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RESEARCH ARTICLE

Dynamics of research motivation: A retrospective analysis of outstanding master's students

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ABSTRACT

To explore the characteristics of research motivation changes of outstanding master's students and the factors influencing these changes, this study employed retrospective drawing and semi-structured in-depth interviews as data collection methods and surveyed five master's students who received the honor of outstanding graduates at university level. Thematic analysis was used to process the interview data. The results demonstrated that the research motivation of outstanding master's students exhibited nonlinear dynamics, self-organization, interindividual variability, and ergodicity. Thematic analysis revealed that factors causing changes in their research motivation include teachers' influence, research team atmosphere, physical and mental factors, research outcomes, and subjective norms. These findings offer a new perspective for understanding the research motivation of master's students and can provide decision-making references for improving graduate education.

Keywords: complex dynamic systems theory; master's students; retrospective charting; research motivation

1. Introduction

Research motivation significantly influences master's students' enthusiasm to participate in research work, which is vital for them to achieve outstanding academic accomplishments [1]. Xie, Vongkulluksn, Cheng and Jiang [2] posited that students' motivation levels are subject to changes as time passes and external factors alter, with the research motivation of master's students being no different. Despite this understanding, most related studies are limited to static snapshots of motivation [3-6], meaning their collection of data is a one-time act, neglecting the progressive changes in research motivation that master's students experience due to various internal and external influences. Additionally, few studies delve into the patterns of these changes and the factors that influence them in a comprehensive and systematic way [7], resulting in a limited understanding of how motivation evolves and the diverse factors contributing to these changes. To address these gaps, this study chose five outstanding master's students as participants to unveil the characteristics of changes in their research motivation levels and the associated influencing factors.

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2. Literature review

2.1. Existing studies on research motivation

Existing research on motivation predominantly targets university educators and full-time researchers from various disciplines. For example, Stupnisky, BrckaLorenz and Laird [8], Stupnisky, Larivière, Hall and Omojiba [9], Zhou, Law and Lee [10] investigated the underlying factors influencing research motivation of different types of teachers and researchers. However, master's students differ notably from these groups in terms of research foundations, objectives, and evaluation criteria [11], underscoring the need for a dedicated investigation into their research motivation.

Motivation levels are subject to a range of external influences and exhibit non-linear fluctuations [12]. Yet, the majority of existing studies overlook this dynamic aspect, and tend to measure motivation levels using one-time data collection. For example, Chang, Wu and Ye [13], Nghia [14], Wang, Sun, Wang and Li [15] measured the learning motivation of master's students by using scales once, but they did not consider the changing characteristics of motivation. Additionally, the prevalent use of questionnaires as the primary data collection tools in current studies, while efficient for compiling large datasets and straightforward in statistical analysis, as Bartram [16] notes, falls short in tracking the dynamic evolution of research motivation over time. These methods, primarily static in nature, often miss the nuanced effects of individual experiences and contextual factors on research motivation. This highlights an evident need for more dynamic and comprehensive data collection approaches that can capture these complexities effectively.

2.2. Complex dynamic systems theory and motivation-related studies

Complex Dynamic Systems Theory (CDST) offers a robust framework for analyzing the dynamic interplay among elements within a system, presenting a comprehensive lens for interpreting complex phenomena [17-19]. Central to CDST is its focus on the internal components of a system and their interactions with external entities. It views systems as inherently open and adaptive, continuously interacting with their surrounding environment. This interaction leads to the formation of feedback loops, a pivotal mechanism where the system's output feeds back as input, prompting internal changes. These loops are crucial for driving systemic evolution by fostering nonlinearity, variability, and unpredictability [20]. They enable the system to adapt, maintain balance, and develop new, emergent properties, which are essential characteristics of complex, evolving systems.

Originally developed in fields of natural sciences and mathematics [21], CDST has been increasingly applied in the humanities and social sciences [22]. Notably, CDST is employed as a theoretical lens to decipher complex phenomena, including second language acquisition and motivational shifts in educational contexts. For instance, De Bot, Lowie and Verspoor [23] demonstrated that language development is a dynamically evolving process; Fogal [24] identified dynamic system characteristics, like nonlinearity, in students' development of second language writing skills. Yamaoka [25], Papi and Hiver [26] investigated the changing patterns of students' motivation to learn English in different environments; Ren and Zhou [7] depicted the research motivational trajectories of EFL teachers in China. Studies like these have noticed that motivation is in a changing status, but few have delved into the specific characteristics and underlying reasons for changes in research motivation of master's students. Understanding the nuances of research motivation in postgraduate study is crucial, as it not only influences the immediate academic achievements of master's students, but also sets the tone for their future scholarly pursuits [27]. Therefore, it is of great significance to investigate the characteristics of changes in research motivation of master's students and explore the reasons for these changes, which is not just academically pertinent but also essential for enhancing the quality of graduate education.

CDST provides an ideal framework for analyzing the multifaceted and evolving nature of master's students' research motivation. This theory could be used to elucidate how various internal and external factors interact and contribute to the nonlinear progression of motivation. By applying CDST, this study seeks to unravel the complex dynamics of research motivation of master's students, examining how it evolves and is influenced by different environmental and personal factors.

Accordingly, this study is guided by two principal research questions:

1. What are the characteristics of research motivation changes of outstanding master's students?

2. What are the primary factors driving research motivation changes of these students?

3. Methodology

3.1. Participants of the study

This study utilized a convenience sampling method [28] to select a cohort of five master's degree students, each recognized as an outstanding graduate by their respective universities. These participants were not only notable for their academic honors but also met specific criteria relevant to our research: each had a demonstrated record of publishing high-quality academic papers and had decided to pursue doctoral studies, indicating a sustained commitment to academic research. Additional details about them are presented in **Table 1**. The interviews were conducted primarily at the conclusion of the participants' master's programs, encompassing various stages such as the onset of doctoral studies, during the summer break following master's graduation, or shortly after completing their master's degrees.

Table 1. Fundamental information about the 5 participants.

Participant	Sex	Major	Papers Published during Study
A	male	Electrical engineering	3 SCI papers
B	male	Veterinary science	2 SCI papers
C	female	Management	1 SCI and 1 SSCI papers
D	male	Chemotherapy	4 SCI papers
E	female	Pedagogy	2 Chinese high-quality papers

3.2. Data collection

This study employed two comprehensive data collection methods: retrospective mapping and semi-structured in-depth interviews.

3.2.1. Retrospective mapping

Pioneered by Jung [29], retrospective mapping has been extensively used to track changes in motivational levels, particularly in the field of second language acquisition [7,30]. In our study, we drew upon Ren and Zhou's[7] and created a retrospective chart to capture the fluctuating research motivation of master's students. These motivation levels were categorized into five distinct grades, with 1 representing the lowest and 5 the highest level of research motivation. The participants were instructed to chart their motivation trajectories throughout their graduate studies using this retrospective mapping technique. The blank chart is shown in **Figure 1**. The graduate program in China lasts for three years, with each academic year divided into autumn and spring semesters. The horizontal axis in the chart represents the timeline of the graduate program, while the vertical axis represents the level of research motivation of master's students.

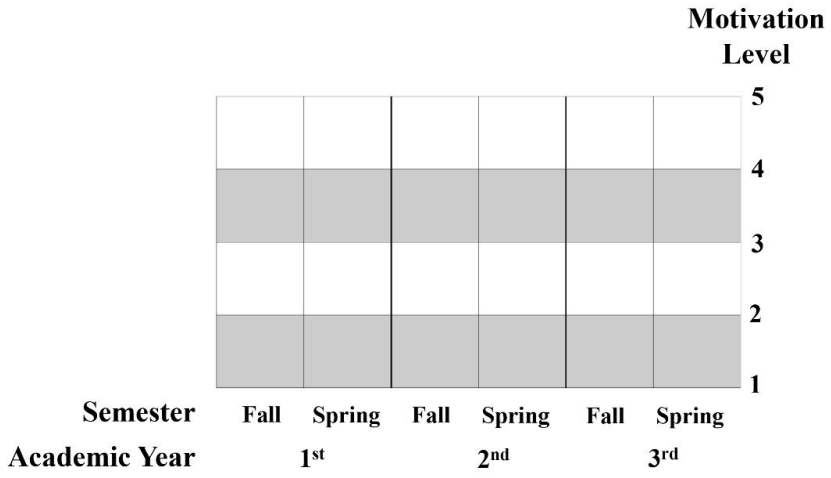

Figure 1. Blank motivation chart.

3.2.2. Semi-structured interviews

Semi-structured interview can offer an avenue to explore the nuanced reasons behind changes in research motivation. The interview encompassed both generic inquiries, such as "Could you give an overview of how your research motivation level changed throughout your master's study?", "Could you elaborate on the factors that propelled you to achieve such outstanding research accomplishments?", and "Could you describe the individuals or incidents that had the most profound impact on the transformation of your research motivation?" Additionally, tailored questions were designed based on each participant's unique research motivation trajectory, for instance, "Why your research motivation level declined rapidly in your first semester?" Each interview, lasting between 20 to 30 minutes, was conducted with the participant's consent for recording and later transcribed verbatim for analysis, guaranteeing a precise and faithful representation of their insights for thorough analysis.

3.3. Data analysis

In this study, we meticulously compiled the trajectories of research motivation changes of the five master's students into a comprehensive retrospective motivation chart. This chart served as a crucial tool for comparative and integrated analysis, enabling a clearer understanding of the patterns and trends in research motivation of these students. Furthermore, the transcripts of the interviews conducted with these five students were imported into Nvivo 12, a qualitative analysis software, to conduct a semantic analysis [31]. The data underwent a two-stage coding process. In the first stage, detailed analysis and summarization presented raw data as a series of important concepts and categories. In the second stage, these categories were further refined to achieve themes with stronger generalizability or higher abstraction. This approach allowed for an in-depth exploration of underlying themes and patterns within the students' responses, providing valuable insights into the factors influencing their research motivation and how these factors interplayed over the course of their studies.

Through thorough data collection and iterative thematic analysis, we achieved data saturation after investigating these five master's degree students. Data saturation is the criterion for stopping coding, reached when no additional data can be obtained that would allow the researcher to discover new categories [32]. To verify whether the factors influencing the research motivation of master's students identified in this study had reached saturation, we conducted semi-structured, in-depth interviews with three other outstanding postgraduate students afterwards. These interviews did not reveal any new concepts or categories, and the

relationships between the categories did not change significantly. Therefore, it can be concluded that the factors identified in this study have reached saturation.

4. Results

4.1. Research motivation change trajectories

Figure 2 illustrates the trajectories of research motivation change of the five outstanding master's students.

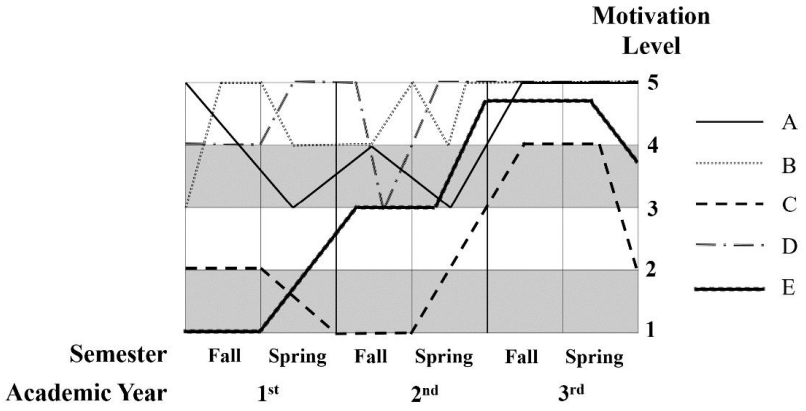

Figure 2. Research motivation change trajectories.

Overall, the trajectories show complexity in motivation levels with notable changes. While there are significant differences in the characteristics of these changes, some students exhibit consistent patterns at certain stages. The detailed characteristics are demonstrated by the following two points:

4.1.1. Nonlinear dynamics

The research motivation levels of outstanding master's students in our study demonstrated significant dynamics over their three-year graduate journey. Despite their commendable academic accomplishments, their research motivation levels were not always consistently high (e.g., above 4), but rather underwent considerable changes. For instance, student D experienced dramatic changes in research motivation during the second semester of his second year, plummeting from the highest level to an average level before rapidly rebounding. Student C's research motivation gradually increased from the lowest level in the second semester of the second year, sustained a high level for a significant duration in the third year, but then experienced a sharp decline.

4.1.2. Interindividual differences and similarities

There exist both similarities and differences in research motivation levels of the five outstanding master's students. In the first two years, the differentiation in research motivation levels was evident, with students A, B, and D maintaining higher levels of motivation compared with C and E. Comparatively, towards the end of their graduate studies, students C and E demonstrated a distinct downward trend, differing from their peers. However, a striking similarity was observed in the third year, especially before the mid-term of the second semester, when all five students exhibited high motivation levels, indicating a convergence in their motivational trajectories.

Overall, the research motivation of outstanding master's students in the initial phase of their graduate studies was marked by pronounced fluctuations and notable individual differences. In contrast, the latter half saw a general trend of sustained high motivation levels with less variation among individuals.

4.2. Main reasons for changes in research motivation

This study conducted semi-structured in-depth interviews with five outstanding master's students and performed thematic analysis on the interview data. The coding process and results of this analysis (partial) are presented in **Table 2**.

Table 2. Results of the Thematic Analysis (Partial).

Original Text	Initial Coding	Theme	Theme Connotation
C: My supervisors are kind to students and always encourage me when my research is not going well.	Mentor encouragement boosted research motivation	Teachers' influence	The influence of mentors or other teachers can have both positive and negative impacts on master's students.
A: My mentor is a professor in his field. Whenever I encounter problems I can't solve, he always guides me in the right direction.	Mentors guided the direction of research		
B: I worked so hard to read the literature, but in the end, one of my teachers criticized me and almost made me depressed, and I had no confidence in research during that time.	Teacher's criticism lowered research confidence		
B: The atmosphere in our research team is quite harmonious, and we are all willing to offer advice when we encounter a difficult problem, so I can get over my failure quickly!	Harmonious team boosted research progress	Team atmosphere	Team atmosphere contributes to the engagement of master's students in research activities.
D: In the second academic year, I broke up with my girlfriend at that time, and I felt quite lost and didn't feel like engaging in research.	Emotional issues undermined research motivation	Physical and mental factors	Physical and mental factors can have both positive and negative effects on master's students' commitment to their research.
E: I feel like I'm starting to get the hang of it, and my passion for scientific research is growing.	Interest increased research investment		
C: Since starting my graduate studies, my health has been poor, and I believe it is related to the excessive formaldehyde levels in our dormitory after it was renovated. During the second semester of my second year, I even had to be hospitalized, which left me with limited energy to focus on my research.	Physical problems impaired research motivation		
A: Since the second semester of my first year in the master's program, I started submitting papers. Some articles I felt were quite well-written, but they just weren't	Difficulty in publishing articles hindered research motivation	Research outcomes	The outcome of research could affect the enthusiasm and motivation of master's

Original Text	Initial Coding	Theme	Theme Connotation
accepted. Every time I received a rejection email, I would feel down for a few days.			students to engage in research.
D: Even with the reagents, temperature, and other conditions set properly, I still can't achieve the desired results. Sometimes, struggling repeatedly with a minor step severely drained my enthusiasm for scientific research.	Test results dampened enthusiasm for research		
E: I published my first article in a good journal in my second year of graduate school, and my confidence grew so much that my motivation to engage in research became stronger after that!	Article publication boosted research confidence		
A: I'm going to write my thesis soon, so of course I need to do more experiments!	Pressure to graduate motivated research activities	Subjective norms	The external pressure that master's students feel can affect their research motivation.
C: After the defense, it was still early to start my PhD candidate journey, so I wanted to go out and travel a bit to give my mind a break from research for a while!	Pressure released reduced research motivation		
B: I remember shortly after the semester started, I received a research project, and I felt that I had to publish a paper to complete it, so whenever I had free time, I went to the lab.	Research projects stimulated research		

Based on the results of thematic analysis, five causes were identified as influential in the changing of the research motivation levels of outstanding master's students:

Teacher's Influence: The encouragement and active guidance from teachers were found to positively enhance students' research motivation. Conversely, excessive criticism could lead to a decrease in motivation.

Team Atmosphere: A positive team atmosphere was unanimously cited as a motivating factor. Participants felt that a supportive and collaborative environment bolstered their research enthusiasm.

Physical and Mental Factors: Students' emotional well-being and physical health were significant determinants of their motivation. Inadequate handling of emotional and physical challenges among master's students could substantially diminish their research motivation. Conversely, an increase in personal interest in research often results in heightened motivation levels.

Research Outcomes: The success or failure of research endeavors, such as the publication of articles or the achievement of expected experimental results, directly impacted motivation.

Subjective Norms: External pressures, such as academic expectations or competition, were found to either motivate or demotivate students, depending on the individual's response to such pressures.

5. Discussion

5.1. Characteristics of changes

5.1.1. Nonlinear dynamics

In line with the principles of CDST, our study found that research motivation levels of outstanding master's students do not follow a simple, linear trajectory. Instead, they evolve in complex and unpredictable ways, exhibiting nonlinear dynamics. According to Kaplan and Garner [18], nonlinear systems are characterized by attractor and repeller states, signifying a system's tendency to gravitate towards or away from certain conditions. This study found that the levels of research motivation of outstanding master's students fluctuated significantly over three years, with alternating attractor and repeller states, demonstrating nonlinear dynamic characteristics. For example, initial physical conditions or research pressures might cause students' research motivation to remain high or low. Subsequently, during their academic and research journey, some positive factors might become attractors in their research motivation system (like obtaining research projects or publishing academic papers), while negative factors might become repellers (such as criticism from teachers or paper rejections). As the energy of these new attractors and repellers accumulates, the balance of the original research motivation system is disrupted, leading to either an increase or decrease in students' research motivation levels. The repeated emergence of positive and negative factors causes fluctuations in research motivation. This pattern of fluctuation resonates with the findings of Ren and Zhou [7], Yuan, Sun and Teng[33], who observed similar nonlinear dynamics in university teachers' research motivation.

5.1.2. Adaptability and self-organization

Adaptability and self-organization are defining characteristics of dynamic systems, which emerge through internal interactions and feedback mechanisms, typically independent of external influences [20]. In examining the motivation trajectories of the master's students through the lens of CDST, we observed a distinct self-organizing pattern. For example, each student demonstrated an ability to autonomously adapt their level of research motivation in response to personal and academic stimuli. The graph revealed instances where students' motivation levels surged collectively, suggesting a group adaptation to shared academic events, i.e., final graduation evaluations. These findings align with those of Ren and Zhou [7], who observed similar patterns of adaptability in language learners, as they navigated the complex interplay of different social factors. However, unlike the gradual adaptations of motivation levels over time observed by Ren and Zhou [7], and Jung [29], the master's students' motivation levels showed rapid adjustments, indicating a more dynamic adaptation process.

5.1.3. Interindividual variability and ergodicity

CDST emphasizes the significance of interindividual variability as well as ergodicity in dynamic systems[34]. Our study revealed distinct trajectories of research motivation of the five master's students, indicating considerable interindividual variability. Ergodicity refers to the presence of recurring patterns across different systems. This concept is evident in our findings as well. For instance, all students exhibited high motivation levels in the third academic year, particularly before mid-term, reflecting a pattern of ergodicity. Moreover, we noted ergodic patterns among students in natural sciences (A, B, and D) and those in humanities and social sciences (C and E). While natural science students showed more consistency with severe fluctuations in the first two years followed by sustained high motivation, humanities and social science students displayed a continuous rise and subsequent decline in motivation. This study's exploration of ergodicity contributes to addressing the ergodicity challenge raised by Lowie and Verspoor [35], bridging individual and group patterns in the development of research motivation.

5.2. Main influencing factors

CDST emphasizes the significance of each component within a system and the impact of these components on the system as a whole [20]. Our study considers the research motivation of outstanding master's students as a complex dynamic system composed of several interacting subsystems: teacher's influence, team atmosphere, physical and mental factors, research outcomes, and subjective norms. In this section, we will examine how these subsystems interplay with and impact the overall system, drawing comparisons with existing studies.

5.2.1. Teacher's influence

The role of teachers was found to be important in influencing the research motivation of master's students. This study found positive reinforcement and support from teachers significantly increased motivation levels, while criticism, on the other hand, could dampen their research enthusiasm. These findings align with the study of Carless and Winstone [36], who noted that teachers' impact on student development is not always positive: inappropriate criticism can diminish motivation and even negatively affect self-esteem and self-efficacy, while supportive feedback can significantly enhance its effectiveness. Furthermore, the expertise and mentorship provided by teachers, crucial in assisting students to pinpoint precise research directions, played a pivotal role in boosting their motivation. Given the dual impact of teacher interactions, it is imperative that educators balance critical feedback with constructive support and guidance to foster an environment conducive to enhancing the research motivation of master's students.

5.2.2. Team atmosphere

Our study further highlights the critical role of a supportive team atmosphere on enhancing master's students' research interest and commitment. In line with the findings of Johnson and Johnson [37], Uyen, Nhu, Nghi, et al. [38], we observed that constructive interactions within the team's atmosphere provided not just academic guidance but also essential emotional support. This support was instrumental in enabling students to overcome research challenges. Additionally, an atmosphere characterized by collaboration encouraged the sharing of knowledge and resources among team members. As Burgess, Haq, Bleasel, et al. [39] also found, such a collaborative atmosphere contributes to improved research efficiency and quality, thereby playing a crucial role in sustaining and elevating research motivation. All five outstanding master's students' research experience recognized the importance of team environment, underscoring the need to cultivate a team atmosphere that is not only collaborative but also emotionally supportive to enhance research motivation.

5.2.3. Physical and mental factors

Physical and mental well-being are crucial internal factors affecting master's students' research motivation. Consistent with Maslow's [40] hierarchy of needs theory, our study found that unmet basic emotional and physiological needs significantly hamper engagement in higher-level activities like academic research. For example, students facing personal issues such as breakups or physical illnesses reported decreased interest and motivation in their research. However, as students gain experience or achieve scientific milestones, their intrinsic motivation tended to increase, aligning with Ryan and Deci's [41] self-determination theory, which pointed out that individuals' intrinsic motivation will be strengthened when they feel their abilities and achievements are recognized. Therefore, it is essential for academic institutions to provide comprehensive wellness support and acknowledge students' achievements to nurture their intrinsic motivation and promote sustained engagement in research activities.

5.2.4. Research outcomes

This study found research outcomes might positively or negatively influence master's students' motivation. The challenging journal acceptance criteria, as noted by Kwiek [42], often lead to submission frustrations, impacting self-evaluation and dampening research enthusiasm. However, Belcher [43] revealed that positive interactions with editors and successful publication after multiple revisions can greatly encourage authors, resonating with Bandura's [44] self-efficacy theory. Additionally, Ommering, van Blankenstein, van Diepen and Dekker [45] affirmed the motivational impact of research success, whose study demonstrated that successful research experiences in courses significantly enhanced medical students' research motivation and self-efficacy beliefs, corroborating the findings of this study. Therefore, it becomes crucial for academic institutions and mentors to provide strategic support and resources to navigate the publication process, enhancing students' self-efficacy and sustaining their motivation through the challenges of scholarly dissemination.

5.2.5. Subjective norms

External pressures, such as upcoming graduation defenses or project deadlines, were found to stimulate research motivation of master's students, in line with Ajzen's [46] theory of planned behavior. However, this study found that the relief of pressure can also lead to a temporary decline in their research motivation. This is a typical feature of the Goal Completion Effect, which manifests a period of relaxation or low motivation status after the completion of an important goal or task [47]. The Goal Completion Effect explains why there is a rapid decline in research motivation for some of the participants after completing graduation defense in the final semester. This understanding of the Goal Completion Effect suggests the necessity for structured post-goal-setting and transitional support systems within academic programs to maintain research motivation even after major milestones have been achieved.

6. Conclusion

This study provides a deep exploration of the changing patterns and influencing factors of research motivation of outstanding master's students. Despite their significant academic achievements, these students experienced notable fluctuations in motivation levels, characterized by nonlinear dynamics, self-organization, inter-individual variability, and ergodicity. Five primary factors were identified for influencing these changes: teachers' influence, team atmosphere, physical and mental factors, research outcomes, and subjective norms. Supportive teachers and a collaborative team atmosphere boost motivation, while criticism and lack of support diminish it. Physical and mental well-being is crucial, as unmet needs hinder motivation. Positive research outcomes enhance motivation, whereas publication challenges can reduce it. Finally, external pressures like deadlines stimulate motivation, but relief can cause a temporary decline, necessitating ongoing support for sustained motivation.

This research reveals the complexity and dynamics of master's students' research motivation and comprehensively presents the factors influencing these changes, holding significant practical implications for graduate educators in guiding their strategies. Additionally, by employing CDST as a framework, this study breaks away from the static research paradigm of research motivation levels, offering new perspectives and directions for research in research motivation.

7. Research prospects

Given that the participants were surveyed at the end of their graduate studies, there is a risk that their recollections of motivation levels may not be entirely accurate, potentially impacting the validity of the

retrospective charts. Future research could employ longitudinal methodologies, conducting periodic assessments of motivation levels to reduce memory bias. Additionally, the focus on outstanding master's students, a subset of the broader student population, suggests a need for further research into the motivational dynamics of other master's student groups. For example, exploring the motivation patterns and fluctuations of underperforming master's students could offer valuable insights into the challenges and barriers that hinder their academic progress. Such investigations could provide a more holistic understanding of research motivation across diverse student demographics.

Author contributions

Conceptualization, X.R.; methodology, X.R.; software, X.R.; validation, X.R., B.L. and L.W.; formal analysis, X.R.; investigation, X.R., B.L. and L.W.; resources, X.R. and B.L.; data curation, X.R.; writing—original draft preparation, X.R. and B.L.; writing—review and editing, X.R., B.L. and L.W.; visualization, X.R. and B.L.; supervision, X.R.; project administration, X.R.; funding acquisition, X.R. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

No conflict of interest was reported by all authors.

Ethics statement

This study was approved by Medical Ethics Committee of Guangxi University (No.: GXU-2023-030). Informed consent was obtained from all participants prior to data collection, ensuring that they were fully aware of the study's purpose, procedures, and any potential risks or benefits. Ethical considerations, including confidentiality and the right to withdraw from the study at any time, were strictly adhered to.

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