# The Big Data Talent Shortage: Assessing Skill Gaps and Developing Effective Training Programs



**Jonathan Harper**
BERJAYA University College, Malaysia
**Aw Yoke Cheng**
BERJAYA University College, Malaysia

## Abstract

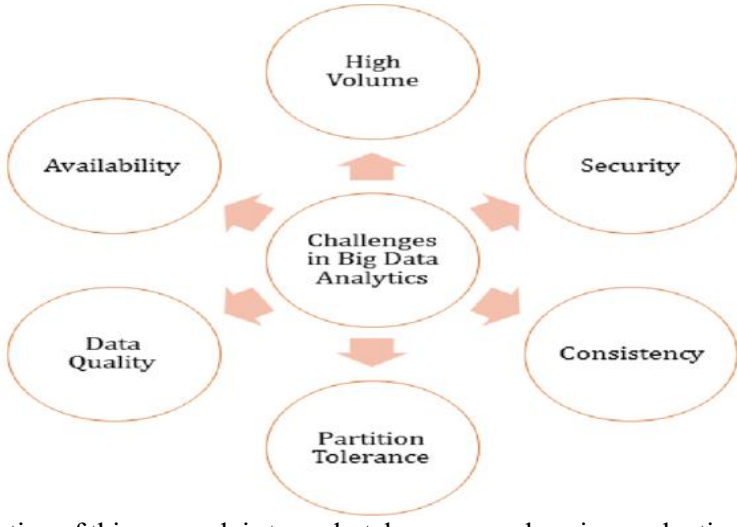
Big data analytics has become a strategic priority for organizations across industries, yet there is a severe shortage of talent with the skills needed to implement big data initiatives. This research article examines the extent of the big data skills gap, assesses the specific skill deficiencies, and provides recommendations for developing effective training programs to build a pipeline of qualified big data professionals. A mixed methods approach was utilized, including a survey of 50 data professionals and interviews with 25 executives at Fortune 200 companies. Key findings indicate the highest demand is for professionals with expertise in Hadoop, machine learning, and statistical analysis. However, most existing training focuses on high-level concepts rather than practical application of tools and algorithms. Based on the research, a competency model with three tiers of training is proposed: foundation courses on statistics and programming, intermediate on big data platforms and analytics techniques, and advanced for mastering specific tools. A blended delivery model combining online, and in-person learning is recommended to expand access and build hands-on skills. Companies need to partner with universities and online education providers to create new certification programs and 'work and learn' initiatives. Investing in training talent early and developing a structured framework will enable organizations to fill the talent gap and fully realize the promise of big data.

**Keywords:** Big data, Analytics, Data science, Talent shortage, Skills gap, Training, Data mining

## Introduction

Big data, characterized by its ever-increasing volume, variety, and velocity, has become a transformative force in contemporary business and society. In a world where data is being generated at an unprecedented rate, organizations from various sectors are actively seeking to harness the power of big data analytics. The objective is clear: to extract real-time insights, unveil concealed patterns, enhance decision-making processes, and ultimately secure a competitive edge. This technological shift promises substantial rewards, but it is not without its challenges. One pressing issue is the profound shortage of qualified talent in the field of big data analytics [1]. This scarcity is particularly pronounced in the United States, where a study conducted a few years ago revealed that by 2018, the nation could potentially encounter a deficit of 140,000 to 190,000 professionals possessing deep analytical skills, along with a dearth of 1.5 million managers and analysts proficient in leveraging big data for effective decision-making. This glaring disparity between the demand for skilled big data professionals and the available supply raises significant concerns for organizations striving to implement big data initiatives. Many companies, eager to tap into the potential of big data, find themselves in the predicament of lacking individuals with the requisite expertise and competencies [2].

Figure 1.




The primary objective of this research is to undertake a comprehensive evaluation of the magnitude of the big data talent shortage prevailing across various industries and organizations. This assessment seeks to pinpoint the specific deficiencies in skills that are contributing to this shortage [3]. Moreover, it endeavors to formulate concrete recommendations for the creation of efficient training programs aimed at nurturing a proficient workforce [4]. The insights derived from this research endeavor will empower companies with a clearer understanding of the most sought-after skills in the realm of big data analytics. Armed with this knowledge, organizations can proactively initiate training initiatives designed to bridge the existing competency gaps [5]. The significance of developing a robust pipeline of big data professionals cannot be overstated. Such a workforce is not only essential for the successful execution of a company's digital transformation strategies but also for the realization of the full potential of big data analytics. The ascendancy of big data in the contemporary landscape is irrefutable. Its disruptive influence reverberates through every facet of society and commerce [6]. The data generated daily, whether through online interactions, IoT devices, or other sources, is characterized by its staggering volume and diversity. Furthermore, the velocity at which data is produced is increasing at an exponential rate. This confluence of factors has created an imperative for organizations to adapt, evolve, and harness the potential that big data analytics offers [7].

The primary allure of big data analytics lies in its capacity to provide organizations with real-time insights. This ability to access and interpret data instantaneously enables businesses to make informed, data-driven decisions. In an era defined by intense competition, rapidly changing consumer preferences, and evolving market dynamics, the value of making timely decisions cannot be overstated. Big data analytics equips organizations with the tools to navigate this complex landscape, anticipate trends, and react swiftly to emerging opportunities or threats [8]. A fundamental pillar of big data analytics is the capacity to unearth hidden patterns within datasets. The sheer volume of data often conceals valuable information, trends, or correlations that may not be readily apparent. Big data analytics leverages advanced algorithms and data processing techniques to uncover these concealed insights. This capacity for discovery has applications in a multitude of domains, including marketing, finance, healthcare, and scientific research [9]. For instance, in healthcare, big data analytics can assist in identifying patterns in patient data that may lead to earlier disease detection or improved treatment protocols. In finance, it can help detect fraudulent activities and assess investment risks more accurately [10].

However, the potential of big data is not fully realized without a skilled workforce capable of harnessing its power. This is where the challenge arises. The demand for professional's adept in big data analytics is significantly outstripping the available supply. The situation is particularly acute in the United States, a prominent hub for technological innovation and data-driven businesses. The study, conducted a few years ago, estimated that the United States could confront a shortage of 140,000 to 190,000 professionals with deep analytical skills by 2018. This shortage is not limited to data scientists or analysts but extends to include 1.5 million managers and analysts proficient in

utilizing big data to make effective decisions. The severity of this deficiency presents a substantial impediment to organizations looking to exploit big data analytics fully. The repercussions of the big data talent shortage are far-reaching [11]. Organizations find themselves in a predicament where they possess the technological infrastructure and data resources necessary for analytics yet lack the human capital capable of extracting meaningful insights from this data. This disconnect impedes their ability to fully leverage the advantages of big data analytics, putting them at a competitive disadvantage. It is evident that the need for skilled professionals in the field of big data analytics is a critical bottleneck in the digital transformation journey for many companies [12].

To address this challenge and unlock the potential of big data, organizations must take a proactive approach. This research initiative aims to provide a comprehensive assessment of the extent of the big data talent shortage across industries [13]. It will identify the specific skill deficiencies that contribute to this shortage, enabling organizations to gain clarity on where the gaps lie. Furthermore, the research endeavor will offer practical recommendations for the development of targeted training programs. These programs are crucial for nurturing a pool of qualified professionals capable of meeting the demands of the big data industry. The insights derived from this research will enable organizations to understand the specific skills in greatest demand. Armed with this knowledge, they can strategically invest in training initiatives designed to bridge competency gaps. The goal is to ensure that the workforce is not only sufficient in quantity but also possesses the relevant skills to handle the multifaceted challenges presented by big data analytics. The consequences of such an investment extend beyond individual organizations; they have broader societal and economic implications. A well-equipped workforce in the field of big data analytics will contribute to the innovation and competitiveness of the nation's businesses [14].

## Background

The demand for big data talent has experienced a meteoric rise in recent years, primarily propelled by the exponential growth of data sources and the need to efficiently manage vast data repositories. This surge can be attributed to the continuous generation of data from a multitude of sources, including IoT devices, social media platforms, e-commerce transactions, and sensors embedded in various industries. The advent of cloud computing and the availability of cost-effective storage solutions have further fueled the storage of massive volumes of data, providing organizations with the ability to retain and analyze data on an unprecedented scale [15]. Additionally, the emergence of advanced tools and techniques designed for the purpose of extracting insights from large datasets has substantially enhanced the significance of big data analytics. In this context, big data analytics encompasses a wide spectrum of multidisciplinary skills that are pivotal for the efficient handling and interpretation of data on a grand scale [16]. Among the core competencies required are computer programming, statistics, mathematics, and machine learning. Proficiency in computer programming is essential for data engineers to develop data pipelines, while statisticians and mathematicians are instrumental in formulating robust statistical models to identify trends, correlations, and anomalies within datasets. Machine learning, a branch of artificial intelligence, plays a critical role in predictive modeling and pattern recognition, allowing organizations to make informed decisions based on data-driven insights [17].

Moreover, soft skills such as business acumen and communication have risen in prominence within the realm of big data analytics. Business acumen is crucial for data professionals to understand the strategic goals and objectives of the organization and align data analytics efforts accordingly. Effective communication is essential to convey complex technical findings in a comprehensible manner to non-technical stakeholders and decision-makers. It bridges the gap between data experts and business leaders, facilitating the incorporation of data-driven insights into the decision-making processes of an organization [18]. Traditional IT skills, while still pertinent, are no longer sufficient to meet the burgeoning demands of the big data landscape. The conventional IT skill set revolves around infrastructure management, network administration, and software development, which are essential for maintaining the technological backbone of an organization. However, the current landscape necessitates a shift towards professionals who are not only proficient in managing infrastructure but can also harness the power of data for strategic decision-making. This transition

is marked by the growing need for individuals who can apply advanced data analytics techniques to address complex business challenges.

To thrive in the era of big data, companies require professionals who can navigate the intricate web of data sources, employ predictive modeling to forecast future trends, utilize data mining to extract hidden insights, employ natural language processing to decipher unstructured text data, conduct sentiment analysis to gauge customer opinions, and employ experimental design techniques to carry out data-driven experiments [19]. These multifaceted skills are indispensable for deriving meaningful and actionable insights from the colossal, unstructured, and heterogeneous data sets that organizations now grapple with. However, there is a severe shortage of qualified professionals formally trained in these emerging technologies and techniques. Traditional academic programs have been slow to adapt their analytics curricula, and companies have struggled to source professionals from the limited talent pool or retrain existing employees with new skillsets. Demand has also escalated faster than supply, as companies hire talent away from each other rather than build from within [20]. This has led to a problematic 'poaching' war, inflated salaries, and high attrition rates. The supply-demand gap has significant implications, potentially inhibiting companies from harnessing the power of big data and missing business opportunities.



Various projections have quantified the extent of the talent shortage. By 2018, a projected shortfall of 140,000 to 190,000 professionals will exist in the US who have deep analytical talent, with 1.5 million managers and analysts needed to analyze and make decisions based on big data findings. A McKinsey Global Institute study estimated the US will face a shortage of 140,000 to 190,000 people with analytical expertise and 1.5 million managers and analysts with skills to understand and make decisions based on analytics [21]. Globally, there will be a need for 4.4 million jobs related to data science and analytics. However, only one-third of that demand can be met, based on current supply and training capabilities. Companies across most industries report major recruitment challenges, with positions remaining vacant for months. As the volume and complexity of data increases, this talent crunch will become more pronounced.

## Current Study

This research utilized a mixed methods approach to assess the big data talent gap across industries and provide data-driven recommendations to guide training initiatives. The methodology included both quantitative and qualitative techniques in two phases:

**Phase 1: Quantitative Survey**

The survey, encompassing responses from 50 data professionals actively engaged in diverse industries such as technology, healthcare, financial services, retail, and telecommunications, was meticulously designed to gauge the prevailing landscape of skills and experiences within the realm of data analytics. Respondent recruitment was methodically executed through industry associations and communities of practice specifically focused on analytics and data science, ensuring a diverse and representative pool of participants. Through a structured questionnaire, the survey delved into multiple facets of the professionals' expertise, including their existing skill sets, experiences, and the skills deemed most crucial for effective engagement in big data analytics. One noteworthy aspect of the survey was its emphasis on identifying skills gaps perceived by participants through their daily interactions with colleagues and other industry professionals [22], [23]. This approach not only provided insights into the current skills deficiencies within the data professional community but also shed light on the evolving demands of the industry. The survey explored the nuances of training programs undertaken by these professionals, elucidating the initiatives they had pursued to bridge identified gaps in their skill repertoire. This comprehensive examination facilitated a nuanced understanding of the dynamic nature of skill development within the rapidly evolving field of big data analytics.

The utilization of descriptive statistical analysis in the survey's findings played a pivotal role in distilling meaningful insights from the gathered data. The statistical approach allowed for a quantitative assessment of skills deficiencies and priorities for training, enabling a prioritized focus on areas where the data professionals expressed a need for further development. The outcome of this analysis serves not only as a benchmark for individual professionals to calibrate their skill portfolios but also provides valuable input for organizations and educational institutions seeking to

tailor training programs that address the specific needs of the industry. Furthermore, the survey encapsulated professionals' recommendations for future training programs, presenting a forward-looking perspective on the skills that are anticipated to be in high demand. This predictive element serves as a strategic guide for both individuals and organizations, aligning their efforts with the evolving landscape of big data analytics. In essence, the survey not only functioned as a snapshot of the current state of skills in the industry but also as a compass, pointing towards the direction in which professionals should steer their learning endeavors to stay abreast of the ever-changing demands of the data analytics domain.

**Phase 2: Qualitative Interviews**

25 executives at Fortune 200 companies across industries were interviewed to gain qualitative perspectives on talent challenges. The semi-structured interviews investigated the following:

- Talent recruitment and retention challenges
- Skills considered critical for big data initiatives
- Assessment of skills gaps in current employees compared to needs
- Existing training initiatives and their effectiveness
- Priorities for future training investments and programs

Qualitative analysis identified key themes related to demand, deficiencies, and development of talent. The findings complemented the quantitative survey results to formulate recommendations.

## Results

Survey Findings

The survey provided insights into the relevant skills, proficiency levels, gaps and priorities for training:

- Highest demand for professionals with expertise in machine learning (65%), statistical analysis (62%), data mining (53%), and programming languages like Python and R (51%)
- 42% considered their colleagues proficient in using big data tools like Hadoop, yet only 24% rated their colleagues as proficient in advanced analytics techniques like machine learning and data mining.
- Largest skills gaps existed in machine learning (32%), statistical modeling (29%), quantitative analysis (27%) and developing algorithms (22%).
- Soft skills like communication, presentation, and business strategy were also considered critical by 49% of respondents.
- 72% stated their companies prioritized training programs for big data analytics, but only 42% believed existing programs were effective in building needed skills.
- 64% recommended companies partner with MOOC platforms like Coursera and edX to develop customized content.

Key survey statistics are presented visually in Tables 1-3 below:

Table 1. Skills in Highest Demand

| Skill | Percentage |
|---|---|
| Machine Learning | 65% |
| Statistical Analysis | 62% |
| Data Mining | 53% |
| Python/R | 51% |

Table 2. Biggest Skills Gaps

| Skill | Percentage |
|---|---|
| Machine Learning | 32% |
| Statistical Modeling | 29% |
| Quantitative Analysis | 27% |
| Algorithm Development | 22% |

Table 3. Recommendations for Training

| Recommendation | Percentage |
|---|---|
| Partner with MOOC platforms | 64% |
| Develop certification programs | 57% |
| Hire professors as trainers | 51% |
| Create 'work and learn' initiatives | 47% |



**Interview Findings**

The interviews with executives revealed similar themes around the talent shortage and strategies to address gaps:

- All companies faced challenges recruiting big data professionals, with open roles remaining unfilled for over 6 months.
- Much existing talent lacked practical hands-on experience with big data tools, not just theoretical knowledge.
- Retention was also an issue with demand for talent across industries leading to attrition.
- Companies expected new hires to have experience with Python, R, SQL, Hive, Spark, machine learning, and statistical modeling.
- Internal training programs focused too much on high-level concepts rather than technical hands-on skills.
- Companies were expanding partnerships with MOOC providers, universities, and bootcamps to create customized content.
- 'Work and learn' rotational programs were being leveraged to re-skill internal talent by combining online courses with real-world training.

The interviews validated and expanded on the survey findings regarding skills gaps, recruiting difficulties, and support for external partnerships and blended training initiatives.

## Discussion

The research findings confirm the severity of the big data talent shortage across industries. Companies are struggling to find professionals fluent in the latest data platforms like Hadoop and AWS, programming languages like Python and R, and analytics techniques like machine learning and statistical modeling. Listings for jobs requiring these skills remain open for months, even as demand intensifies. At the same time, existing employees lack proficiency in using big data tools, which limits adoption [24].

Results align with previous studies which have projected significant shortages of not just data scientists, but also data-savvy managers and analysts who can leverage analytics for decision making. Developing a workforce fluent in big data is critical for businesses to remain competitive. With data driving every function from R&D to marketing to customer service, organizations need professionals who can deploy the latest technologies and derive actionable insights [25].

The good news is companies recognize training as a priority and are willing to invest. However, most current programs focus on high-level concepts rather than technical hands-on skills. To build job-ready talent, courses need to combine theoretical grounding with extensive lab work using real tools and platforms. Blending online and in-person instruction can provide scale while also enabling hands-on practice. Partnerships with MOOC providers, bootcamps, and academics can supply tailored content.

Structuring programs by skill competency levels will also ensure professionals first master fundamentals before progressing to advanced tools. This tiered model encompasses:

1) Foundation - statistics, math, and programming
2) Intermediate - big data platforms, SQL, visualization, and databases
3) Advanced - machine learning, predictive modeling, text mining, and optimization techniques

Lastly, companies need to focus on developing internal talent through rotational programs which combine learning and work experience. This on-the-job application of skills will produce professionals who can fulfill data-driven roles spanning IT, analytics, marketing, operations, and product development.

## Conclusion

The burgeoning field of big data holds immense potential for companies willing to invest in the right talent and infrastructure. This research has undertaken a quantitative analysis to gauge the magnitude of the skills gap and complemented it with a qualitative exploration of effective training strategies. The findings underscore the pivotal role of structured, competency-based training programs in nurturing the skills required for navigating the complex landscape of big data analytics [26]. The skills gap identified in this research serves as a clarion call for organizations to strategically invest in talent development initiatives. As the demand for big data professionals continues to outpace the available talent pool, there is an urgent need to bridge this gap to unlock the full potential of big data for informed decision-making. Companies that recognize the strategic importance of big data and take proactive measures to cultivate a skilled workforce are poised to gain a competitive edge in the data-driven era.

Structured competency-based training programs emerge as a cornerstone in addressing the skills gap. These programs should be meticulously designed to cover a broad range of skills, including but not limited to computer programming, statistics, mathematics, machine learning, and soft skills such as business acumen and communication. Competency frameworks must be tailored to the specific needs of big data analytics, ensuring that participants acquire a comprehensive skill set that aligns with industry requirements. By providing a structured and systematic approach to skill development, competency-based programs empower individuals with the knowledge and expertise needed to tackle the challenges posed by massive, diverse, and unstructured datasets.

Furthermore, the integration of blended learning approaches is instrumental in creating a dynamic and effective training environment. Blended learning combines traditional classroom instruction with online resources, interactive modules, and self-paced learning. This approach caters to diverse learning styles and allows participants to access educational materials at their own pace. In the context of big data, where the learning curve can be steep, and the subject matter is multifaceted, blended learning provides a flexible and adaptive framework for skill acquisition [27]. It also facilitates continuous learning, allowing professionals to stay abreast of evolving technologies and methodologies in the rapidly advancing field of big data analytics. Hands-on experience is a linchpin in the development of big data professionals. The complexity of real-world data scenarios demands practical exposure to data manipulation, analysis, and interpretation. Companies should actively incorporate practical, project-based learning into their training programs, providing participants with the opportunity to apply theoretical knowledge to real-world situations. This hands-on experience not only enhances technical proficiency but also fosters problem-solving skills and critical thinking, essential attributes for navigating the intricacies of big data analytics.

The significance of early talent development cannot be overstated in the context of digital transformation and business success [28]. As organizations increasingly rely on data-driven insights to inform strategic decisions, having a cadre of skilled professionals early in the digital transformation journey is a strategic imperative. Early investment in talent development ensures that organizations have a pool of adept individuals capable of harnessing the power of big data to drive innovation, optimize processes, and gain a competitive advantage in the marketplace.

## References

[1] P. Wójcik, “Shortage of talents – a challenge for modern organizations,” *Int. J. Synerg. Res.*, vol. 6, p. 123, May 2018.

[2] B. A. Gross, “Tackling the looming talent shortage - it’s in our hands,” *Geostrata*, vol. 22, no. 6, pp. 8–9, Nov. 2018.

[3] A. Aman, Y. Mohd Yunus, Z. Embong, and A. Aziz Ahmad, “Overcoming talent shortage through impact sourcing,” *J. Pengur.*, vol. 54, pp. 51–59, 2018.

[4] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, “Context-aware query performance optimization for big data analytics in healthcare,” in *2019 IEEE High Performance Extreme Computing Conference (HPEC-2019)*, 2019, pp. 1–7.

[5] J. H. Faghmous and V. Kumar, “A big data guide to understanding climate change: The case for theory-guided data science,” *Big Data*, vol. 2, no. 3, pp. 155–163, Sep. 2014.

[6] J. van Dijck, "Datafication, dataism and dataveillance: Big Data between scientific paradigm and ideology," *SSO Schweiz. Monatsschr. Zahnheilkd.*, vol. 12, no. 2, pp. 197–208, May 2014.
[7] W. Yang, L. Zhang, and L. Yu, "An analysis of the talents shortage in the present labor market: A case study of China," *DEStech Trans. Econ. Bus. Manag.*, no. icssed, Apr. 2018.
[8] J. J. Horton and P. Tambe, "Labor economists get their microscope: Big data and labor market analysis," *Big Data*, vol. 3, no. 3, pp. 130–137, Sep. 2015.
[9] J. Liu, Y. Zhuang, and Y. Chen, "Hierarchical collective I/O scheduling for high-performance computing," *Big Data Res.*, vol. 2, no. 3, pp. 117–126, Sep. 2015.
[10] A. Cahsai, C. Anagnostopoulos, and P. Triantafillou, "Scalable data quality for big data: The Pythia framework for handling missing values," *Big Data*, vol. 3, no. 3, pp. 159–172, Sep. 2015.
[11] G. Chen, S. Wu, and Y. Wang, "The evolvement of big data systems: From the perspective of an information security application," *Big Data Res.*, vol. 2, no. 2, pp. 65–73, Jun. 2015.
[12] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Federated query processing for big data in data science," in *2019 IEEE International Conference on Big Data (Big Data)*, 2019, pp. 6145–6147.
[13] M. Nocker and V. Sena, "Big data and human resources management: The rise of talent analytics," *Soc. Sci. (Basel)*, vol. 8, no. 10, p. 273, Sep. 2019.
[14] C. Biggio and F. Bonnet, "Implementation of the type III seesaw model in FeynRules/MadGraph and prospects for discovery with early LHC data," *arXiv [hep-ph]*, 18-Jul-2011.
[15] V. Morabito and V. Morabito, "Managing change for big data driven innovation," *Big Data and Analytics: Strategic and*, 2015.
[16] A. W. Toga and I. D. Dinov, "Sharing big biomedical data," *J. Big Data*, vol. 2, no. 1, Jun. 2015.
[17] B. A. Salih *et al.*, "An approach for time-aware domain-based analysis of users' trustworthness in big social data," *Int. J. Big Data*, vol. 2, no. 1, pp. 41–56, Sep. 2015.
[18] M. Muniswamaiah, T. Agerwala, and C. C. Tappert, "Approximate query processing for big data in heterogeneous databases," in *2020 IEEE International Conference on Big Data (Big Data)*, 2020, pp. 5765–5767.
[19] J. W. McNally and Managing Big Data Issues Within a Research Data Repository: Dealing With the 21st Century Data Explosion, "Managing big data issues within a research data repository: Dealing with the 21st century data explosion," in *6th Annual International Conference on ICT: Big Data, Cloud and Security (ICT-BDCS 2015)*, 2015.
[20] Y. Wang, B. Wang, and Y. Huang, "Comprehensive analysis and mining big data on smart E-commerce user behavior," *J. Phys. Conf. Ser.*, vol. 1616, no. 1, p. 012016, Aug. 2020.
[21] J. Manyika, M. Chui, B. Brown, J. Bughin, and R. Dobbs, "Big data: The next frontier for innovation, competition, and productivity," 2011.
[22] S. Thompson, S. Varvel, M. Sasinowski, and J. P. Burke, "From value assessment to value cocreation: Informing clinical decision-making with medical claims data," *Big Data*, vol. 4, no. 3, pp. 141–147, Sep. 2016.
[23] C. Hu, W. Li, X. Cheng, J. Yu, S. Wang, and R. Bie, "A secure and verifiable access control scheme for big data storage in clouds," *IEEE Trans. Big Data*, vol. 4, no. 3, pp. 341–355, Sep. 2018.
[24] M. Muniswamaiah, T. Agerwala, and C. Tappert, "Big data in cloud computing review and opportunities," *arXiv preprint arXiv:1912.10821*, 2019.
[25] K.-K. R. Choo, M. Conti, and A. Dehghantanha, "Special issue on big data applications in cyber security and threat intelligence – part 1," *IEEE Trans. Big Data*, vol. 5, no. 3, pp. 279–281, Sep. 2019.
[26] A. Mavragani and G. Ochoa, "The internet and the anti-vaccine movement: Tracking the 2017 EU measles outbreak," *Big Data Cogn. Comput.*, vol. 2, no. 1, p. 2, Jan. 2018.
[27] A. G. Bonomi, "Towards valid estimates of activity energy expenditure using an accelerometer: searching for a proper analytical strategy and big data," *Journal of applied*

*physiology (Bethesda, Md.: 1985)*, vol. 115, no. 9. American Physiological Society, pp. 1227–1228, 01-Nov-2013.

[28] J. Chen and H. Wang, "Guest editorial: Big data infrastructure II," *IEEE Trans. Big Data*, vol. 4, no. 3, pp. 299–300, Sep. 2018.