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Research on the Mechanism of the Role of Big Data Analytic Capabilities on the Growth Performance of Start-Up Enterprises: The Mediating Role of Entrepreneurial Opportunity Recognition and Exploitation

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Abstract: With the advent of the era of big data, the application of big data analytics in entrepreneurial activities has become increasingly prevalent. However, research on the relationship between big data analytic capabilities and entrepreneurial activities is still in its infancy, and the mechanism by which the two interact remains unclear. Drawing on resource-based theory and entrepreneurial process theory, this research examines the impact mechanism of big data analytic capabilities on the growth performance of start-up enterprises and explores the mediating role of entrepreneurial opportunity recognition and entrepreneurial opportunity exploitation. Empirical analysis reveals that big data analytic capabilities have a significant positive impact on the growth performance of start-up enterprises; entrepreneurial opportunity exploitation plays a mediating role in the relationship between big data analytic capabilities and the growth performance of start-up enterprises, but entrepreneurial opportunity recognition does not show a significant mediating effect between the two; and entrepreneurial opportunity recognition and entrepreneurial opportunity exploitation play a chain-mediated role in the relationship between big data analytic capabilities and the growth performance of start-up enterprises. These research findings enrich the study of digital entrepreneurship and provide valuable references for the entrepreneurial practice of start-up enterprises.

Keywords: big data analytic capabilities; growth performance of start-up enterprises; entrepreneurial opportunity recognition; entrepreneurial opportunity exploitation

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1. Introduction

The Fourth Industrial Revolution, which is centered on digital technology, has brought enormous opportunities and driven the emergence of a new wave of entrepreneurship. However, due to the shortcomings of start-up enterprises, such as lack of experience and weak risk-resistance ability, the failure rate of entrepreneurship in start-up enterprises is generally high [1–3]. Therefore, the formidable challenge confronted by numerous start-up enterprises revolves around elevating the caliber of entrepreneurial endeavors and fostering the growth of businesses [4].

Under the trend of digital transformation, various types of data experience explosive growth. The production and operation of enterprises, the changing demands of customers, and the fluctuations in market policies and environmental conditions give rise to a vast amount of structured and unstructured data. These data embody immense value and market prospects [5]. The big data analytic capability refers to the ability to employ big data technologies for the management, processing, and analysis of extensive data [6]. With the aid of big data technologies, enterprises can amass and manipulate copious amounts of data, thereby transmuting tem into invaluable insights and erudition, thus bridging the

void that plagues fledgling enterprises in terms of experiential deficiency. Through in-depth analysis of data, start-up enterprises can better grasp customer needs and market trends, improve market insights, and formulate more targeted marketing strategies and product solutions to enhance the competitiveness of enterprises [7–9]. Therefore, the construction of big data analytic capability is of great significance for start-up enterprises to improve entrepreneurial efficacy and expand the realm of survival and growth.

The existing research findings have confirmed a positive correlation between the big data analytic capability and the promotion of enterprise growth [10–12]. These studies provide valuable guidance to enterprises in utilizing the big data analytic capability to promote their growth. However, these studies have not been examined in the context of startup enterprises, which lack the resource advantage compared to mature enterprises. Although the enhancement of big data analytic capabilities improves the competitiveness of businesses, the establishment of such capabilities requires continuous resource investment, which may increase the company's cost expenditure, thereby leading to a decline in return on investment [13]. Therefore, it is worth questioning whether the research findings are applicable to the growth process of startup enterprises. This study selects startup enterprises as the research subjects to explore the relationship between big data analytic capabilities and the growth performance of startup enterprises to fill the existing research gap.

Furthermore, scholars have currently drawn most attention on the pathways of the role between big data analytic capabilities and growth performance of enterprises from various perspectives. For instance, Wamba, et al. [14] elucidated from the standpoint of supply chain management that the big data analytic capability can effectively align the relationship between consumers and suppliers, thereby fostering mutually beneficial associations, reducing costs, and enhancing operational efficiency, consequently leading to growth performance. Gupta and George [15] and Mikalef, et al. [16] expound from the perspective of dynamic capabilities, asserting that due to the inherently dynamic nature of the business environment, the facilitative impact of big data analytic capability on growth performance necessitates the realization through organizational dynamic capabilities. Jian, et al. [17] emphasized the perspective of decision support, contending that managers can acquire insights and optimize strategic decision-making by leveraging the big data analytic capability and application, thereby facilitating growth performance. However, these studies predominantly focus on the discussion of digital transformation in mature enterprises, thus making it highly imperative to explore pathways that minimize risks and cater to the growth process of start-up enterprises' investing in big data analytic capabilities.

Entrepreneurial process theory suggests that entrepreneurial opportunity is the core of the entrepreneurial process, and recognizing and exploiting entrepreneurial opportunities are crucial for firms to gain sustained competitive advantage and enhance performance [18]. In the digital age, entrepreneurial opportunities have fragmented and dynamic characteristics [19], making it difficult for entrepreneurs to accurately and quickly identify them. Some scholars suggest that companies with big data analytic capabilities can more accurately and quickly obtain customer and partner demand information, identify unknown and known entrepreneurial opportunities in the market, and efficiently develop entrepreneurial opportunities through rational resource allocation [20,21]. Therefore, the recognition and exploitation of entrepreneurial opportunities may play a very important role in the path of big data analytic capabilities' impact on the performance of start-up enterprises. However, this issue has not been discussed in existing research, and there is a lack of theoretical and empirical testing. Based on this, this study aims to explore the path of achieving growth performance for start-up enterprises from the perspective of entrepreneurial opportunity. This study attempts to address the following questions:

Question 1: Could the growth performance of start-up enterprises be enhanced through the big data analytic capabilities?

Question 2: Can the recognition and exploitation of entrepreneurial opportunities play an mediating role between the big data analytic capabilities and the growth performance of start-up enterprises?

To address these research questions, this research framework is arranged as follows: in Section 2, a thorough literature review elucidates the definitions of variables pertaining to big data analytic capabilities, recognition, and exploitation of entrepreneurial opportunities, along with the presentation of hypotheses. Section 3 introduces the design of the questionnaire and the collection of data. Section 4 analyzes the data and validates the research hypotheses and model. Section 5 summarizes and reflects upon the limitations of this study, thereby proposing future research recommendations. Finally, Section 6 presents the conclusive findings of this paper.

2. Literature Review and Research Hypotheses

2.1. Big Data Analytic Capabilities and Growth Performance of Start-Up Enterprises

Big data are valuable and voluminous datasets, characterized by high volume, velocity, variety, and value, generated through activities such as transactions, interactions, and communications [22]. Presently, big data are considered a strategic resource of equal importance to land, labor, and capital. However, they do not confer a competitive advantage on their own and require further processing to endow enterprises with stronger insights and decision-making capabilities [23]. The ability to analyze big data is described as an organizational capability for companies to allocate, integrate, and leverage data resources [11]. By excavating, collecting, cleaning, and managing massive amounts of discrete data, enterprises can organize, integrate, and reconfigure internal and external resources to create potential commercial value in real time. According to the Resource-Based Theory, constructing unique, scarce, and difficult-to-imitate big data analytic capabilities is an effective way for enterprises to gain a competitive advantage [24]. Existing studies regard big data analytic capabilities as a complete set of resource capabilities [15,25,26], comprising tangible resources, human skills, and intangible resources. Tangible resources refer to big data technology, data, infrastructure, funding, and time resources. Big data human resources mainly refer to the skills of obtaining, integrating, analyzing, predicting, and applying big data formed by professional personnel. Big data intangible resources mainly include the data-driven decision-making culture and organizational synergy of the enterprise.

In the growth process of start-up enterprises, big data analytic capability plays a crucial role. On the one hand, it can assist enterprises in improving the scientific validity of their decisions. Compared to mature companies, start-up enterprises have a harder time withstanding the risks associated with decision-making errors [27]. Big data analytic capability has changed the traditional decision-making process, which was previously dominated by entrepreneurs. It enables companies to collect market data in real-time, filter useful information through processing and refinement, and ensure the completeness, accuracy, and timeliness of information. By making data-driven decisions, enterprises can better match market demand, reduce the risks of speculative behavior, greatly reduce uncertainty in the decision-making process, and improve their response to external environments, thus promoting business growth [10,28]. On the other hand, big data analytic capability can assist enterprises in optimizing their operational processes. It can help enterprises quickly identify the attributes of internal and external resources, achieve efficient allocation of entrepreneurial resources, reduce the cost of entrepreneurial activities, promote the establishment of modular business processes within the company, and build competitive advantages [29,30]. Meanwhile, analysis and monitoring of an organization's financial data and management operations can promptly and accurately detect problems and shortcomings in management activities, help companies improve business processes, coordinate and integrate production, supply, logistics, and warehousing, achieve refined and intelligent management, reduce operating costs, enhance operational efficiency, and improve business performance [31]. In conclusion, although the construction of big data analytic capabilities requires increased investment in enterprise digital infrastructure and talent, it can ultimately enhance the scientific validity of decision-making and operational

efficiency and promote rapid business growth. Based on this, this study proposes the following hypothesis:

Hypothesis 1 (H1). *The big data analytic capability has a significant positive impact on the growth performance of start-up enterprises.*

2.2. The Ability to Analyze Big Data and Recognize and Exploit Entrepreneurial Opportunities

The entrepreneurial process theory posits that entrepreneurial opportunities are the core element of the entrepreneurial process. Entrepreneurial activities are driven by entrepreneurial opportunities. However, entrepreneurial opportunities do not only exist in the initial stages of entrepreneurship. Start-up enterprises must continually seek new entrepreneurial opportunities throughout their growth process and rationally utilize and integrate resources to ensure balanced development [32]. Entrepreneurial opportunity is defined as a series of continuous dynamic processes that include the initial generation of commercial ideas to the point where entrepreneurs put them into action [33]. Recognizing and exploiting entrepreneurial opportunities correspond to two critical stages. Entrepreneurial opportunity recognition refers to the process by which entrepreneurs consciously and systematically collect, process, and identify information to promote the generation of commercial ideas. Entrepreneurial opportunity exploitation refers to the process by which entrepreneurs match opportunities with resources to create value [34]. With the advent of the digital age, entrepreneurial opportunities are increasingly fragmented and dynamic in nature [19]. "Fragmentation" means that diversified and personalized customer needs bring many small opportunities to the market, providing entrepreneurs with a wide range of opportunities and choices but also posing higher requirements for their information integration and processing capabilities. "Dynamic" means that market opportunities are not static but change with market and environmental changes. Therefore, entrepreneurs need to continuously monitor and discover market changes in order to identify and rapidly develop opportunities.

The big data analytic capabilities can enhance the level of enterprise information acquisition, processing, and analysis, providing strong support for the recognition of entrepreneurial opportunities. Kirzner [35] pointed out that no enterprise or individual can fully grasp market information, and the asymmetry of information in the market is the root cause of entrepreneurial opportunities. Therefore, the completeness of market information and the reserve of self-knowledge are important foundations for recognizing entrepreneurial opportunities. Start-up enterprises with a high level of big analytic capability tend to use big data technology to track changes in relevant customer demands, competitors' behaviors, and technological changes in real-time, collecting and integrating massive market information, which provides an information and knowledge basis for recognizing entrepreneurial opportunities [36]. In addition to acquiring market data, it is also necessary to interpret and extract the commercial value contained in these data to identify entrepreneurial opportunities [37]. Big data analysis technology can conduct in-depth analysis of collected data, explore potential customer needs, and gain insight into future market changes, thereby discovering unknown entrepreneurial opportunities in the market. In this digital era, data have become an important carrier of entrepreneurial opportunities. Leveraging the capability of big data analysis can realize the collection, processing, and analysis of data, reducing uncertainty in the recognition process and improving the success rate of recognizing entrepreneurial opportunities.

Unlike the recognition of entrepreneurial opportunities, the exploitation of entrepreneurial opportunities is more focused on the behavioral aspect of how opportunities create value for entrepreneurs. This is typically manifested in the process of transforming potential business ideas into new products, services, or business models through the allocation of resources [38]. Big data analytic capability also plays an important role in this process. By using big data analysis techniques, multidimensional and contextual modeling of customer data can be performed to analyze their interests, preferences, and consumption behavior, thus gaining insight into potential customer needs and predicting consumption

trends. This can lead to the development of products and services that better meet market demand [25]. Additionally, research indicates that big data analysis technology can be used for intelligent analysis and decision-making regarding customer positioning, product pricing, and inventory levels, leading to the optimization and reengineering of business processes [10]. Moreover, the big data analytic capability can help enterprises better understand the needs of their customers and partners. By sharing and exchanging market information with partners, real-time and efficient communication between producers, suppliers, and customers can be achieved, enabling various stakeholders to participate in the research, design, and production of products and services to optimize their values [39]. Based on these findings, the following hypothesis is proposed in this study:

Hypothesis 2 (H2). *The big data analytic capability has a significant positive impact on the recognition of entrepreneurial opportunities.*

Hypothesis 3 (H3). *The big data analytic capability has a significant positive impact on the exploitation of entrepreneurial opportunities.*

2.3. The Mediating Effect of Entrepreneurial Opportunities Recognition and Exploitation

Recognition of entrepreneurial opportunities is of paramount importance for the growth of start-up enterprises [40]. Khin and Lim [41] suggest that the level of entrepreneurial opportunity identification reflects a start-up enterprise's ability to discover opportunities and expand market potential, and thus the higher the level of opportunity recognition is, the more likely it is to succeed in entrepreneurship. However, in the context of digitization, entrepreneurial opportunities exhibit features of "fragmentation" and "dynamism", making it difficult for entrepreneurs to accurately identify such opportunities subjectively. Systemic big data analytic capabilities can help overcome the limitations of entrepreneurial cognition. Firstly, start-up enterprises equipped with big data analytic capabilities can conduct in-depth analysis and prediction of market data, gaining insights into unmet needs in the market [42]. Secondly, leveraging big data analytic capabilities, entrepreneurs can further evaluate the feasibility of establishing new businesses based on entrepreneurial opportunities and whether such businesses can bring sustained profits to the enterprise, thereby reducing risks and increasing returns [43]. Under the drive of big data analytic capabilities, start-up enterprises can be more keenly aware of market changes, identify valuable business opportunities, and thus promote their growth performance. Therefore, the recognition of entrepreneurial opportunities may serve as a mediator between big data analytic capabilities and the growth performance of start-up enterprises.

Based on the previous discussion, there exists a causal relationship between the big data analytic capability and the exploitation of entrepreneurial opportunities, as well as a causal relationship between the exploitation of entrepreneurial opportunities and the performance growth of start-up enterprises. Firstly, the ability to analyze big data can integrate internal and external data resources of the enterprise, mine the inherent value of data through in-depth analysis, predict the trend of market changes, and provide support and directional guidance for the exploitation of entrepreneurial opportunities [44]. Secondly, entrepreneurial opportunity exploitation is the process of transforming potential business opportunities into actual profits [45]. The exploitation of entrepreneurial opportunities can realize efficient resource allocation, enhance the competitive advantage of start-up enterprises through heterogeneous products, services, or business models, and thereby promote the performance growth of start-up enterprises [46]. Therefore, the exploitation of entrepreneurial opportunities may also serve as a mediator between the big data analytic capabilities and the growth performance of start-up enterprises.

Recognition and exploitation of entrepreneurial opportunities are two important stages in the process of entrepreneurship. Although not all entrepreneurial opportunities may be exploited, the recognition of entrepreneurial opportunities is a prerequisite for their development, providing the possibility for their realization [47]. Therefore, with the support of big data analytic capabilities, start-up enterprises can possibly improve their growth

performance through the recognition and exploitation of entrepreneurial opportunities. On the one hand, start-up enterprises can integrate, process, and analyze massive amounts of data with the help of big data analytic capabilities, continuously eliminating data uncertainty in this process. This facilitates the transformation of data into information and then into opportunities [8], enabling start-up enterprises to quickly and accurately identify entrepreneurial opportunities in a dynamic and complex market environment. On the other hand, for start-up enterprises, after recognizing valuable entrepreneurial opportunities, further consideration is required on how to deliver value to customers, satisfy customer needs, and produce definite products or services to enhance performance. Entrepreneurial opportunity exploitation essentially involves the integration and restructuring of resources and the mobilization of resources to create new value [48], providing a feasible path for the transformation of entrepreneurial opportunities into performance.

Based on the above discussions, the following hypotheses have been proposed:

Hypothesis 4 (H4). *Entrepreneurial opportunity recognition acts as a mediator between big data analytic capability and the growth performance of start-up enterprises.*

Hypothesis 5 (H5). *Entrepreneurial opportunity exploitation acts as a mediator between big data analytic capability and the growth performance of start-up enterprises.*

Hypothesis 6 (H6). *Entrepreneurial opportunity recognition and exploitation act as chain mediators between big data analytic capability and the growth performance of start-up enterprises.*

According to the above discussions and analyses, this study has formulated six hypotheses, which have formed the basis for constructing a model of the impact of big data analytic capability on the growth performance of start-up enterprises, as illustrated in Figure 1.

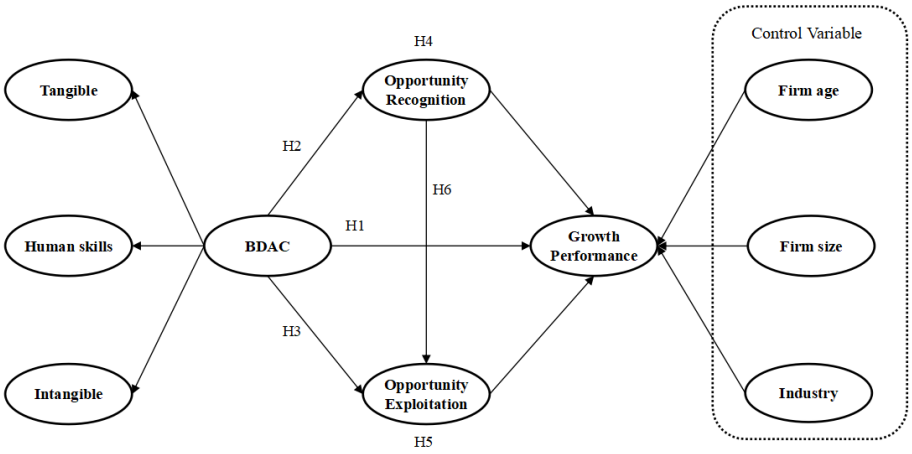

Figure 1. Conceptual model.

3. Research Design

3.1. Sampling and Data Collection

The quality of the sample directly determines the reliability of the research results. Therefore, this study employed a scientific questionnaire survey method to collect data. The purpose of this research is to investigate the mechanism of the effect of big data analytic capability on the growth performance of start-up enterprises. Drawing on the sampling methods of existing research samples, this study ultimately selected companies established for less than 8 years as research objects [49]. In order to expand the universality of the conclusions by covering regions with different levels of economic development, the survey range includes cities such as Beijing, Shanghai, Xi'an, Guangzhou, and Changchun, covering economically developed and underdeveloped cities comprehensively. Given that managers and IT (information technology) managers have a comprehensive understanding of the big data application and development of start-up companies, this study selected the

aforementioned two categories of personnel as survey objects in order to more accurately reflect the overall situation of the enterprise. The research team promised to strictly keep the questionnaire responses confidential and only use the data and results for scientific research purposes. Furthermore, specific information regarding companies or projects will not be disclosed in the research report to ensure the response rate of the questionnaire.

The research team utilized a diverse range of methods to gather data. They collaborated with big data research companies, utilized their personal networks, and employed both online and offline surveys to distribute invitations to participate in the survey to eligible businesses across China. A total of 559 questionnaires were distributed, resulting in 501 valid responses, yielding an effective response rate of 89.6%. The distribution of the sample is shown in Table 1. The industry classification was based on the "National Economic Industry Classification" issued by the Chinese government, which divided industries into two categories: the digital economy industry and the traditional industry. The digital economy industry includes computer communication and other electronic equipment manufacturing, telecommunications broadcasting and satellite transmission services, the internet and related services, and software and information technology services, while the non-digital economy industries are collectively referred to as traditional industries. In both industries, the digital economy sector has a higher proportion compared to the traditional sector. Among the samples in the digital economy sector, the highest number of newly established enterprises is in the internet and related services, accounting for 22.5% of the total samples. To some extent, this reflects the entrepreneurial trend in China, which benefits from the development of digital technology and the support of national policies. The digital economy industry is more favored by Chinese entrepreneurs.

Table 1. Distribution of samples.

Factors	Sample (N = 501)	Percentage (%)
Firm Age		
<1 year	24	4.8%
1–3 years	93	18.6%
3–5 years	126	25.1%
5–8 years	258	51.5%
Industry		
Digital Economy Industries:		
Computer communication and other electronic equipment manufacturing	99	19.8%
Telecommunications broadcasting and satellite transmission services	8	1.6%
The internet and related services	113	22.5%
Software and information technology services	80	16.0%
Traditional industries	201	40.1%
Firm Size (Number of employees)		
<50	142	28.3%
50–100	162	32.3%
101–500	116	23.2%
>501	81	16.2%

3.2. Variable Measurement

This questionnaire drew upon previously developed and highly reliable and valid mature scales and appropriately revised some of the measurement items based on suggestions from professional scholars and business practitioners to enhance the scientificity of the items. With this, a survey questionnaire was designed, which includes variables such as big data analytic capabilities, entrepreneurial opportunity recognition, entrepreneurial opportunity exploitation, and start-up enterprise growth performance. In terms of the measurement methods, this study employed Likert's 7-point scaling method to measure respondents' response, where 1 denotes "completely disagree" and 7 denotes "completely agree", with higher scores indicating a higher level of agreement with the measurement items. Among these, big data analytic capabilities were based on the scales of Mikalef,

Pappas, Krogstie and Pavlou [23], and Lin and Kunnathur [26], including three dimensions of tangible resources, human skills, and intangible resources, with a total of 14 items; entrepreneurial opportunity recognition utilized the scale of Ozgen and Baron [50], with three items; entrepreneurial opportunity exploitation borrowed from the scales of Kuckertz, Kollmann, Krell and Stöckmann [48], and Chen and Liu [51], with a total of five items; and start-up enterprise growth performance adopted the scale of Adomako, et al. [52], which comprehensively evaluates the growth of start-up enterprises from four aspects: sales, number of employees, operating profit, and market share. The scales and item lists can be found in Appendix A.

Furthermore, due to the sizable sample of this study, the research findings may vary depending on the distinct features of the enterprises' background. Therefore, it is imperative to control the factors that may have an impact on this study to ensure its accuracy. The longevity and scale of the enterprises are closely related to their resources and capabilities, which could potentially affect their growth performance [53]. Similarly, the speed of development and evolution of an enterprise may also differ depending on the industry to which it belongs [54]. This is especially relevant in the context of China's thriving economy, where the digital economy industry, due to its unique industry attributes and government support policies, typically possesses stronger big data analytic capabilities and faster growth rates than other industries. Therefore, in summary, this study selects the enterprises' age, size, and industry type as control variables.

4. Results

4.1. Reliability Test

Table 2 presents the reliability test results of the scale used in this study. The research findings indicate that the corrected item total correlations between each item and construct are all greater than 0.5, suggesting that the scores of items within each construct can be regarded in a similar range to each other [55]. Moreover, the Cronbach's α values for each constructs are all above 0.8, and the Cronbach's α values did not increase after deleting any item, indicating that all items in this study can be retained. Overall, these results demonstrate that the data possess good reliability and are suitable for further analysis.

Table 2. Results of reliability test.

Construct	Items	Corrected Item Total Correlation	Cronbach's Alpha If Item Deleted	Cronbach's Alpha
Tangible	T1	0.772	0.908	0.921
	T2	0.802	0.901	
	T3	0.806	0.900	
	T4	0.781	0.906	
	T5	0.819	0.898	
Human Skills	HS1	0.780	0.912	0.925
	HS2	0.797	0.909	
	HS3	0.825	0.903	
	HS4	0.809	0.906	
	HS5	0.807	0.907	
Intangible	I1	0.757	0.879	0.900
	I2	0.788	0.867	
	I3	0.763	0.876	
	I4	0.804	0.861	
Opportunity Recognition	OR1	0.696	0.744	0.825
	OR2	0.667	0.772	
	OR3	0.682	0.759	

Table 2. *Cont.*

Construct	Items	Corrected Item Total Correlation	Cronbach's Alpha If Item Deleted	Cronbach's Alpha
Opportunity Exploitation	OE1	0.757	0.879	0.909
	OE2	0.788	0.867	
	OE3	0.763	0.876	
	OE4	0.804	0.861	
	OE5	0.611	0.891	
Growth Performance	GP1	0.767	0.869	0.897
	GP2	0.737	0.880	
	GP3	0.782	0.864	
	GP4	0.800	0.857	

4.2. Exploratory Factor Analysis

This research used SPSS 24.0 to conduct Kaiser–Meyer–Olkin (KMO) test and Bartlett's sphericity test, as indicated in Table 3. The KMO values of each construct ranged from 0.721 to 0.904, all of which were above the threshold value of 0.5. Furthermore, the significance level of Bartlett's sphericity test was less than 0.05, and the Bartlett's sphericity tests for all constructs were significant. This indicates that all constructs are suitable for factor analysis [56,57]. Consequently, principal component analysis was further employed to conduct factor analysis on each construct. The results showed that each construct could only extract one factor with an eigenvalue greater than 1, and the cumulative variance contribution rate of each construct was higher than 50%. This indicates that the factors extracted in this study can provide a good explanation for each construct. Moreover, all items' commonalities were greater than 0.5, and their factor loadings were greater than 0.6, which falls within the range of suggested values from previous studies [58]. Overall, the scale used in this study demonstrates good unidimensionality.

Table 3. Results of exploratory factor analysis.

Construct	Items	KMO	Bartlett's Sphere Test	Commonality	Factor Loading	Eigenvalue	Total Variation Explained
Tangible	T1	0.897	0.000	0.732	0.855	3.805	76.10%
	T2			0.770	0.877		
	T3			0.774	0.880		
	T4			0.742	0.861		
	T5			0.788	0.887		
Human Skills	HS1	0.904	0.000	0.740	0.860	3.845	76.90%
	HS2			0.761	0.872		
	HS3			0.795	0.892		
	HS4			0.776	0.881		
	HS5			0.773	0.879		
Intangible	I1	0.838	0.000	0.746	0.863	3.083	77.07%
	I2			0.781	0.884		
	I3			0.755	0.869		
	I4			0.801	0.895		
Opportunity Recognition	OR1	0.721	0.000	0.756	0.869	2.225	74.16%
	OR2			0.726	0.852		
	OR3			0.742	0.862		
Opportunity Exploitation	OE1	0.893	0.000	0.753	0.868	3.663	73.26%
	OE2			0.708	0.841		
	OE3			0.729	0.854		
	OE4			0.735	0.857		
	OE5			0.739	0.859		

Table 3. *Cont.*

Construct	Items	KMO	Bartlett's Sphere Test	Commonality	Factor Loading	Eigenvalue	Total Variation Explained
Growth Performance	GP1	0.840	0.000	0.760	0.872	3.059	76.47%
	GP2			0.725	0.851		
	GP3			0.778	0.882		
	GP4			0.797	0.893		

4.3. Confirmatory Factor Analysis

The present study utilized IBM AMOS software for confirmatory factor analysis. Firstly, factor loadings of each item on the corresponding construct were obtained through confirmatory factor analysis. If the factor loading exceeds 0.5, it indicates that all items within each construct consistently explain themselves [59]. Next, composite reliability (CR) and average variance extracted (AVE) were computed based on factor loadings of each item. According to Hair [60] suggestion, the CR value should not be less than 0.7, and additionally, 0.5 is the minimum standard for both SMC and AVE values [61,62]. As shown in Table 4, the factor loadings in this study were all above 0.7, CR values were all above 0.8, and both SMC and AVE values were above 0.6, indicating good convergent validity of the related constructs.

Table 4. Results of convergent validity.

Construct	Items	Factor Loading	SMC	AVE	CR
Tangible	T1	0.805	0.648	0.701	0.921
	T2	0.833	0.694		
	T3	0.851	0.724		
	T4	0.827	0.684		
	T5	0.869	0.755		
Human Skills	HS1	0.826	0.682	0.712	0.925
	HS2	0.843	0.711		
	HS3	0.870	0.757		
	HS4	0.842	0.709		
	HS5	0.836	0.699		
Intangible	I1	0.811	0.658	0.695	0.901
	I2	0.834	0.696		
	I3	0.825	0.681		
	I4	0.864	0.746		
Opportunity Recognition	OR1	0.792	0.627	0.613	0.826
	OR2	0.769	0.591		
	OR3	0.788	0.621		
Opportunity Exploitation	OE1	0.834	0.696	0.666	0.909
	OE2	0.787	0.619		
	OE3	0.818	0.669		
	OE4	0.818	0.669		
	OE5	0.822	0.676		
Growth Performance	GP1	0.829	0.687	0.687	0.897
	GP2	0.777	0.604		
	GP3	0.849	0.721		
	GP4	0.857	0.734		

Based on the suggestion of Fornell and Larcker [62], this study examines the discriminant validity of the scale by comparing the correlation coefficients between constructs and the square root of the AVE. If the square root of AVE is higher than the correlation coefficients between constructs, the scale has good discriminant validity. As shown in Table 5, there are significant correlations between the main constructs of this study: Tangible (T), Human Skills (HS), Intangible (I), Opportunity Recognition (OR), Opportunity Exploitation (OE), and Growth Performance (GP), and the square root of AVE is greater

than the correlation coefficients between constructs. Therefore, it can be concluded that the discriminant validity among the constructs of the scale is good.

Table 5. Results of discriminant validity.

	Firm Age	Industry	Firm Size	T	HS	I	OR	OE	GP
Firm Age	—								
Industry	0.263 **	—							
Firm Size	0.377 **	0.095 *	—						
T	−0.033	−0.332 **	0.036	**0.837**					
HS	−0.002	−0.312 **	0.011	0.825 **	**0.844**				
I	0.006	−0.266 **	0.005	0.791 **	0.811 **	**0.834**			
OR	0.052	−0.205 **	−0.042	0.645 **	0.650 **	0.692 **	**0.783**		
OE	0.026	−0.243 **	0.000	0.728 **	0.769 **	0.762 **	0.743 **	**0.816**	
GP	−0.020	−0.279 **	0.045	0.712 **	0.685 **	0.707 **	0.684 **	0.763 **	**0.829**

Note: * significant at $p < 0.05$; ** significant at $p < 0.01$.

4.4. Model Fit Test

The fit indices obtained from confirmatory factor analysis are commonly used standards for evaluating the validity of a scale. According to Kline [63] and Whittaker [64], if the ratio of chi-square to degree of freedom is less than 5, RMSEA is less than 0.08, SRMR is less than 0.08, and if GFI, AGFI, NFI, and CFI values are all greater than 0.9, then the model fits well. As shown in Table 6, this study found that all indicators of the model were within the suggested range, indicating a high degree of fit between the model and data. Therefore, it can be inferred that the scale has good construct validity.

Table 6. Results of confirmatory factor analysis.

Common Indices	χ^2/df	RMSEA	GFI	AGFI	NFI	CFI	SRMR
Judgment criteria	<5	<0.08	>0.9	>0.9	>0.9	>0.9	<0.08
CFA Value	1.581	0.034	0.937	0.922	0.960	0.985	0.020

4.5. Hypotheses Validation

This study used structural equation modeling to conduct path analysis and examine the proposed hypotheses. The results of the model's path analysis can be found in Figure 2, while the regression coefficient results of the structural equation model can be found in Table 7. The findings indicate that hypotheses H1, H2, and H3 are all supported. Additionally, it was found that firm size significantly facilitates the growth performance of the company ($\beta = 0.074$, $p < 0.05$). This suggests that the control variables used in our study have a certain explanatory power over the growth performance of enterprises. Therefore, it is necessary to control these variables during the computation process.

This study further employs Bootstrap analysis to examine the mediating effects and chained mediating effects in the model. The hypotheses are validated by observing the confidence interval (95%) in the output results. According to Hayes [65], if the upper and lower bounds of the confidence interval (95%) do not contain 0, then the hypothesis is considered to be supported. In this study, the Bias-corrected Percentile method is used to conduct 2000 times sampling in the confidence interval of 95%. The results, shown in Table 8, indicate that the mediating path (BDAC → OR → GP) has a confidence interval of 95% of [−0.006, 0.386], which includes 0, with a p-value of 0.054 (>0.05). Thus, hypothesis H4 is not supported. The confidence interval for the mediating path (BDAC → OE → GP) is [0.054, 0.404], and the confidence interval for the chained mediating path (BDAC → OE → OR → GP) is [0.045, 0.272], both of which do not contain 0, and the p-values are less than 0.05. Therefore, hypotheses H5 and H6 are supported.

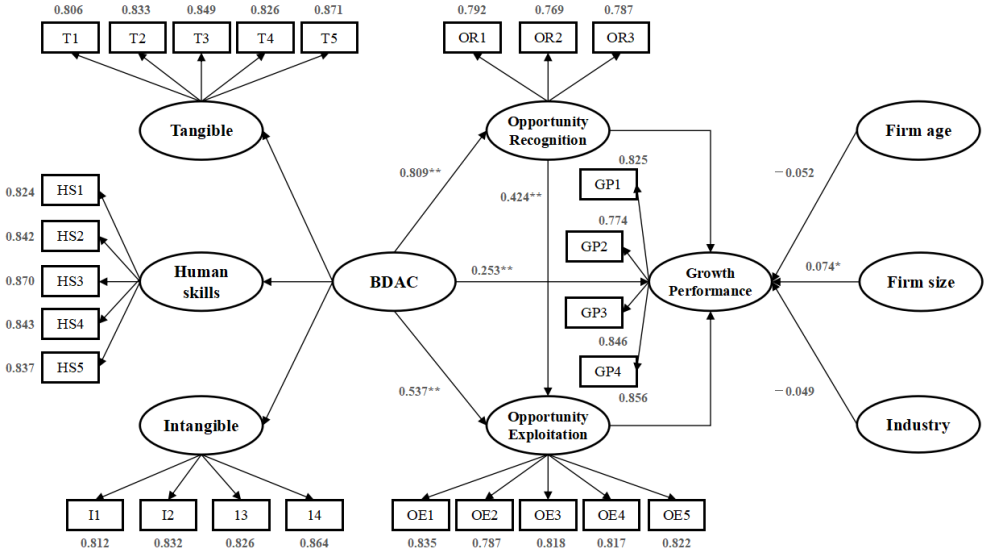

Figure 2. The impact model of big data analytic capabilities on the growth performance of start-up enterprises. Note: * significant at $p < 0.05$; ** significant at $p < 0.01$.

Table 7. Results of direct effect.

Hypothesis	Relationship	Path Coefficient	*SE*	*p*	Support
H1	BDAC → GP	0.253	0.073	0.002	Yes
H2	BDAC → OR	0.809	0.043	0.000	Yes
H3	BDAC → OE	0.537	0.059	0.000	Yes
	Firm Age → GP	−0.052	0.035	0.097	No
	Firm Size → GP	0.074	0.030	0.015	Yes
	Industry → GP	−0.049	0.064	0.109	No

Note: BDAC, big data analytic capabilities; GP, growth performance; OR, opportunity recognition; OE, opportunity exploitation.

Table 8. Results of mediation effect.

Hypothesis	Relationship	Path Coefficient	*SE*	Bias-Corrected Percentile 95%CI		*p*	Support
				Lower	Upper		
H4	BDAC → OR → GP	0.181	0.095	−0.006	0.386	0.054	No
H5	BDAC → OE → GP	0.203	0.086	0.054	0.404	0.012	Yes
H6	BDAC → OE → OR → GP	0.130	0.055	0.045	0.272	0.009	Yes

Note: BDAC, big data analytic capabilities; GP, growth performance; OR, opportunity recognition; OE, opportunity exploitation.

5. Discussion, Contribution, and Limitations

5.1. Discussion

This study examined the relationship between big data analytic capability, entrepreneurial opportunity recognition, entrepreneurial opportunity exploitation, and the growth performance of 501 start-up enterprises through empirical research. The results of this study revealed the impact mechanism of big data analytic capability on the growth performance of start-up enterprises. Among the six hypotheses, all but H4 were supported by the research findings. The detailed discussion is as follows.

Firstly, the big data analytic capabilities have a significant positive impact on the growth performance of start-up enterprises (H1 is supported). The findings of this study once again confirm the empirical research conclusions in the literature of business management regarding the relationship between the big data analytic capabilities and growth performance [10,66,67], which mainly focused on the relationship between big data analytic capabilities and enterprise performance, and emphasized providing theoretical and

practical guidance for the digital transformation of enterprises. In contrast, this study focused on start-up enterprises in the micro market and has demonstrated positive results. This suggests that with the development and popularization of big data technology, its application scenarios have been further expanded. Big data analytic capabilities can not only support the digital transformation of mature enterprises but also play an important role in the survival and development of start-up enterprises. This aligns perfectly with the perspective of how digital technology fosters entrepreneurial activities [4,68].

Secondly, the big data analytic capabilities have a significant positive impact on the recognition and exploitation of entrepreneurial opportunities (H2 and H3 are supported). Previous researchers have primarily focused on the impact of individual cognitive abilities of entrepreneurs on the recognition and exploitation of entrepreneurial opportunities [69,70]. However, with the advancement of the economy, fragmentation and dynamism have emerged as two prominent characteristics of entrepreneurial opportunities in the digital era [71]. Relying solely on the individual cognitive abilities of entrepreneurs has become increasingly challenging in accurately identifying highly dispersed and transient entrepreneurial opportunities. This study shifts its focus from the abilities of individual entrepreneurs to the capabilities possessed by the enterprises. The findings suggest that big data analytic capabilities can aid enterprises in rapidly integrating market information, while the big data mining techniques can help them discover the underlying business value, thereby assisting enterprises in recognizing and exploiting entrepreneurial opportunities in the market. The existing literature has yet to explore the relationship between the big data analytic capability and the recognition and exploitation of entrepreneurial opportunities, and this conclusion to some extent fills the research gap in this relevant field.

Thirdly, the recognition and exploitation of entrepreneurial opportunities play a mediating role between big data analytic capabilities and the growth performance of start-up enterprises (H6 is supported). The exploitation of entrepreneurial opportunities has a significant mediating effect between big data analytic capabilities and the growth performance of start-up enterprises (H5 is supported), which validates the viewpoint proposed by Yang, et al. [72] that IT capability, through entrepreneurial opportunity exploration, can influence entrepreneurial performance.

However, the mediating effect of the recognition of entrepreneurial opportunities between big data analytic capabilities and the growth performance of start-up enterprises is not significant (H4 is not supported). This may be because, although new entrepreneurial enterprises can recognize commercial opportunities in the market through big data analytic capabilities, opportunities cannot generate profits for enterprises before they are exploited. The core of enterprise growth lies in how to use opportunities to gain more profits. After recognizing entrepreneurial opportunities, enterprises need to invest manpower and financial support in exploiting these opportunities and improve or innovate products and services based on new entrepreneurial opportunities to improve their market competitiveness, which also partially elucidates the paradoxical phenomena observed in related research findings regarding IT investment and productivity enhancement [73,74]. Although big data analytic capabilities can increase the probability of recognizing entrepreneurial opportunities, if enterprise resources cannot match opportunities and exploit them effectively, then big data analytic capabilities cannot effectively promote the growth performance of start-up enterprises.

5.2. Theoretical Contribution

This study focuses on start-up enterprises in the digital era and constructs an integrated model of the impact of big data analytic capabilities on the growth performance of start-up enterprises by combining relevant theories and the literature and conducting empirical tests. It has the following theoretical significance: first, the category of big data analytic capabilities has received considerable attention from scholars in the field of information systems research. This study extends this category to the field of digital entrepreneurship and, based on the resource-based theory, verifies the positive effect of big data analytic

capabilities on the growth performance of start-up enterprises, enriches the theoretical connotation of big data analytic capabilities, and expands the research content of big data analytic capabilities. Second, based on the theory of the entrepreneurial process, this study proposes the internal relationship pathway of the impact of big data analytic capabilities on the growth performance of start-up enterprises. Currently, the relationship between big data analytic capabilities and enterprise growth performance has received attention from the academic community [10,66,67]. However, existing research lacks in-depth exploration of the internal relationship pathway between big data analytic capabilities and the growth performance of start-up enterprises. Based on the logic of "ability-behavior-performance," this study explores the mediating mechanism of entrepreneurial opportunity recognition and entrepreneurial opportunity exploitation in the relationship between big data analytic capabilities and the growth performance of start-up enterprises. It provides enlightening significance for opening the black box of the effect mechanism of big data analytic capabilities on the growth performance of start-up enterprises and fills the deficiency of existing research in explaining the internal mechanism between the two.

5.3. Practical Implication

The conclusion of this article provides important practical insights for empowering entrepreneurial practice with big data analytic capabilities. Firstly, start-up enterprises should focus on cultivating big data analytic abilities. On the one hand, start-up enterprises should target the construction of big data software and hardware resources based on their own conditions and business needs. This can be achieved by learning and updating big data technologies, introducing skilled personnel in big data and management, and fostering a culture of learning within the organization to lay the foundation for enhancing big data analytic abilities. On the other hand, start-up enterprises need to cultivate a culture of big data and digital thinking internally, actively explore the potential value of big data, and proactively engage in innovative activities of data empowerment to provide diversified options for enterprises to adapt to digital environmental changes. Additionally, start-up enterprises should pay attention to the protection of user privacy when using data, avoid excessive collection and misuse of data, and ensure the reasonable and compliant application of big data.

Secondly, start-up enterprises should attach importance to the critical role of big data analytic capabilities in entrepreneurial opportunity recognition and exploitation in relation to enterprise growth performance. First of all, start-up enterprises should make full use of data collection techniques and integrate internal enterprise data, market data, user data, etc., to provide data-based foundations for recognizing entrepreneurial opportunities. Additionally, mining and analyzing data can provide insights into changes in market demand, recognizing potential entrepreneurial opportunities and providing directional guidance to entrepreneurs. Finally, based on recognized entrepreneurial opportunities, outputs should be made that consist of heterogeneous products, services, and business models to better meet customer needs, thereby increasing the probability of entrepreneurial success.

Thirdly, although big data analytic capabilities are of significant importance to the development of start-up enterprise, building these capabilities requires additional investment. This presents a dilemma for start-up enterprises. Therefore, government departments should encourage and support the application of big data in entrepreneurship and create a good entrepreneurial environment. First, there should be increased investment in basic infrastructure such as big data public information platforms and regional cloud computing centers to help start-up enterprises reduce data acquisition costs and expand data acquisition channels. In addition, start-up enterprises should be encouraged to engage in digital and intelligent construction through policy incentives, financial support, tax concessions, credit support, etc., to help start-up enterprises overcome development and financing difficulties. Yet more, it is necessary to improve the institutional environment that is conducive to digital entrepreneurship in order to help entrepreneurs remove cultural and institutional constraints, create a fair and orderly market competition environment,

standardize data activities, improve the data security governance system, safeguard the secure circulation of data, and help create a good ecological environment for data mutual benefit for all parties involved.

5.4. Limitations and Future Studies

Although the research results of this study have certain theoretical contributions and practical implications, due to time and length constraints, there are still some limitations, mainly reflected in the following aspects, which need to be improved in future research.

To begin with, the survey sample has limitations. The focus of this study is on newly registered start-up enterprises within China. Future researchers can further expand the scope of the survey to study enterprises in other countries and regions to expand the adaptability of the conclusions. Additionally, the survey process has limitations. The data collected and analyzed through questionnaire surveys in this article are subjective static cross-sectional data, which can only reflect the current situation of a certain time point of start-up enterprises. However, the growth of start-up enterprises is a dynamic and evolving process, and this processing method cannot reflect more accurate and dynamic rules or describe the sustained impact of variables. Therefore, future research can analyze data of enterprises at different development stages through longitudinal tracking to enhance the effectiveness and credibility of research conclusions. Lastly, the integrated model has limitations. This study has constructed a model for the mechanism of the impact of big data analytic capabilities on the growth performance of start-up enterprises. It has verified the chain-mediated effect of entrepreneurial opportunity recognition and exploitation. However, the process by which big data analytic capabilities impact the growth performance of startup enterprises may be a complex process with multiple factors and influence paths. Therefore, in the future, different research perspectives can be explored, considering whether the integration of other intermediate or moderating variables into the model can further improve and enrich the integrated framework and research findings proposed in this paper.

6. Conclusions

This study draws the following conclusions: first, there is a significant positive correlation between big data analytic capabilities and growth performance of start-up enterprises; second, there is a significant positive correlation between big data analytic capability and entrepreneurial opportunity recognition and entrepreneurial opportunity exploitation; third, entrepreneurial opportunity recognition and entrepreneurial opportunity exploitation play a chain mediating role in the relationship between big data analytic capability and growth performance of start-up enterprises. This study provides a theoretical framework, which has certain reference value for guiding start-up enterprises to build big data analytic capabilities, recognize entrepreneurial opportunities in the digital environment, and improve growth performance through entrepreneurial opportunity exploitation.

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Appendix A

Table A1. Checklist of variables items.

Variable	Items
Big Data Analytic Capabilities [23,26]	Tangible T1 We can promptly acquire the data required by enterprises. T2 We can analyze massive, unstructured, or highly dynamic data. T3 We can introduce or develop professional techniques such as data storage, data mining algorithms, and visualization. T4 We allocate sufficient funds to support big data analytics projects. T5 We dedicate ample time to achieve the goals set in big data analytics projects. Human Skills HS1 We are able to introduce or cultivate sufficient professionals with expertise in data analysis. HS2 Our professionals have the fundamental skills required for conducting big data analysis. HS3 We are capable of mining and analyzing data to extract valuable information. HS4 We are able to identify potential customer needs through big data analysis. HS5 We can accurately predict market development trends through big data analysis. Intangible I1 We have a corporate culture that supports the application of big data. I2 Our senior executives have a positive stance towards implementing big data. I3 We are capable of using big data analysis to support the production and operational activities of the company. I4 We can utilize big data analysis to support management decision-making.
Opportunity Recognition [50]	OR1 In handling daily work, we generate new ideas (e.g., new ideas about products/services, markets, and management models). OR2 We remain vigilant and sensitive to new opportunities (e.g., new ideas about products/services, markets, and management models). OR3 Discovering potential opportunities (as mentioned above) is not a difficult task for us.
Opportunity Exploitation [48,51]	OE1 We provide sufficient manpower support for developing new business opportunities. OE2 We invest funds to develop new business opportunities. OE3 Based on new business opportunities, we improve or innovate products and services. OE4 Based on new business opportunities, we adjust or innovate management models. OE5 Based on new business opportunities, we explore new markets.
Growth Performance [52]	GP1 Our sales growth is faster compared to our competitors. GP2 Our employee growth rate is faster compared to our competitors. GP3 Our operating profit growth is faster compared to our competitors. GP4 Our market share growth rate is faster compared to our competitors.

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