) that fail to account for readers' evolving needs. While location-aware recommendation engines (Muhamedale et al., 2025) or physical reading spaces (Noone, 2024) can enhance access, their influence is diluted without alignment with time and interest. For example, a well-designed library (spatial factor) may attract readers, but without timely updates to its collection (time) or alignment with user interests (interest), its impact on lending volume remains minimal. Similarly, virtual spaces like VR environments (McIntosh, 2022) create immersive experiences, but their effectiveness diminishes if content does not evolve with readers' changing

interests or temporal constraints (e.g., academic deadlines). Hybrid learning spaces (Brooks et al., 2012) illustrate this: their value lies not in physical/virtual diversity alone, but in how they adapt to when (time) and what (interest) readers need—highlighting why isolated spatial factors underperform.

Interest, in isolation, is equally constrained. While interest drives engagement—whether through student choice of materials (Oturgasheva, 2018), news chatbots (Baviskar et al., 2025), or alignment with self-actualization needs (Olivier, 2023)—its impact weakens without temporal and spatial support. For instance, a reader's strong interest in a topic (e.g., climate science) will not translate to lending volume if relevant resources are unavailable when needed (time) or inaccessible (space). Hedonistic readers seeking relaxation (Allred & Cena, 2020) or problem-oriented readers prioritizing life experiences (Oturgasheva, 2018) require resources that are not only interest-matched but also timely (e.g., new releases) and accessible (e.g., digital copies for on-the-go reading). Single-dimensional interest factors, focused solely on preference matching, miss these critical dimensions, leading to multi-link transmission that weakens their influence.

TSI factors overcome these limitations by integrating time, space, and interest into a dynamic framework. Time shapes behavior through contextual shifts—such as the pandemic-driven rise in interactive reading (Elisondo, 2023)—and ensures resources align with readers' evolving schedules (e.g., exam periods, research deadlines). Space, whether physical (libraries) or virtual (VR environments), provides the infrastructure for access, but only when paired with time and interest (e.g., hybrid learning spaces that adapt to when and what readers need; Brooks et al., 2012). Interest, as the motivational core, drives depth of engagement (Olivier, 2023) but requires temporal relevance (e.g., current research trends) and spatial accessibility (e.g., on-campus availability) to translate into lending behavior.

This integration explains TSI's direct and real-time impact. For example, a student's interest in AI research (interest) is amplified when relevant texts are available digitally (space) during their project timeline (time)—a TSI-aligned scenario that streamlines borrowing decisions. In contrast, a single-dimensional interest factor fails to account for when the student needs them or how to access them, reducing its influence. Similarly, TSI factors reflect dynamic changes like shifting academic calendars (time), new library

branches (space), and emerging research interests (interest), allowing them to directly shape cost-benefit calculations for both readers and lenders.

Single-dimensional factors are inherently limited by their static, isolated nature, while TSI factors thrive on the synergy of time, space, and interest. By mirroring the complex, dynamic reality of readers' behavior—where engagement depends on when, where, and what—TSI factors deliver a more direct, timely, and impactful influence on lending volume.

4.2 The Core Role of TSI Factors in Shaping Lending Dynamics

The TSI factor reflects the dynamic change process of interest rates over time and space. As lending behavior and borrowing needs are time-based, it can better reflect real-time requirement changes. A higher eigenvalue of the TSI factor leads to a greater impact on lending volume, thus exerting a positive effect on LogTotal and becoming the core driving factor.

The primacy of TSI factors in shaping lending dynamics is further underscored by their alignment with broader mechanisms governing how time, space, and interest (TSI) interact to influence reading behavior and renewal intention. Across diverse contexts, the interplay of these three factors dynamically shapes interpretations, engagement, and repeated interaction with content—paralleling their role in driving lending volume.

For instance, Prothi et al. (2023) draw parallels between urban development and reading behavior: riverfront developments (space) evolve over time in response to community interests, and their narratives (analogous to reading materials) reflect how spatial transformations are intertwined with temporal changes and collective interests. This mirrors how college readers' interpretations of texts are shaped by when (time), where (space), and what (interest) they read—highlighting that TSI factors, by integrating these dimensions, capture the nuanced drivers of lending behavior more effectively than static or single-dimensional factors.

Similarly, high-integrated hybrid reading models, defined by the convergence of flexible digital/physical spaces, personalized interest-driven content, and structured time for pre/post-reading activities (e.g., selection, sharing), maximize renewal intention (Li & Liu, 2019). This aligns with the TSI framework: just as hybrid reading leverages time, space, and interest to foster re-engagement, TSI factors optimize lending dynamics by aligning resources with readers' real-time spatial access, temporal needs, and evolving interests—directly boosting the likelihood of repeated borrowing (and thus LogTotal).

Empirical evidence from educational contexts reinforces this interplay. Eye-tracking data in MOOCs (Sharma et al., 2020) shows that temporal focus (content coverage over time), spatial alignment (visual cues in lectures), and interest (motivation) interact to predict learning performance. Translating this to lending behavior, college readers' renewal intention is strongest when reading activities are time-efficient (temporal), spatially accessible (spatial), and interest-driven—exactly the dimensions captured by TSI factors. This explains why TSI exerts a more direct and impactful influence on lending volume than static factors: it dynamically adapts to these interacting needs.

Real-world examples further illustrate this dynamic. Conlin (2012) examines how seasonal access (temporal limitation), pleasure gardens as social hubs (physical space), and interest-driven activities (concerts, art viewing) combine to encourage repeated visits. For college readers, analogous dynamics unfold in time-sensitive, interest-aligned events (e.g., campus book clubs) that merge spatial convenience, temporal relevance, and personal interest—reinforcing renewal intention and, by extension, lending volume. TSI factors encapsulate this synergy, making them uniquely effective in driving borrowing behavior.

Even cognitive and urban studies highlight the universality of TSI interplay. Visuospatial attention in reading (Mendonça, Garrido, & Semin, 2020) is shaped by script direction (spatial alignment), interest in content, and temporal efficiency (faster processing), which together enhance comprehension and repetition—paralleling how college readers' familiarity with a text's structure (space), content interest, and practice time (repetition) drive renewal intention. Similarly, urban "supertexts" (Korshunova, 2020) blend historical time, cultural space, and reader interest in mythology to create narratives that encourage repeated exploration, much like interdisciplinary texts (merging time, space, and interest) boost college readers' desire to re-engage.

The TSI factor's core role in lending dynamics stems from its ability to encapsulate the universal interplay of time, space, and interest—dimensions that consistently shape human engagement, repetition, and behavior across contexts. By mirroring these dynamics, TSI factors effectively capture the real-time, evolving needs of readers, making them the primary driver of lending volume.

4.3 Interactions of TSI Factor and Renewal in Influencing Lending Volume

The preceding analyses highlight the roles of TSI factors, renewal behavior, temporal variations, and contrasting influence mechanisms in shaping lending volume. A critical dimension to contextualize these findings is the interplay between renewal intention and reading behavior, which underpins readers' sustained engagement with materials and ultimately affects lending patterns.

Raymond Williams' perspective on communication and education emphasizes that classroom criticism—characterized by unhurried reading and critical analysis of media texts—fosters readers' intention to re-read (Westgate, 2009). This aligns with our observation that renewal behavior (as a proxy for re-reading intention) exerts both direct and moderating effects on lending volume: deep textual engagement, as advocated by Williams, likely strengthens readers' propensity to renew loans, thereby sustaining their interaction with materials and amplifying the continuity of lending behavior.

Beyond educational contexts, the availability of reading resources emerges as a key driver of renewal intention. Following Latvia's independence, donations of materials to local libraries filled resource gaps, prompting repeated re-reading (Smith & Štrāmlē, 2006). This suggests that abundant and relevant resources—mirroring the dynamic, timely provision of materials implied by TSI factors—enhance renewal intention, which in turn reinforces lending volume. In our framework, TSI factors, by integrating time, space, and interest, may facilitate access to such resources, indirectly boosting renewal behavior and thus amplifying their positive impact on

lending. Conversely, the inhibitory moderating role of renewal could reflect scenarios where excessive re-reading of specific materials reduces the need for new loans, creating a counterbalance to TSI-driven borrowing.

Furthermore, engagement with substantial or diverse content—such as Romantic poetry—encourages active exploration and risk-taking, increasing intentions to re-read or explore related materials (Torgerson, 2010). This aligns with the dynamic nature of TSI factors, which might curate diverse, interest-aligned resources that spark prolonged engagement. For instance, graduate students and faculty/staff, whose TSI effects strengthened over time, may exhibit higher renewal intentions due to deeper engagement with specialized content, reinforcing the link between TSI, renewal, and sustained lending.

In the digital age, internet texts with embedded links facilitate deeper exploration, enhancing intentions to continue engaging with related content (Weigel et al., 2010). While analysis focuses on physical or traditional lending, this insight resonates with the role of TSI factors in connecting readers to time-sensitive, interest-driven resources: just as hyperlinks enable continuous exploration, TSI factors may guide readers to related materials, fostering renewal intentions and extending lending cycles.

Collectively, these perspectives underscore that renewal intention—shaped by resource availability, deep engagement, and content richness—acts as a bridge between readers' behavior and lending volume. The interaction between TSI factors (which structure access and relevance) and renewal behavior (which reflects sustained engagement) thus emerges as a micro-level mechanism that amplifies or tempers the macro-level patterns observed in lending dynamics. For instance, the strengthening TSI effect among faculty/staff could partly stem from their higher renewal intentions, driven by ongoing research needs and deeper content engagement, whereas the weakening effect among undergraduates might reflect shallower engagement and lower re-reading propensity.

Renewal intention and reading behavior, as informed by critical engagement, resource availability, and content diversity, provide a theoretical foundation for interpreting the observed interactions between TSI factors, renewal, and lending volume. These dynamics highlight the importance of fostering sustained reader engagement—through curated resources and opportunities for deep analysis—in optimizing lending systems.

4.4 Temporal Variation in the Effect of TSI Factor on Total Lending Volume Across Reader Groups

Undergraduate students exhibited a gradual weakening of the positive effect of TSI on LogTotal over time. Among graduate students, the effect of TSI showed a trend of first decreasing and then increasing, with the strongest positive effect observed in 2022–2024. For faculty and staff, TSI's positive effect on LogTotal increased continuously, peaking in 2022–2024, which indicates its growing centrality in influencing LogTotal.

These temporal variations in TSI's impact align with broader insights into how time shapes reading behavior, comprehension, and renewal intention across contexts. The time dimension—encompassing specific events, duration of engagement, historical continuity, and evolving contexts—exerts a dynamic influence on readers' interactions with texts, which in turn may explain the divergent trends observed across reader groups.

First, specific time-bound events can reshape reading interactions, as highlighted by Pierce (2022), who notes that the pandemic period shifted reading contexts: new media (e.g., Zoom sessions featuring bookshelves) and late-night TV shows fostered engagement with old books through interactive exchanges. This suggests that external temporal disruptions (such as global events) may alter how readers align with TSI factors. For undergraduates, whose academic journeys are often structured around short-term semesters and rapidly changing coursework, the weakening TSI effect over time could reflect shifting priorities driven by transient events (e.g., curriculum updates, campus activities) that disrupt sustained alignment with time-space-interest dynamics. In contrast, graduate students and faculty, with longer-term research goals, may adapt more gradually to such events, allowing TSI effects to rebound or strengthen as they reorient their engagement with resources.

Second, the relationship between time spent reading and comprehension is non-linear, with repeated engagement over time leading to fluctuations in inference types (literal, inferential, critical-intertextual) and comprehension levels (Gutiérrez-Romero et al., 2023). For elementary students, reading trajectories vary with duration and text type—a pattern that likely extends to college readers: their renewal intention may depend on temporal investment and repeated engagement. This could explain graduate students' fluctuating TSI effect: initial periods of adjustment (e.g., adapting to research demands) may reduce their alignment with TSI factors, but sustained engagement over time (e.g., deepening research focus) strengthens this alignment, leading to increased lending volume. For faculty, whose long-term research involves cumulative temporal investment, the continuous strengthening of TSI's effect may reflect their growing reliance on time-sensitive, space-aligned, interest-driven resources to advance ongoing projects.

Temporal dynamics also include historical continuity and repeated exposure, which shape interpretation and renewal intention. Paterson (2018) notes that literary works retain core themes (e.g., chivalry) while evolving with cultural ideals, enhancing readers' historical context awareness. For college readers, repeated engagement with texts over semesters or years strengthens their grasp of evolving ideas—paralleling faculty and staff's deepening alignment with TSI factors, as their long-term engagement with academic literature fosters a nuanced understanding of how resources align with temporal shifts in their fields. Similarly, non-stop reading events (Nikonova & Morozova, 2019) show that prolonged temporal immersion enhances readers' connection to texts, fostering renewal intention. This mirrors the sustained focus of graduate students (in later periods) and faculty, whose prolonged engagement with specific fields amplifies TSI's impact.

Large-scale text analysis further illustrates that tracking themes over time reveals evolving reader interests (Catherine et al., 2018), suggesting that renewal intention depends on texts' alignment with changing temporal contexts. Undergraduates, navigating diverse coursework and shifting interests, may find fewer texts that remain relevant across their academic journey, weakening TSI's effect. In contrast, graduate students and faculty, with more stable research interests, are better positioned to engage with resources that evolve in tandem with their fields, strengthening TSI's influence.

Finally, longitudinal studies (Ding & Kim, 2018) show that reading achievement evolves over time, with consistent engagement strengthening revisiting likelihood. This aligns with faculty and staff's continuous TSI effect growth: their sustained engagement with academic resources builds a cycle of renewal intention, where each interaction reinforces the value of time-space-interest aligned materials. For undergraduates, whose engagement is more episodic, this cycle is less pronounced, leading to a weaker TSI effect over time.

5. Conclusion

The temporal variation in TSI's effect across reader groups is rooted in how time shapes engagement, investment, and renewal intention. Undergraduates' transient, diverse engagement weakens TSI's influence, while graduate students' adaptive, sustained focus and faculty's long-term, cumulative engagement strengthen it. These patterns underscore that time is not merely a background variable but a dynamic force that, when intertwined with space and interest, drives divergent lending behaviors across reader groups.

Beyond these quantitative findings, it is critical to recognize that the interplay of these factors dynamically shapes reading behavior. Literary texts (Davies, 2020) position readers in a "caesural space" (simultaneously proximate to and distant from the text) where temporal ambiguity (contemporaneity) and thematic interest (relationality) interact, influencing interpretation and the desire to re-read. Similarly, geographies of reading (Cornejo-Nieto, 2019) show how travel narratives' spatial descriptions (e.g., mountain summits) and temporal contexts (19th-century vs. modern) interact with readers' interest in global discourses, driving critical engagement—mirroring how college readers' interest in global issues interacts with texts' spatial (e.g., international settings) and temporal (e.g., timelines) dimensions to boost renewal intention. These insights underscore that reading behavior is a multifaceted phenomenon, shaped by the dynamic interplay of textual, temporal, spatial, and individual factors, with renewal behavior serving as both a direct outcome and a critical moderator in this complex system. These insights guide decision-makers to prioritize core drivers, navigate moderating complexities, and adapt to context, fostering targeted total borrowings improvements.

To start with, recognizing the TSI factors as the core driver of LogTotal underscores the need for targeted strategies that optimize temporal, spatial, and interest-related elements in relevant contexts. For instance, in fields like education, resource allocation, or user engagement, designing interventions that align with individuals' time availability, spatial accessibility, and intrinsic interests could effectively enhance the outcome measured by LogTotal.

Notably, the dual role of Renewal—exerting a direct positive impact while also acting as a significant moderator with an inhibitory effect—highlights the complexity of its influence. This suggests that while promoting renewal (e.g., updating systems, policies, or services) can directly boost LogTotal, its interaction with other key variables must be carefully managed. Library should avoid over-reliance on renewal alone and instead adopt a nuanced approach, considering how renewal interacts with factors like time, space, or interest to prevent unintended inhibitory effects, thereby maximizing overall effectiveness.

Equally important, the context-dependent relevance of gender as a covariate emphasizes the importance of avoiding one-size-fits-

all assumptions. For undergraduate students and graduate students in the 2016–2021 period, gender-related differences merit attention in strategy design, such as tailored support or resource distribution. Conversely, for faculty, staff, and graduate students in 2022–2024, gender may not require prioritization, allowing resources to be redirected to more impactful factors. This contextual sensitivity ensures that interventions are both efficient and equitable.

The TSI factor exerts a positive effect on LogTotal, emerging as the core driving factor. The higher the eigenvalue of the TSI factor, the greater its impact on the lending volume. The two-dimensional SI factor, and the one-dimensional S and I factors have relatively smaller impacts on the borrowing volume. Renewal demonstrates a direct positive impact on LogTotal; however, its moderating role (characterized by an inhibitory effect) has strengthened significantly, rendering the interaction between Renewal and other key variables a pivotal determinant of LogTotal. Regarding covariates, gender consistently exhibits non-significance across all periods for faculty and staff, as well as for graduate students in the 2022–2024 period. In contrast, gender proves significant for undergraduate students and graduate students during the 2016–2021 period, indicating its context-dependent relevance.

The analysis is limited to specific time periods (2016–2024) and may not generalize to other contexts. Covariates beyond gender were not fully explored, leaving potential factors unexamined. Future research could extend the analysis to broader populations and more extensive timeframes to validate the universality of the TSI factors, ensuring its applicability across diverse contexts and over longer periods. Additionally, it would be valuable to investigate other potential moderators that might interact with Renewal to influence LogTotal, as this could uncover more nuanced dynamics and enhance the depth of understanding regarding the factors shaping LogTotal outcomes.

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