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Big Data and Management: From the Editors

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FROM THE EDITOR

BIG DATA AND MANAGEMENT

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Editor's Note: This editorial launches a series written by editors and co-authored with a senior executive, thought leader, or scholar from a different field, to explore new content areas and grand challenges with the goal of expanding the scope, interestingness and relevance of the work presented in the Journal. The principle is to use the editorial notes as "stage setters" for further work and opening up fresh new areas of inquiry for management research. GG

Big Data is everywhere. In recent years, there is an increasing emphasis on big data, business analytics and 'smart' living and work environments. Though these conversations are predominantly practice-driven, organizations are exploring how large volume data can be usefully deployed to create and capture value for individuals, businesses, communities and governments (McKinsey Global Institute, 2011). Whether it is machine learning and web analytics to predict individual action, consumer choice, search behavior, traffic patterns or disease outbreaks, Big Data is fast becoming a tool that not only analyzes patterns, but can also provide the predictive likelihood of an event.

Organizations have jumped on this bandwagon of using ever increasing volumes of data, often in terra or petabytes worth of storage capacity, to better predict outcomes with greater precision. The United Nations' Global Pulse is another initiative that uses new digital data sources, such as mobile calls or mobile payments, with real-time data analytics and data mining to assist in development efforts and understanding emerging vulnerabilities across developing countries. Though Big Data has now become commonplace as a business term, there is very little published management scholarship that tackles the challenges of using such tools; or better yet,

explores the promise and opportunities for new theories and practices that Big Data might bring about. In this editorial, we explore some of its conceptual foundations and possible avenues for future research and application in management and organizational scholarship.

WHAT IS BIG DATA?

Big data are generated from an increasing plurality of sources including internet clicks, mobile transactions, user-generated content and social media as well as purposefully generated content through sensor networks or business transactions such as sales queries and purchase transactions. In addition, genomics, healthcare, engineering, operations management, the industrial internet, and finance all add to big data pervasiveness. These data require the use of powerful computational techniques to unveil trends and patterns within and between these extremely large socioeconomic datasets. New insights gleaned from such data value extraction can meaningfully complement official statistics, survey and archival data sources that remain largely static, adding depth and insight from collective experiences—and doing so in real time, thereby narrowing both information and time gaps.

Perhaps the misnomer is in the 'bigness' of big data, which invariably attracts researchers' attention to the size of the dataset. Among practitioners, there is emergent discussion that 'big' is no longer the defining parameter, but rather how 'smart' it is; i.e., the insights that the volume of data can reasonably provide. For us, the defining parameter of Big Data is the fine-grained nature of the data itself, therefore shifting the focus away from the number of participants to the granular information about the individual. For example, a participant in a Formula 1 car race generates 20 gigabytes of data from its 150 sensors on the car that can help analyze technical performance of the components, but also driver reactions, pit stop delays, and communication between crew and driver that contribute to overall performance

(Munford, 2014). The emphasis moves away from outcomes (win/lose race), but rather focuses on every proximal, contributory element for its success or failure mapped every second during the race. Alternatively, one could analyze the social networks and social engagement behaviors of individuals by mapping mobility patterns onto physical layouts of workspaces using sensors, or the frequency of meeting room usage with remote sensors that track entry and exit patterns which could provide information on communication and coordination needs based on project complexity and approaching deadlines. These micro data provide a richness of individual behaviors and actions that have not been fully tapped in management research. Whether it is big or smart data, the use of large scale data to predict human behavior is gaining currency in business and government policy practice and in scientific domains where physical and social sciences converge, recently referred to as social physics (Pentland, 2014).

Sources of Big Data

Big Data is also a wrapper for different types of granular data. Below we list five key sources of high volume data: *Public Data*, *Private Data*, *Data Exhaust*, *Community Data*, and *Self-Quantification Data*.

Public Data are data typically held by governments, governmental organizations and local communities that can potentially be harnessed for wide ranging business and management applications. Examples of such data include transportation, energy use, and healthcare that can be accessed by under certain restrictions to guard individual privacy. *Private Data* are data held by private firms, non-profit organizations and individuals that reflect private information that cannot be readily imputed from public sources. For example, private data include consumer transactions, organizational supply chains using RFID tags, movement of company goods and resources, website browsing, and mobile phone usage among several others.

Data Exhaust is ambient data that are passively collected non-core data with limited or zero value to the original data collection partner. These data were collected for a different purpose but can be recombined with other data sources to create new sources of value. When individuals adopt and use new technologies (e.g., mobile phones), they generate ambient data as by-products of their everyday activities. Individuals may also be passively emitting information as they go about their daily lives (e.g., when they make purchases, even at informal markets; when they access basic health care; or when they interact with others). Another source of data exhaust is information-seeking behavior, which can be used to infer people's needs, desires, or intentions. This includes Internet searches, telephone hotlines, or other types of private call centers.

Community Data is a distillation of unstructured data- especially text - into dynamic networks that capture social trends. Typical community data include consumer reviews on products, voting buttons (such as 'I find this review useful'), and twitter feeds among many others. These community data can then be distilled for meaning to infer patterns in social structure (e.g., Kennedy, 2008). *Self-Quantification Data* are types of data that are revealed by the individual by quantifying personal actions and behaviors. For example, a common form of self-quantification is through the wrist bands that monitor exercise and movement which is then uploaded to a mobile phone application which can then be tracked and aggregated. In psychology, individuals have 'stated preferences' of what they would like to do versus 'revealed preferences' where the preference for an action or behavior is inferred. For example, an individual might buy energy efficient bulbs with the goal of saving electricity but instead keep the lights on longer because it is now using less energy. Such self-quantification data helps bridge the connection between psychology and behavior. Social science scholars from diverse

areas such as psychology, marketing, or public policy could benefit from stated and implicit preference data for their research.

Data Sharing, Privacy and Ethics

In current information technology infrastructures, the provision of services such as network connectivity is usually associated with a Service Level Agreement (SLA) defining the nature and quality of the service to be provided. Such SLAs are important to limit liability, to enable better provisioning of the operational infrastructure for the provider, and to provide a framework for differential pricing. The exponential expansion of network connectivity and web-services was in large part due to significant technological advances in the automation of Service Level Agreement enforcement, in terms of monitoring and verification of compliance with the contract. In contrast, the realm of big data sharing agreements, remains informal, poorly structured, manually enforced and linked to isolated transactions (Koutroumpis & Leiponen, 2013). This acts as a significant barrier to the market in data – especially for social science and management research that cannot access these private data for integration with other public sources.

Data Sharing Agreements need to be linked into the mechanisms for data protection and privacy including anonymization for open data, access control, rights management and data usage control. Issues such as imputed identity, where individual identity can be inferred through data triangulation from multiple sources, will need to be carefully considered and explicitly acknowledged and permitted. Management scholars will be invited to embed themselves into social issues based on defining research questions that integrate data sharing and privacy as part of their research methodology. Doing so will likely allow us to refine the model for data sharing

and data rights which could be universally beneficial and define big data collaborations in the future.

ANALYZING BIG DATA

Equally relevant as the source of data are methodologies to analyze them and the standards of evidence that would be acceptable to management scholars for publication. As with any nascent science, there is likely a trade-off between theoretical and empirical contribution, and the rigor with which data are analyzed. Perhaps with Big Data, one is likely initially confounded by the standard of evidence that should be expected. The typical statistical approach of relying on p-values to establish the significance of a finding is unlikely to be effective because the immense volume of data means that almost everything is significant. Using our typical statistical tools to analyze Big Data, it is very easy to get false correlations. However, this doesn't necessarily mean that we should be moving toward more and more complex and sophisticated econometric techniques to deal with this problem; indeed, such a response poses a substantial danger of over-fitting the data. Instead, basic Bayesian statistics and stepwise regression methods may well be appropriate approaches. Beyond these familiar approaches, there are a range of specialized techniques for analyzing Big Data that are important for those entering this field to understand, though beyond the scope of this editorial. These techniques draw from several disciplines, including statistics, computer science, applied mathematics, and economics. They include (but are not limited to) A/B testing, cluster analysis, data fusion and integration, data mining, genetic algorithms, machine learning, natural language processing, neural networks, network analysis, signal processing, spatial analysis, simulation, time series analysis, and visualization (McKinsey Global Institute, 2011).

The challenge, though, is to shift away from focusing on p-values to focusing rather on effect sizes and variance explained. With further empirical work, perhaps scholars can develop and converge on rough heuristics, for example, an R-square of more than 0.3 could suggest that

closer scrutiny of the pattern of relationships is warranted. Another pitfall of Big Data, again amplified by our commonly used statistical techniques, lies in focusing too much on aggregates or averages, and too little on outliers. In many situations, averages are very important, and often revealing about how people tend to behave under particular conditions. But in the vastness of a Big Data universe, the outliers can be even more interesting: critical innovations, trends, disruptions or revolutions may well be happening outside the average tendencies, yet still involve enough people to have dramatic effects over time. The fine-grained nature of Big Data offers opportunities to identify these sources of change – be they business innovations, social trends, economic crises, or political upheavals - as they gather steam.

Once promising leads have been identified, the next challenge of analyzing Big Data is to then move beyond identifying correlational patterns to exploring causality. Given the unstructured nature of most Big Data, causality is not built into their design, and the patterns observed are often open to a wide range of possible causal explanations. There are two main ways to approach this issue of causality. The first is to recognize the central importance of theory. An intuition about the causal processes that generated the data can be used to guide the development of theoretical arguments, grounded in prior research and pushing beyond it. The second, complementary, way is to then test these theoretical arguments in subsequent research, ideally through field experiments. Of course, laboratory experiments offer the advantage of greater control, but they usually focus on a very limited number of variables, and the nature of Big Data research is that there may be many factors driving the observed correlational patterns. In a field experiment, a wider net can be cast, as a richer set of data about behaviors and beliefs can be collected, and over an extended period of time. For scholars as well as managers with an interest in action research, there are alluring opportunities here to engage in "management

engineering" that goes beyond more typical management research by bringing theory and practice together with much faster cycle times between the identification of a promising theoretical insight and the testing of that insight with a well-designed intervention that can help to both advance management knowledge and address pressing practical questions.

Ultimately, the promise and the goal of strong management research built on Big Data should be not only to identify correlations and establish plausible causality, but ultimately to reach *consilience* – that is, convergence of evidence from multiple, independent, unrelated sources, leading to strong conclusions (Wilson, 1998). Big Data offers exciting new prospects for achieving such consilience due to its unprecedented volume, micro-level detail, and multi-faceted richness. The vast majority of current management research relies on painstaking collection of low numbers of measures that cover a short duration of time (or possibly, in the case of more historically-based research, a longer duration but comprised of larger periods, such as years). In contrast, Big Data offers voluminous quantities of data over multiple periods (whether seconds, minutes, hours, days, months, or years).

While some Big Data datasets are uni-dimensional or single-channel, focusing for example on a particular transaction or communication behavior, and relying on single-channel interactions (e.g. via phone or email), there are increasingly opportunities to collect and analyze multi-dimensional datasets that offer insight into constellations of behaviors, often through a variety of channels (e.g., call center customer interactions that switch between voice, web, chat, mobile, video, etc). For management researchers, the result of such richness is that there are unprecedented opportunities to notice potentially important variables that previous studies might have failed to consider at all, due to their necessarily more focused nature. And once such

variables capture a researcher's attention, the relationships between them can be explored and the contextual conditions under which these relationships may or may not hold can be examined.

BIG DATA IN MANAGEMENT RESEARCH

Our intent in this editorial is to encourage fresh new areas of scholarly inquiry – it is not to provide a systematic review of Big Data applications; neither do we pretend to provide a definitive guide for future research. Instead, our goal is to trigger broader discussions of Big Data in society and its implications for management research. The constantly changing environment in the digital economy has challenged traditional economic and business concepts. Huge volumes of user-generated data are transferred and analyzed within and across different sectors, gradually increasing the markets' dependency on precise and timely information services. A mere tweet from a trusted source can cause losses or profits of billions of dollars and a chain reaction in the press, social networks and blogs. This situation makes information goods even more difficult to value as they have a catalytic impact on real-time decision-making. In contrast, entrepreneurs and innovators have taken aggregate open and public data as well as self-quantification and exhaust data to create new products and services that have the power to transform industries. In private and public spheres, Big Data sourced from mobile technologies and banking services such as digital/mobile money when combined with existing 'low tech' services such as water or electricity can transform societies and communities. There is little doubt that over the next decade it will change the landscape of social and economic policy and research.

What is unclear is how these 'new models' for mixing and matching these services and data come about and evolve into a sustainable social and economic model. Categorizing Big Data, assessing their quality and identifying their impact is radically new in social sciences,

especially in management and organizational research. The rate and scale of content generation multiplies their impact and diminishes the time to respond. Consequently, management scholars will need to unpack how ubiquitous data can generate new sources of value and the routes through which such value is manifest (mechanisms of value creation), how this value is apportioned among the parties and data contributors, entrepreneurs, businesses, industries, and government through new business models and new governance tools such as contracts and licenses (mechanisms of value capture).

Empirical research in management research often infer the relations; for example, two companies might be competing in the same market, have complementary products, collaborate in production or R&D, or linked through supplier-customer relationships or they might be close to each other in geographic, technology or some other space that might facility knowledge spill-overs between them. Detailed data on these relationships is typically unavailable in firm level datasets that allow representative statistical inference. However, information on such relationships is often available in un-structured textual form in news articles or company blogs on the web. IBM estimates that as much as 80% of the information is unstructured "content" of various communications through email, texts and videos -- and they reckon unstructured content data is growing at twice the rate of conventional structured databases. To address this data, content analytics is emerging as a commercial evolution of what academics call content analysis, the analysis of text and other kinds of communication for the purposes of identifying robust patterns.

There are additional uses of Big Data that have broader implications for communities and societies, but which managers would find useful. For example, disease spreads, commuting patterns, emotions and moods of communities which can all be accessed through live Twitter

feeds or Facebook postings could affect organizational responses, products and services, and their strategies. Patterns in social media are being used to gleam information on the creation of new markets and product categories. Many companies now use digital intervention labs that track social media on a real time basis around the world, thereby creating longitudinal data structures of millions of posts, tweets or reviews. Any deviations from normal patterns that invoke their brand or products are immediately flagged for action to provide rapid responses to consumer reactions, shape new product introductions, and create new markets.

The continuous, ubiquitous nature of the data means that for the first time scholars can focus on the microfoundations of organizational strategies or behaviors; for instance, we can examine the dynamics of how business processes and opportunities evolve on a minute-to-minute, day-to-day basis, rather than being constrained to assess snapshots such as quarterly inputs and outcomes, or sales cycle trends. If we take the famous examples of the Hubble space telescope having the wrong optics installed because one group assumed metric measurements and another English measurements, or the Airbus 380 example where the wiring harness built in Germany and Spain did not fit the airframe built in Britain and France because the standards adopted were different. Current practice would be to review procedures and suggest more checkpoints; i.e., a relatively static measurement and control of organizational actions. Instead, we could use Big Data to check what sorts of communication patterns are required to avoid such disasters, where we might discover that the lack of face-to-face communication at the 'alpha test' stage was the critical variable, and then suggest establishment of a real-time data monitoring mechanism to insure that face-to-face communication happened at all the necessary 'alpha test' junctures.

Big Data can also be a potent tool for analysis of individual or team behavior using sensors or badges to track individuals as they work together, move around their workspace, or time they spend interacting with others or allocating to specific tasks. While early management research codified diaries and time management techniques of CEO, current practices using big Data can allow us to study entire organizations and workgroups in near real time to predict individual and group behaviors, team social dynamics, coordination challenges, and performance outcomes. Scholars could examine questions around the differences between stated versus revealed preferences by tracking data on purchasing, mobile applications, and social media engagement and consumption to state a few examples. Social network studies could also use Big Data to examine the dynamics of formal and informal networks as they form and evolve as well as their impact on individual, network and organizational behaviors. Such granular, high volume data can tell us more about workplace practices and behaviors than our current data collection methods allow and have the potential to transform management theory and practice.

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