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Technology Use, Exposure to Natural Hazards, and Being Digitally Invisible: Implications for Policy Analytics

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Policy analytics combines new data sources, such as from mobile smartphones, Internet of Everything devices, and electronic payment cards, with new data analytics techniques for informing and directing public policy. However, those who do not own these devices may be rendered digitally invisible if data from their daily actions are not captured. We explore the digitally invisible through an exploratory study of homeless individuals in Phoenix, Arizona, in the context of extreme heat exposure. Ten homeless research participants carried a temperature-sensing device during an extreme heat week, with their individually experienced temperatures (IETs) compared to outdoor ambient temperatures. A nonhomeless, digitally connected sample of 10 university students was also observed, with their IETs analyzed in the same way. Surveys of participants complement the temperature measures. We found that homeless individuals and university students interact differently with the physical environment, experiencing substantial differences in individual temperatures relative to outdoor conditions, potentially leading to differentiated health risks and outcomes. They also interact differently with technology, with the homeless having fewer opportunities to benefit from digital services and lower likelihood to generate digital data that might influence policy analytics. Failing to account for these differences may result in biased policy analytics and misdirected policy interventions.

KEY WORDS: marginal populations, bias, homelessness, natural hazards, personal heat exposure, digital divide, policy analytics, policymaking

Introduction

Public policy responses and interventions based on the best available evidence should be better positioned to address public problems than policy based on anecdote, informal beliefs, inaccurate data, or partial data (Quade, 1975). When public policy systems have greater access to more data, the ability to adapt policy interventions based on fine-grained evidence collected from a variety of sources can dramatically change the traditional practice of policy formulation, implementation, and evaluation (Cook, 2014; Decker, 2014; Pirog, 2014). As

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digital, Internet-connected devices become ubiquitous, public policymaking can take advantage of the signals that individuals generate through their everyday activities using communication devices like mobile smartphones (through both passive and active data generation; Laurila et al., 2012), consumer products connected to the Internet of Everything (IoE; Gubbi, Buyya, Marusic, & Palaniswami, 2013), and electronic transaction cards (Mayer-Schönberger & Cukier, 2013). When these data sources are combined with new data analytics techniques and capacities, the emergence of a policy analytics approach in support of public policymaking becomes possible (Daniell, Morton, & Insua, 2016; Tsoukias, Montibeller, Lucertini, & Belton, 2013).

While more, and more accurate, evidence can improve our picture of the world and form the basis for better policy, the means for collecting and interpreting evidence should never be assumed to be value neutral. Rather, our evidence-gathering and interpretation systems reflect choices that privilege what we care about and ignore what we consider unimportant. With limited budgets for data collection, computation, analysis, and the attention we can pay to the information that flows from these (Festré & Garrouste, 2015), effective governing requires us to ignore some information and make choices about what we can hope to monitor and understand (6, 2004). Our choices in what we measure are influenced by our values, and in turn that evidence influences what we value. For that part of policy-relevant data that are collected from mobile smartphones, IoE devices, and transaction cards, the world illuminated by that evidence is one populated by those who own and use those devices and make those transactions. Despite the mesh of sensors, card readers, cell towers, cables, and servers that act as the collection net for a range of data reflecting the choices, actions, and behaviors of people in society, we propose that those without the right devices may be rendered "digitally invisible" and that policy based primarily on device-derived data will be biased toward those owning the devices, failing to reflect the reality of those not revealed in the data; a concern increasingly being shared in academic and policymaking circles (e.g., Mergel, Rethemeyer, & Isett, 2016; Podesta, Pritzker, Moniz, Holdren, & Zients, 2014; United States Federal Trade Commission, 2014).

Digitally invisible subpopulations can manifest in different ways, paralleling categories in the "digital divide" literature that identify populations with less access to Internet-connected technology such as the elderly, minorities, and the poor. While disadvantaged groups at risk of being neglected when policymaking relies on new data sources are several, we focus on the homeless as one identifiable category of persons in considering the concept of the digitally invisible. While all categories of the digitally invisible are important, we focus on the homeless as one of the most "visible" categories of the digitally invisible (even as we have collectively and individually chosen to make modern homelessness *cognitively invisible* through public policies and personal avoidance; Koepfler, Mascaro, & Jaeger, 2014; Waldron, 1991), and thus easiest to identify as participants for this exploratory study.

The homeless may be underrepresented in data collected through Internet-connected technology because their housing and poverty situation makes it unlikely that they will own an always-connected smartphone, use IoE devices, or use transaction cards. In the policy context that we investigate—public infrastructure to reduce expose to extreme heat, extreme weather event-warning systems, and heat relief services—the homeless are particularly vulnerable. Compared to the general public, the homeless by nature of their daily lives are especially at risk of acute health events related to outdoor environmental exposure. Among the exposures of concern for the homeless population are extreme high and low temperatures, which collectively account for nearly 95 percent of all weather-related deaths (for the total population) in the United States (Berko, Ingram, Saha, & Parker, 2014). In our geographic setting of Phoenix, Arizona, located in the hot desert southwest of the United States, extreme heat is a well-documented public health hazard that disproportionately impacts the homeless (Harlan, Declet-Barreto, Stefanov, & Petitti, 2012; MCDPH, 2014; Petitti, Hondula, Yang, Harlan, & Chowell, 2016). Reducing such disparities in adverse health events related to extreme heat exposure is a goal shared by many agencies involved in preparedness and response efforts. Where new and precise data sources can be used to improve the precision of those efforts, data-informed policymaking should better serve the needs and interests of vulnerable populations. However, policy responses will be less effective if the data used by public agencies is based on an inaccurate picture of the world.

Do our modern data sets render some subpopulations invisible, and bias our view of the world as a consequence? Consider the seminal statement in computational social sciences, sketching a foundation for data-driven policy, that begins with this day-in-the-life description of its collective authorship:

> *We live life in the network. When we wake up in the morning, we check our e-mail, make a quick phone call, walk outside (our movements captured by a high definition video camera), get on the bus (swiping our RFID mass transit cards) or drive (using a transponder to zip through the tolls). We arrive at the airport, making sure to purchase a sandwich with a credit card before boarding the plane, and check our BlackBerries shortly before takeoff. Or we visit the doctor or the car mechanic, generating digital records of what our medical or automotive problems are. We post blog entries confiding to the world our thoughts and feelings, or maintain personal social network profiles revealing our friendships and our tastes*. (Lazer et al., 2009, p. 721)

This may well describe the daily life of the authors of that article, the authors of this article, and much of our audience. Consider, however, another socioeconomic audience that lives a quite different experience: homeless individuals in our societies who—whether for reasons related to poverty, mental health, or addictions—suffer chronic periods of living without private, permanent, stable housing, and spend most of their days without shelter for themselves and their belongings. As opposed to the hyperconnected lives of those living in the flow of data and analytics, the homeless face a much harsher daily life:

> *On average, homeless adults have eight to nine concurrent medical illnesses. Nearly every organ system is at risk. Cardiovascular diseases (such as hypertension, peripheral vascular disease, and cardiac arrhythmias), liver disease, human immunodeficiency virus infection and AIDS, chronic airflow obstruction, and malnutrition are prevalent and in many cases are probably secondary to the use of tobacco, alcohol, and illicit substances. Cancers commonly involve the skin and the aerodigestive, respiratory, and genitourinary tracts. In addition to traumatic injuries, musculoskeletal conditions resulting from manual labor are common. Together, street violence and these acute and chronic medical conditions contribute to markedly increased mortality among the homeless, resulting in an average life span of less than 45 years*. (Levy & O'Connell, 2004, p. 2331)

While there is great potential in expanding the use of data for public policymaking, our focus here is on the distinction between those whose daily lives are deeply connected to the generation of those data, and those who—by virtue of poverty and circumstance—are less connected (with the homeless being but one example). Our objective is to consider how that distinction might be manifested in the accumulation of public policymaking relevant data, and consequently how policy based on that data might be biased or inaccurate since the lived experience of the less connected is underrepresented in the data. Data built on the activities and choices of highly digitally connected people may fail to observe certain subpopulations who leave no traces in these data sets if they do not regularly carry smartphones, do not own IoE devices, and do not make electronic card-based transactions (Haklay, 2012).

We consider the proposed concept of the digitally invisible by reporting on an exploratory study focused on homeless individuals in Phoenix, Arizona, their experience with digital technology, and the relationship between their individually experienced temperature (IET) and measures of outdoor ambient temperature (OAT) (Kuras, Hondula, & Brown-Saracino, 2015), set in the context of extreme heat exposure. Ten homeless research participants carried a temperature-sensing device during an extreme heat week in Phoenix, and their IETs are compared to contemporaneous OAT measures. A nonhomeless, digitally connected sample of 10 university students was observed in contrast, with their IETs collected and analyzed in the same manner. We also report on intake and exit surveys with the participants focusing on their experience with digital technology, their experience with homelessness and dealing with extreme heat, and their perceptions of policymaking based on the digital traces left by electronic devices and transaction cards. We discuss the implications of our findings and conclude by considering the public policy implications of the digitally invisible.

Data in Support of Policymaking and the Emergence of Policy Analytics

Harold Lasswell's original concept for the policy sciences sought to distinguish analysis from political decision making, and position policy analysis as a foundation of good governance (Lasswell, 1951). *The Policy Sciences* (Lerner &

Lasswell, 1951) envisioned policy analysis as an integrated, multidisciplinary approach to the study of public problems and the development of rational solutions based on careful analysis. Performing a core function of government, policy analysts are tasked with providing support for decision making with the aim of contributing to better decisions than would be made in the absence of such analysis (Quade, 1975).

While the tasks and methods of the practicing policy analyst have evolved over the intervening decades, in the half-century since Lasswell (1951) the epistemology and methodology of policy analysis have oscillated wildly between positivist technocracy (Parson, 2015) and post-positivist deliberation (Fischer, 2003; Ungerleider, 2015). Policy analysis exhibits a wide epistemological scope that accommodates a variety of theoretical perspectives and methodologies (Riccucci, 2010), despite the longing of many in the field for more rigorous "scientificness" (Raadschelders, 2011, p. 917).

Lasswell's (1951) vision for the policy sciences was based on social science knowledge and quantitative methods to analyze policy choices, methods strongly influenced by economics. Positivism—the application of logical and mathematical treatment to empirical evidence as the basis for determining authoritative, scientific knowledge—dominated the discipline's intellectual infrastructure in its early years, and the policy analysis profession has been strongly influenced by the training, practice, and specialization of the academics that taught succeeding generations of policy analysts (Morçöl, 2001). During the first 25 years of the policy analysis movement, techniques such as modeling, quantification of data, descriptive statistics, statistical inference testing, operations research and systems analysis, cost–benefit and risk–benefit analysis, Markov analysis, linear programming, dynamic programming, stochastic modeling, Bayesian analysis, quasi-linearization, invariant embedding, and general systems theory became staples of the profession (Radin, 2000). This "golden era" of the policy analysis movement in the late 1960s was a time when "policy analysis was essentially quantitative analysis" (Yang, 2007, 351). During that period, theoretical and applied advances continued to be made into the 1980s using mathematical equations and computer programming (Quade, 1980) and additional advances such as system dynamics (Forrester, 1971; Meadows, Meadows, Randers, & Behrens, 1972), Integrated Assessment Models for integrating science with policy (Parson & Fisher-Vanden, 1997), and increasingly sophisticated simulation tools (Wolfson, 2015).

Yet despite the coming of age of policy analysis in the early 1970s, debates over the real, perceived, and proposed role of the policy analyst have colored the profession's latter years. While technical policy analysis rooted in quantitative methods became increasingly sophisticated during the 1970s and 1980s, high-profile failures during this period exposed the limits of positivist policy analysis (May, 1992). Coupled with the perceived inability of quantitative policy analysis to solve public problems during the 1970s, critics of positivism argued that the attempt to model social interactions on the natural sciences model was misguided (Amy, 1984), that policy wisdom should be seen as more than the results of data impressively distilled (Prince, 2007; Wildavsky, 1978), and that positivism was fundamentally incapable of dealing with complex problems in a democracy (Fischer, 1995). At the same time, the implementation problem (i.e., the disconnect between policymaking and action required on the ground to realize the intent of the policy initiative) highlighted how autonomous human behavior and judgment was not adequately accommodated in positivist models (Pressman & Wildavsky, 1973).

The subsequent post-positivist movement led to calls for a balancing of softer skills along with technical mastery (Fischer, 1980, 2003), and approaches such as participatory design, stakeholder involvement, citizens' input, qualitative methods, and mixed methodology, among others, were advanced. Part of the response to the implementation problem focused on the knowledge gained through the work of the "street level bureaucrat" (Lipsky, 1971; Pressman & Wildavsky, 1973). Based on this revised appreciation of the actual work of the policy analyst, policy analysis skills came to include case study methods, interviewing and qualitative data analysis, organizational culture analysis, political feasibility analysis, stakeholder engagement, and small-group facilitation (Radin, 2000).

Whether positivism is still dominant in practice is an open question. Morçöl (2001) found that there was considerable support for positivism among policy professionals, especially among practitioners and professionals with educational backgrounds in economics, mathematics, and science. This could reflect the position of policy analysts within government bureaucracies, positions that do not afford much scope for independent inquiry and the questioning of underlying assumptions (Amy, 1984). However, when considering the methods employed in their work, a recent survey of practicing policy analysts found that when asked to rank five policy analyst archetypes ("connector," "entrepreneur," "listener," "synthesizer," "technician") in the order of how they understood and practiced policy analysis, the "synthesizer" archetype (defined in part as developing "recommended ways to deal with the problem") was strongly identified with, and the "technician" archetype (defined in part as undertaking "statistical policy research") was consistently ranked lowest (Longo, 2013, p. 67). That is, respondents strongly supported a post-positivist, narrative policy analytic approach over quantitative positivist traditions.

It is into these debates between the positivist and post-positivist camps that the promise of policy analytics in support of policymaking has entered. The decline in hegemony of quantitative methods since the 1970s is partly a reflection of limitations in the tools of analysis and the lack of data availability. With the enhanced capacity both in techniques and data quantity embodied in these new data approaches, these post-positivist critiques of positivism are being addressed. Advances in recent years in our ability to capture, store, and process data have the potential to revive the positivist tradition in policy analysis, and through it how data and analysis can better support decision making and policymaking. These advances go beyond just the accumulation of data at high volume and speed, from a range of sources, to include analysis and usage concepts such as data analytics, business intelligence, algorithmic decision making, machine learning, deep learning, and artificial intelligence. While referred to elsewhere *inter alia* as "big data in public affairs" (Mergel et al., 2016, p. 931) and "policy informatics" (Johnston, 2015, p. 3), we use the term "policy analytics" to refer to the combination of new sources and forms of policy relevant data with the use of new analytics technique and capacity, designed to support policymaking (Daniell et al., 2016; Tsoukias et al., 2013).

Massive amounts of data are now accumulated daily through the online activity and social networking of individuals, purchasing behavior, and transportation choices revealed through electronic payment cards, movement and interaction captured through mobile smartphones, behavioral choices measured through IoE consumer products, a range of measurements captured by *in situ* and personal sensors, satellite remote sensing, counters and smart meters, and interactions with devices and control technology (Chen, Chiang, & Storey, 2012).

An alternative categorization of data sources segments them into public data, private data, data exhaust, community data, and self-quantification (George, Haas, & Pentland, 2014). The accumulation of these data and associated metadata such as geolocation information and time and date stamps results in a previously unimaginable amount of data, measured with precision, taken from multiple perspectives, and captured continually in real-time. Advances in data storage technologies now make it possible to preserve increasing amounts of data. Additional advances in data mining and visualization can yield valuable new insights and serve as helpful supports for decision making. The combination of these signals and new analytics techniques can help in understanding and predicting human behavior in contexts such as transportation patterns, criminal behavior, energy use, and purchasing decisions. Applied to public policy problems, "high-volume data that frequently combines highly structured administrative data actively collected by public sector organizations with continuously and automatically collected structured and unstructured real-time data that are often passively created by public and private entities through their Internet interactions" (Mergel et al., 2016, p. 931) can provide the foundation for the emergence of a positivist policy analytics approach, and the potential for it to influence how policy analysis is done inside government is profound (Decker, 2014; Longo, 2015). With massive amounts of digital data increasingly available, analysis spanning problem definition framing to solution identification can be built on a platform of robust, precise, continuous, and complete data, potentially transforming the very idea of policy research and analysis.

Policy analysis traditionally involved a process of extrapolating from data collected from some representative sample, or developing an aggregate picture of an average person and then developing policies or interventions based on that composite. Policy analytics based on new data sources coupled with data analytics can provide a much richer and more detailed view of a system and the individual agents in it. Even when we have data on (nearly) everyone—from a census, for example—that data provides only a point-in-time snapshot, with a delay between the time of data capture and the release of the statistics. New sources and forms of data offer the possibility of continually updated, real-time data availability. Traditional data snapshots also do not tell us about the way that people are dynamically interacting with their world; continuous data offer the promise of revealing how agents and systems react to changes in environmental conditions and variables. Traditional data collection approaches also largely rely on respondents to cooperate with researchers, raising challenges such as low response rates and respondent bias; new data approaches eliminate this researcher/respondent interaction by focusing on direct observation of behavior, presenting policymakers with a direct view of what people actually do rather than a survey of what they think. Policy analytics can be used as a foundation for both reactive and proactive policy, as a basis for understanding, eliminating, constraining, encouraging, or otherwise modifying behavior, or as an input into framing a policy problem before it is apprehended as such, indicating where a need is being unmet or where an emerging problem might be countered early. Such data approaches can also change the implementation process, where policy ideas can become subject to real-time micro-experimentation where governments can manipulate input variables in law, markets, architecture, social norms, and information (Johnston & Hondula, 2015; Lessig, 2006), and measure with fine-grained accuracy the impacts correlated with those changed variables in order to propose, pilot, test, evaluate, and redesign policy interventions (Haynes, Goldacre, & Torgerson, 2012; Paquet, 2009).

This new enthusiasm for ubiquitous data and policy analytics rests on the widespread belief that large data sets offer a higher form of intelligence, revealing objective and accurate truth. However, if this movement fails to acknowledge some of the limitations of new forms of data collection and analytics, the core critiques of post-positivism will go unanswered (boyd & Crawford, 2012; Hitchcock, 2013). Here, we address two critiques of policy analytics, derived from earlier critiques of positivism: that the "fact/value dichotomy" is not as clearly delineated as positivists contend; and that the empiricism of policy analytics is impressive but still represents an incomplete view of the world when considering the digitally invisible.

A central premise of positivism is the fact/value dichotomy, which holds that value judgments are subjective and should be considered distinct from statements of fact that are objectively true. This can also be expressed as the distinction between positive statements about what is, and normative claims about what ought to be. Post-positivism argues that this distinction has collapsed, largely because the derivation of facts is influenced by the values of the observer (Putnam, 2002). The theories, values, and position of the policy analyst frame the facts that are sought and the methods by which they are determined (Rein, 1983; Schön & Rein, 1995). In the context of policy analytics, the evidence collected and the methods by which it is analyzed are not value neutral (boyd & Crawford, 2012), and those values influence the data that are collected and the facts that are determined (Diesing, 1982). One benefit of the policy analytics approach is that we no longer have to ask people what they think or prefer (i.e., ascertaining their values); we can instead observe what they do (i.e., measuring facts). The post-positivist would counter that the methods and analytics techniques that collect and derive those facts are influenced by the values of the researchers that determine what is measured and how.

The policy analytics movement also promotes the idea that massive amounts of data drawn from ubiquitous devices have addressed any concerns about data limitations. As Benoit (2015) has expressed it, data analytics contains "the myth that N = All," or that with sufficiently large data sets, we can assume that the resulting picture is complete. With part of the data analytics approach focused on the digital traces emerging from mobile and standard computing devices (i.e., smartphones, tablets, and laptops), consideration of the digitally invisible requires a brief review of the concept of the "digital divide," a term that emerged in the 1990s as a shorthand to signal inequalities and disparities related to digital technology (Drori & Jang, 2003; Norris, 2001; Parker, 2007), resulting from a range of factors. While originally conceived as a concept to distinguish those with physical access to ICTs and those without (whether within societies or between nations), broadening the notion of access following the growing importance of Internet-connected personal computers during the 1990s, the digital divide concept bifurcated between research focused on the issue of simply having access as distinct from more complex questions related to attitudes and cognitive capacity, education and skills, and purpose and usage (DiMaggio & Hargittai, 2001; Katz & Rice, 2002; Mossberger, Tolbert, & Stansbury, 2003; Van Dijk, 1999; Warschauer, 2003). As the cost of material access to the Internet has continued to fall, accelerated through the proliferation of mobile technology facilitating Internet access, concern over material access has diminished (Wareham, Levy, & Shi, 2004), although education, income, race, and disability continue to influence whether one has stable, regular Internet access (NTIA, 2014). Global access to the Internet is also still uneven, as the International Telecommunications Union found in 2015 that only 46 percent of households globally have Internet access, with 81 percent in developed countries but less than 7 percent in Africa; however, mobile cellular subscriptions are near universal, with 97 percent penetration (ITU, 2015). Smartphones and tablet computers are an increasingly important mobile bridge over the digital divide (DeGusta, 2012) with approximately 64 percent of Americans having a smartphone in 2015 (Smith, 2015) due in part to their lower cost, ease of use, and multifunctionality (Sung, 2015). A recent study by the Pew Research Center's Internet & American Life Project found that nearly two-thirds of the U.S. cellphone owners now use their phone to go online; because 91 percent of all Americans own a cellphone, 57 percent of all American adults are "cell Internet users," a proportion that has doubled since 2009 (Duggan & Smith, 2013). Public libraries are also important providers of Internet access across all income and educational brackets, but especially so for the unemployed (Bertot, Jaeger, Langa, & McClure, 2006; NTIA, 2014).

Even if the divide in physical access to digital technology has been bridged, concerns about differing attitudes toward Internet connectivity, skill disparities, and the nature of Internet use persist (e.g., Hargittai & Hinnant, 2008; Van Dijk, 2005; Zillien & Hargittai, 2009). Related to this, changing technology and the capacity for multidirectional information flow in the Web 2.0 era has expanded earlier concerns over the ability to access information over digital channels (Drori & Jang, 2003; Norris, 2001; Parker, 2007) to include, more recently, the capacity of some groups to affect change using those channels (Hargittai & Hinnant, 2008; Helbig, Gil-Garća, & Ferro, 2009; Macintosh, 2004). Yet even with more near ubiquitous physical access, differences in the ability to influence those channels remain. The digital divide concept masks some variability within these groups, where differences in age, gender, education, income, personal data safeguards, and other variables, along with differences such as time of year, regional differences, and particular events can affect one's digital exposure. Older populations are found to be less likely to adopt new technologies quickly (Brodie et al., 2000; Kiel, 2005; Loges & Jung, 2001; Millward, 2003, Zickuhr & Madden, 2012). Some may lack knowledge required to use new technology, or may not be comfortable with it (Hargittai, 2009). Race, class, and ethnicity can play a role in whether someone uses particular technologies (Lin et al., 2015), as can some psychological factors (Selwyn, 2004). Computer ownership and Internet access is simply not evenly distributed in society (NTIA, 2010). Purpose and use is largely influenced by socioeconomic status, regardless of connectivity status (DiMaggio, Hargittai, Celeste, & Shafer, 2004; Van Dijk, 2005; Witte & Mannon, 2010). Higher-status users use the Internet to look up health information, conduct financial transactions, and research purchases, while those with lower socioeconomic status use it for casual browsing, entertainment, and game play (Hargittai & Hinnant, 2008; Madden & Rainie, 2003). Recent evidence from Europe shows that, across all user groups, smartphones are not serving as mobile nano-computers but rather serve a limited number of functions such as SMS texting, picture taking, and as substitutes for watches and alarm clocks (Fortunati & Taipale, 2014). As one simple measure, note that only 23 percent of online adults in the United States use Twitter (Perrin, 2015), and only about one-third of those use it regularly (Duggan, Ellison, Lampe, Lenhart, & Madden, 2015), though the service is freely available to anyone.

Homelessness, Technology, and Extreme Heat Exposure

The particular marginalized socioeconomic group we focus on here is the homeless, those individuals in our societies who—whether for reasons related to poverty, mental health, or addictions—suffer chronic periods of living without stable housing, and spend most of their days without shelter for themselves and their belongings.[1] In January 2014, over 578,000 people in the United States were homeless on a given night with most (69 percent) staying in residential programs for homeless people and the remainder found in unsheltered locations or exposed areas such as streets, in abandoned buildings, or other places not meant for continuous human habitation such as a vehicle or a tent in a public park (HUD, 2014). There are an estimated 22,000 homeless people in the state of Arizona and about half of those people reside in Maricopa County, where the city of Phoenix is situated (Arizona Department of Economic Security, 2010). In 2014, officials counted 17,558 homeless people in the Phoenix metropolitan area throughout the year (the area has a population of roughly four million people) (Carter, 2014). On one particular night in 2014, there were 4,865 homeless individuals in shelters and 1,044 on the streets of Phoenix. These numbers are estimates given the difficulty in accurately counting such a marginalized population and because of the variety of methods used for counting the homeless (Cagle, 2015). But most observers agree that the decades-long crisis of homelessness in the United States has begun to show signs of improvement in many cities (HUD, 2014), owing to federal government efforts such as the *Strategic Plan to Prevent and End Homelessness* (U.S. Interagency Council on Homelessness, 2010) that includes targeted programs and initiatives such as "Housing First" that focus first on the fact of homelessness rather than attempting to address possible root causes prior to securing housing (Nelson et al., 2014).

Homeless people are disproportionately affected by serious health problems including mental illness, substance abuse, and infectious and chronic diseases (Hwang & Dunn, 2005). Because the homeless suffer from serious health problems, they stand to benefit greatly from support services provided by agencies such as our research partner, the Phoenix Rescue Mission (PRM). When homeless people have access to financial, emotional, and instrumental social support through their personal social networks, they experience better physical and mental health status (Hwang et al., 2009). Extending this idea to health care support services delivered using mobile communication devices, Post et al. (2013) found that new media can be a powerful tool to connect patients experiencing homelessness to health care services. Mobile technology-based support for homeless individuals in outpatient health care can be as simple and inexpensive as providing text message reminders of appointments, leading to a reduction in missed appointments and lower emergency department use (McInnes et al., 2014a).

There is an emerging body of research indicating that many homeless persons have access to and regularly use a variety of information technology, principally mobile phones, to engage in text messaging and telephone calls, send and receive emails, run apps, and browse the Internet. With fewer and fewer public payphones available, personal cellphones and other means for connecting to people and information have become increasingly necessary for the homeless. While having a cellphone or smartphone may seem like a luxury that the homeless cannot afford, the absence of a fixed address (part of what defines homelessness) makes a mobile phone highly necessary for a homeless person. Some of the reasons a mobile phone might be useful to a homeless person are to connect with potential resources such as employment prospects, shelters, and other social services; to call friends for temporary accommodations; to stay in contact with family; and to look up public transportation schedules. Safety is also a factor, providing at least the impression that one can call for help if needed (Woelfer, Iverson, Hendry, Friedman, & Gill, 2011). As noted above, 91 percent of all Americans own a cellphone, and 57 percent of all American adults are "cell Internet users" (Duggan & Smith, 2013). A recent systematic literature review of technology use by homeless persons found that mobile phone ownership ranged from 44 percent to 62 percent and that computer access and use ranged from 47 percent to 55 percent (McInnes, Li, & Hogan, 2013). While mobile phone coverage has expanded among the homeless, about half have regular cellular data coverage requiring the user to find publicly accessible WIFI to use the phone's Internet capabilities (CTA, 2013). Given how rapidly mobile technology adoption is proceeding (DeGusta, 2012), mobile phone ownership among homeless people is likely much higher today (see, e.g., McInnes et al., 2014b, who report 89 percent cellphone ownership among homeless people surveyed, with one-third owning smartphones). One reason may be the Low-Income (Lifeline) program that uses fees levied on telecommunications customers to fund telephone ownership for poor Americans. This program has been a part of the American universal service regime since the Reagan administration, with the first Bush administration extending the original landline program to include cellular phones. Phones acquired under the Lifeline program are now commonly referred to as an "Obamaphone" despite their earlier origin (Colley, 2014; Cramer, 2015), though a recent survey found less than 2 percent of respondents had heard of the Lifeline program and 62 percent had not heard of it (CTA, 2013). Public libraries are also an important part of bridging the digital divide, providing access to Internet-connected computers with few restrictions (Eyrich-Garg, 2011; Gordon, Moore, & Gordon, 2003). The evidence would appear to support the argument that the digital divide has been bridged for the homeless—at least for the access conceptualization of the digital divide—with recent interview evidence confirming this view (Gordon, 2015).

While the digital divide may appear to have been significantly addressed through the spread of cheap, ubiquitous mobile phones, a robust view of the digital divide in the context of policy analytics can be further stretched to consider the trail of data left through devices connected to the IoE, and data generated from various noncash electronic financial transactions (van Deursen & van Dijk, 2014). These extensions represent unexplored areas of research. However, it would seem unlikely that the homeless, with their limited capacity to carry personal belongings and the lack of a fixed address, would be deeply connected to the IoE and the many devices it connects, though we have found no research addressing this issue. The experience of the homeless with electronic financial transaction cards such as debit and credit cards, electronic benefit transfer (EBT) cards, transit system passes, and retailer loyalty cards, however, can be connected to a nascent literature.

Debit and credit card use by the homeless is connected to the issue of financial exclusion that has been raised in recent years as an acknowledgment that a modern economy with a high-functioning banking system places a strong emphasis on having a client relationship with a financial institution (Kempson, Atkinson, & Pilley, 2004). Many transactions we take for granted, such as renting an apartment, are made difficult when one does not have a bank account, with the homeless being at a particular disadvantage (Wallace & Quilgars, 2005). The main barriers to getting a bank account (and thus an electronic payment card like a debit card) are identity requirements, service charges, physical access problems, and psychological barriers (Collard, Kempson, & Whyley, 2001). Financial exclusion has been exacerbated by identity requirements now strengthened by governments in response to money laundering and terrorism-financing threats.

EBT cards—a digital debit-based payment card system used since the 1980s by the U.S. county welfare departments to disburse and manage benefits (Wright et al., 2014)—can serve as a data source for policy analytics. Homeless individuals in the United States are eligible to receive benefits from the federal Supplemental Nutrition Assistance Program (SNAP; formerly known as the Food Stamp Program), and EBT cards are used to manage program disbursement and use (Martins et al., 2015). The SNAP program provides monthly benefits to approximately 46 million low-income individuals and families (USDA, 2014). However, since one of the central tenets of SNAP is that benefits be used to purchase foods that can be prepared at home, homeless individuals may not fully benefit from this program as they do not have regular access to cooking facilities and food storage (Richards & Smith, 2006), though the U.S. Department of Agriculture has attempted to address this concern by advising homeless recipients that they can purchase easily prepared foods and, in same cases, already-prepared meals (USDA, 2015). While there are anecdotal reports of EBT data being used by welfare caseworkers to monitor the consumption patterns of individual recipients (Eubanks, 2014), it is likely that policy analytic approaches to assessing EBT data are at least being considered if not actively under way (Schwabish, 2015).

Using data collected from "smart card," municipal transit system passes is clearly an area ripe for policy analytics (Pelletier, Trépanier, & Morency, 2011; Tao, Corcoran, Mateo-Babiano, & Rohde, 2014). Smart card systems require transit passengers to tap their smart cards when boarding a bus or entering a train station, or to have their ticket checked by an inspector in an open access, fare monitoring system. The card readers capture card details and combine that with information about the service being used. While the card is identifiable, sociodemographic characteristics (e.g., income, gender, household) of smart card users are not regularly provided in smart card data (Bagchi & White, 2005). Le Dantec and Edwards (2008) provide a report on the challenges that movement toward electronic transit passes may pose for homeless individuals.

Retailers and service providers offer retailer loyalty cards to encourage continued patronage from consumers and, more recently, as a means for accumulating and analyzing data (McAfee, Brynjolfsson, Davenport, Patil, & Barton, 2012). The combination of personal information about the account holder (usually provided as part of the process of enrolling in the program) and the detailed record of their transactions when using the account number or card results in rich data about consumer characteristics, decision making, and habits. Even where the supplied personal information was purposely inaccurate or withheld, policy analytics can be used to characterize the cardholder and send them targeted advertising. We have found no literature that looks specifically at the use of loyalty programs among homeless individuals.

Finally, we review the issue of extreme heat and associated health risks in Phoenix, especially as it affects homeless people. Extreme heat is among the leading weather-related causes of death in the United States and other developed countries (Berko et al., 2014), leading to more fatalities each year than most other natural hazards (e.g., hurricanes, tornadoes, lightning, flooding) combined. Beyond those who die, many times more people experience some form of heat-related illness, which can result in the need for emergency department care or hospital admission (Petitti et al., 2016). Heat is a ubiquitous hazard in many geographic settings; all people are potentially at risk of suffering adverse health outcomes if they are exposed to dangerously hot conditions for a sufficient period of time. However, the impacts of heat are experienced disproportionately by certain demographic groups and in certain communities (Harlan et al., 2012; Hondula, Davis, Saha, Wegner, & Veazey, 2015). Among the populations at highest risk of suffering adverse health outcomes related to heat are the homeless, who by the nature of their daily life circumstances are exposed to outdoor environmental hazards, including heat, more frequently than much of the public at large. Furthermore, because of frequent medical illnesses and preexisting conditions, homeless individuals experiencing heat exposure are more likely to experience adverse outcomes.

The specific context for this exploratory project is the health impacts on homeless individuals exposed to extreme heat events when those people do not have access to appropriate shelter and artificial cooling resources, a setting in which the social world and the physical world intersect (Pentland, 2014). Heat-related illness and death are among the many health events experienced among homeless individuals at a disproportionately high rate compared to housed individuals. In the geographic setting for this research, Maricopa County, Arizona, located in the desert southwest of the United States, homeless individuals accounted for 144 of the 632 (23 percent) heat-associated deaths documented by the Maricopa County Department of Public Health over the period 2006–13 (MCDPH, 2014). Although exact counts of the total homeless population in a given region are difficult to obtain and official estimates vary from source to source, annual point-in-time volunteer counts estimated the total number of homeless persons in Maricopa County to be upward of 6,000 in recent years (MAG, 2013, 2014). The disparity in the heat-related mortality rate between homeless and housed individuals is striking: while the crude heat-associated death rate for all County residents was 1.6 per 100,000 over the period 2006–13, we estimate the death rate for the homeless to be almost 200 times higher at 300 deaths per 100,000 people. Even if the homeless point-in-time count data underestimate the total population by 50 percent or 100 percent (as might be the case when the data are compared to those collected by the Arizona Department of Economic Security), a clear disparity in adverse health events related to extreme heat exposure is present.

Jurisdictions around the world develop and maintain strategic plans and emergency response protocol for extreme heat events that often cross multiple sectors of government including weather forecasting agencies, public health departments, emergency management coordinators, and human services units (Ebi & Schmier, 2005; Hess, McDowell, & Luber, 2012). Other programs and policies in place in many settings for reducing the health impacts of extreme heat, some of which are formalized into laws or ordinances, and others of which appear in long-term planning documents, include suspension of utility shutoffs during declared heat emergencies, operation of publicly available cooling shelters, home weatherization and energy assistance programs, and urban greening programs aimed at increasing natural shading in populated areas (Berisha et al., 2016; Kovats & Kristie, 2006; Middel, Chhetri, & Quay, 2015). Concerns about the health consequences of future warming, as a result of global-scale increases in greenhouse gas concentrations as well as regional development and growth of urban heat islands (Hondula, Georgescu, & Balling, 2014; Sheridan, Allen, Lee, & Kalkstein, 2012; Stone, Paciorek, Pall, & Wehner, 2013) will likely continue to motivate a wide range of agencies and actors to continue to improve and invest in heat preparedness and response initiatives in the years ahead.

Methods

The preceding literature review highlights two post-positivist critiques that can be applied to the policy analytics movement: that the fact/value dichotomy is not clearly delineated; and that the impressive empiricism of policy analytics nonetheless represents an incomplete view of the world. We explore both arguments here: that a values-influenced method for collecting data will be reflected in the facts that are collected, ignoring other facts; and that, despite the volume of data collected, policy analytics methods produce blind spots and can cause some members of society to be rendered digitally invisible. We explore these concepts in the context of homeless people living in Phoenix, Arizona coping with extreme heat.

The emerging literature surveyed above on the use of mobile devices and Internet connectivity indicates that a tenuous bridge is being built across the digital divide—in both its simple "access" form and its more complex "usage" form—with the homeless benefitting greatly from mobile connectivity, finding ways to make mobile device ownership, and use affordable while accessing social network resources. However, there is insufficient evidence upon which to judge the other categories of new data sources and forms we identify: devices connected to the IoE and card-based electronic transactions.

At this early stage in conceptualizing the digitally invisible, this exploratory study is designed to consider the concept, and test a prototype approach for reducing that invisibility. We focus on one measure of personal welfare within a specific population: IETs (Kuras et al., 2015) among homeless individuals in Phoenix, Arizona (Harlan et al., 2008). The IETs of a comparison group of digitally connected participants provide a benchmark against which to evaluate the experiences of the research participants. This focus on heat-health is supplemented by data gathered from participants through intake and exit interviews on their technology use and access to financial services. Thus, in this exploratory study, we address the following research questions:

1. RQ1: Are the IETs (measured relative to OATs) of those we hypothesize to be digitally invisible objectively different from the digitally connected?
2. RQ2: Are other data sources (e.g., technology use, financial services) of those we hypothesize to be digitally invisible objectively different from the digitally connected?
3. RQ3: Is the concept of the "digitally invisible" empirically supported?

We followed a method developed by Kuras et al. (2015) in which research participants were equipped with a Thermochron iButton (Maxim Integrated, San Jose, CA), a small and lightweight mobile sensor that measures and records instantaneous air temperature at five-minute intervals. With the cooperation of the PRM,[2] we engaged a convenience sample of 10 participants in the research who were all clients of PRM and expected to sleep there that night. Seven of the research participants were "program participants," engaged in a year-long residential addiction recovery and job training program. Three of the research participants were "walk-in clients," visiting PRM for a meal and a place to sleep. An iButton was given to each of the participants at the intake interview and the time recorded. Participants clipped their iButtons to a belt loop or bag so that the device was continuously exposed to the surrounding air as they went about their daily lives. Participants were asked to carry the device on their person or belongings, but otherwise were not asked to change anything about their daily behavior. The device was returned to the study team at the exit interview approximately two weeks later, though the device only captured data for a one-week period—the maximum capacity of the iButton model used when recording at five-minute intervals. The devices were in the field during late spring/early summer 2015, a period when temperatures in Phoenix are already approaching dangerous levels. A comparison group of 10 digitally connected participants (university students selected as being more closely representative of the population from whom policy analytics data are currently derived) carried iButtons for a one-week period in early autumn 2015, using the same protocol as above. For both groups, the average IET readings are compared to OAT readings taken at Sky Harbor International Airport (PHX) in Phoenix, Arizona during the corresponding time period.

In addition to collecting iButton data, intake and exit interviews were conducted with homeless participants to understand their experiences as a homeless person, perceptions and concerns with respect to privacy and obtrusiveness of the iButton, their experience coping with extreme heat, their experience with technology and the electronic banking system, and their openness to more complex data capture protocols and future researcher/participant collaboration. Comparison group participants completed a pretest and posttest online survey that included most of the same questions from the intake and exit interviews. Interview and survey questions were developed by modifying items previously used (Eyrich-Garg, 2011; Sanchez, 2011) adding questions relevant to our research questions. The intake interview guide for the homeless participants included 26 questions and the exit interview included 21 questions, some of which were repeated from the intake interview to identify changes over the study period. For the university students in the comparison group, there was no intake survey; an exit survey containing 25 questions was completed online by the respondents. Responses were quantified where possible, and qualitative responses were evaluated by all authors. Descriptive statistics and narrative description of the results are provided below.

Homeless participants were provided with a $25 Visa gift card at the exit interview (no data from the use of this card were collected). Participants in the comparison group were not compensated. The study was approved by the Arizona State University Institutional Review Board in May 2015 (Protocol STUDY00002516).

Data

Temperature Data

IET data were successfully captured from all 10 PRM participants and 10 comparison group participants. Because of varying compliance among participants in wearing the sensors near the start and end of the data collection periods, we constrained the data used for subsequent analysis to time periods of approximately five days in duration for each study group. Mean IET data for homeless participants are presented in the left panel of Figure 1, overlaid with corresponding OAT data from PHX during the study period. The right panel of Figure 1 shows the corresponding data for the comparison group of university students. PRM participants had an average IET of 29.5°C during a study period in which the average temperature at PHX was 37.4°C. In contrast, the comparison group participants had an average IET of 24.9°C during a study period with an average temperature at PHX of 29.6°C.

To account for differences in outdoor weather between the two IET data collection periods and to contextualize IETs in terms of health risks, we performed an additional series of calculations. The basis for these calculations was the concept of heating and cooling degree-days, commonly applied in the energy industry to anticipate power demand during the winter and summer months. A cooling degree day (when energy is needed to cool homes), for example, is calculated as the

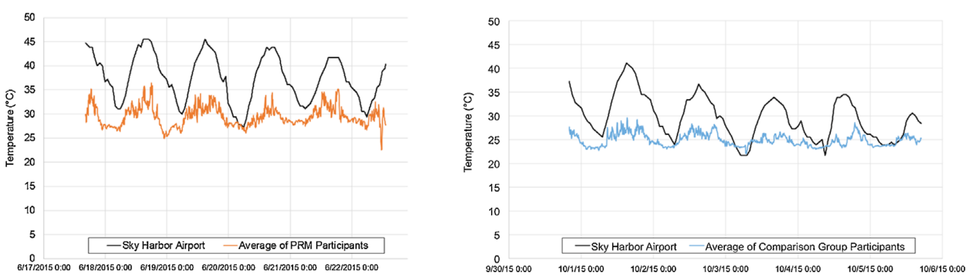

Figure 1. Mean IET for Homeless (PRM) Participants (n = 10) and OAT at PHX (Left Panel) and Mean IET for Comparison Group Participants (n = 10) and OAT at PHX (Right Panel).

difference between a day's maximum daily temperature and a reference temperature of 65°F (18.3°C), only on days on which the maximum temperature exceeds the reference. This difference is a "degree day," and these degree days can be added across different time periods and/or compared between geographies to understand or anticipate patterns in energy demand.

Here, we utilized a similar concept of extreme heat degree minutes (EHDMs) (Karner, Hondula, & Vanos, 2015). We set a reference threshold for a temperature associated with known health risks as 29°C, drawn from epidemiological analysis by Petitti et al. (2016) for the Phoenix region. For each research participant and for the data from PHX, EHDMs were calculated as the difference between IETs and 29°C for each five-minute period. Only positive differences were included in the summing of EHDMs; IETs below 29°C were assigned an EHDM of 0. We then tallied the total EHDMs for PHX to indicate the theoretical heat stress that would be experienced by someone who was outdoors for the entire time period. EHDMs were also tallied for each research participant. The ratio between these two quantities—participant EHDMs and PHX EHDMs—was defined as the percent of possible heat stress experienced by each participant. This quantity represents the fraction of the dangerous heat exposure that each participant experienced during the time period in which their IET data were collected and standardizes the meteorological differences between different time periods.

The homeless population in our study experienced, on average, 241 percent of the heat stress experienced by the comparison group. The percent of possible heat stress across the 10 homeless individuals ranged from 5.5 percent to 61.8 percent (mean: 23.6 percent); whereas in the comparison group, percentages ranged from 0.04 percent to 23.6 percent (mean: 9.8 percent). Among the homeless individuals, the mean possible heat stress for those participating in the residential recovery program was 12.5 percent, and for the "walk-in clients" visiting PRM for the day, mean possible heat stress was 49.4 percent. Histograms comparing the percent of possible heat stress between the two groups (homeless and comparison) are shown below as Figure 2.

Interview Data

Homeless Participants. All homeless interview respondents were male, with a median age of 44 and ranging from 21 to 60. While all 10 "homeless participants" were included based partly on an inclusion criterion that the participant considered themselves homeless, or were nominated by PRM staff based on that criterion, two of the respondents (each of whom were program participants) did not consider themselves homeless. While we did not probe this discrepancy, we hypothesize that some stop considering themselves homeless once they become stable program participants at PRM. None of the respondents reported a change in their homelessness status over the study period. When asked to estimate how long their current episode of homelessness had lasted, the median length of time was eight months (excluding one respondent who estimated he had been homeless "on and off for nine years"). Eight respondents were single adults, and

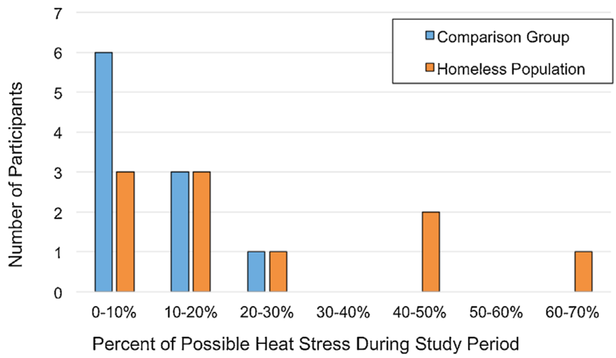

Figure 2. Percent of Possible Heat Stress Experienced by Homeless Population and Comparison Group Participants During Their Respective Study Periods. *Note*: Percent of possible heat stress is calculated as the ratio between EHDM experienced by each participant, as derived from their IET data, and EHDM observed at PHX.

two were parents in families with children. One respondent was an armed services veteran. When these questions were repeated during exit interviews, responses were generally consistent with the intake interviews.

Respondents were asked about any medical conditions they have to manage. Three reported no medical problems, and one respondent refused to answer the question, noting that having a medical condition led him to "get the sense you're looked down upon." Specific responses included chronic conditions such as HIV, diabetes, migraines, arthritis, sleep apnea, scoliosis, addiction, and high blood pressure. One respondent noted the long-term effects of a stroke suffered in 2003.

When asked "Have you ever felt discriminated against because you are homeless?," three responded "yes" in both the intake and exit interviews, while four responded "no" at both times. One response changed from "no" to "yes" between the intake and exit interviews, and two changed from "yes" to "no." When asked "Since you've been homeless, have you experienced any violence?," two responded "yes" in both interviews, and five responded "no" at both times. Three responses changed from "yes" to "no" between the intake and exit interviews. While experience with discrimination and violence were reported by half the respondents in the intake interviews, those reports declined in the exit interviews.

Respondents identified several motivations for joining PRM, many related to the Christian values the mission advances and its drug rehabilitation program (though respondents speculated that these aspects were also reasons for why some homeless people do not seek PRM services). When asked whether respondents felt included in government policies, or in different types of social services or health interventions, respondents generally voiced support for the attempts by governments and social service agencies like PRM to help with homelessness.

Respondents were asked about their experience with Arizona extreme heat: two were about to experience their first summer; the remainder had gone through between one and eight summers, with a median value of 1.5 summers. Coping strategies for avoiding or dealing with extreme heat included finding shade, staying hydrated, and staying indoors whenever possible. As clients of PRM, respondents were able to find shelter at the facility. When referring to private establishments such as stores and restaurants, two respondents noted that they were aware of time limits or being asked to leave. PRM clients had no difficulty finding water as it is readily made available there or in stores or restaurants (one respondent referred to an Arizona state law that requires establishments to give water to patrons when requested). For impending heat events, most respondents said that they relied on traditional media like television weather reports. Four respondents have seen heat exposure illness in friends, with three of those cases resulting in hospitalization. Two were aware of deaths due to heat exposure. These experiences generally led to increased awareness and greater caution with respect to the dangers of extreme heat.

We next asked questions about technology use. Eight of the respondents owned a cellphone on intake, with all respondents having a cellphone in the exit interviews.[3] Of these, six were smartphones with monthly prepaid service costing between $30 and $60 per month; the three others were "Obamaphones." The two respondents who acquired mobile phones before the exit interview applied for and got "Obamaphones." The purposes for which mobile phones were used were primarily for phone and texting, including "to look for jobs" and for "doctor appointments," with additional uses being entertainment (videos and music) and social media. When asked if they would accept and use a free smartphone from either a social support center like PRM, a university research group, or the government, all respondents replied in the affirmative except for one respondent who said "no" to a government-provided phone. Potential uses for such a free smartphone mirrored the current uses identified above. Eight respondents stated that they use a computer (seven on exit), with access available through the PRM learning center, public libraries, the respondent's workplace and "on Obamaphone." In response to the question "Do you use social media?," four said "yes" on the intake interview with that number increasing to five on exit. All respondents said they had an email account on intake, though one respondent changed their answer to "no" on exit.

With respect to financial services, only three respondents had a bank account, and none had a credit card.

Comparison Group. Half of the comparison group survey respondents were female, with a median age of 18 and ranging from 18 to 37. We confirmed that none of the respondents had ever considered themselves homeless, and did not ask any additional questions about their experience of being homeless. Eight respondents were single adults, one was a single parent with children, and one was in a relationship with no children.

Respondents were asked about their experience with Arizona extreme heat: only one respondent noted a mild negative heat-health experience, but noting the precautions they take to stay hydrated and avoid prolonged exposure. For impending heat events, respondents had a variety of sources of information about extreme heat warnings including their smartphone interface, smartphone weather apps, Internet-based weather services such as Weather Underground and the Weather Network, search engine queries, Twitter, and their university's alert system.

We next asked questions about technology use. All 10 respondents owned a smartphone (six used an iPhone and four used an Android phone), ranging in cost from $400 to $800 to purchase, with monthly service fees of approximately $80. When asked what the purpose of the phone was, many responses indicated being somewhat bemused by the question: "You know, it's a smartphone" was indicative of the tone of the responses. All respondents stated that they use a computer, with access available "everywhere" through a personally owned device like a laptop and at locations such as campus computer labs. In response to the question "Do you use social media?," nine responded "yes." All respondents said they had an email account.

With respect to financial services, nine respondents had a bank account, and five had a credit card.

Results

The small number of research participants in each convenience sample—homeless individuals and university students—limits the extent to which we can generalize. Nonetheless, our objective of conducting a limited exploratory study of the concept of the digitally invisible has resulted in some interesting initial findings.

Our central observation is to confirm the obvious: individuals dealing with homelessness, and students privileged enough to attend a major public university, experience the world differently both in respect of their interaction with the physical world and with its technology. To answer RQ1, we find a substantial difference in temperature experiences relative to outdoor conditions between those we hypothesize to be digitally invisible and the digitally connected. Specifically, the homeless population experienced more than double (241 percent) the amount of potential heat stress compared to the student population during the study period. This difference has likely been compounded over the many more summers in which the homeless respondents experienced Arizona's heat relative to the student respondents. Much of the difference during the study period was driven by three homeless participants who experienced more than 40 percent of potentially dangerous heat exposure (mean: 49.4 percent), while none of the student participants experienced more than 30 percent of the dangerous heat (mean: 9.8 percent). The other seven homeless participants had similar percentages of possible heat stress (mean: 12.5 percent) compared to student participants. If we used OATs alone to understand IETs, we would fail to observe the experienced temperatures of those three individuals whose heat exposures were unlike their fellow homeless participants or the students. This is particularly troublesome because the heat exposure of some of the individuals most likely to be digitally invisible—those who fall outside of our heat exposure paradigm informed by the comparison group—experience heat in a much more severe manner. The three homeless individuals associated with the highest levels of heat stress during the study period were the three who identified themselves as "walk-in" clients of PRM and not enrolled in the year-long "residential" program. While sample size limitations and privacy concerns prohibit us from describing the circumstances of these three individuals in great detail or drawing generalizations from their responses, we suspect that homeless individuals who are not connected to particular recovery problems are more likely to be digitally invisible. This speculation, however, merits further investigation. If true, the observation that the thermal experience of the walk-in clients contrasts so sharply even from other individuals who identify themselves as homeless provides further support for the notion that the experienced temperatures of the digitally invisible are not only different from, but also of much greater concern, than the digitally connected.

In regard to RQ2, we find noticeable differences between the two groups in respect of technology use and financial services. When asked to identify sources of information for impending extreme heat events, homeless respondents identified traditional media like television weather reports exclusively. Student respondents, on the other hand, identified a range of new media sources centered on their smartphones and the Internet, and none mentioned television as an information source. The student comparison group interacts with the Internet in a constant and ubiquitous way that is quite distinct from how the homeless respondents do.

While all respondents in both groups had mobiles phones, we observe differences in device function, capacity, model, and data access. Whereas all student respondents had smartphones of recent vintage, homeless respondents had a mix of smartphones, "Obamaphones" and basic cellphones. While survey responses from the student comparison group did not describe their data coverage in detail, the context of their responses indicated that data access was not a constraint—whether they used data over cellular networks or on WiFi. Homeless respondents, however, often referred to the challenge of getting data access, especially given the short-term ban on mobile phones for those individuals participating in PRM's addiction recovery program. Aligning with the digital divide literature that differentiates between access to digital resources and their use, homeless respondents referred to specific purposes for having and using a mobile phone ("to look for jobs" and for "doctor appointments") while the student respondents characterized mobile phone usage as an integral part of modern life: "It organizes my life," as one student said.

For computer use, whereas most respondents across both groups said they used a computer, the difference centered on ownership and regular access. Whereas all student respondents owned their own laptop and had additional access at locations such as campus computer labs, homeless respondents described access as being limited to the homeless shelter learning center, public libraries, the workplace, and via their mobile phone. About half the homeless respondents said they used social media, whereas almost all of the student respondents did. All respondents across both groups had an email account. What emerges from these observations is the degree to which digital technology is central and ubiquitous for the student respondents, while having less of a central place in the lives of the homeless participants.

Last, on financial services, the student respondents were clearly better represented in the formal banking system. Even though most of the student respondents had just reached the age of majority in Arizona (18 years) at the time of the survey, almost all of the respondents had bank accounts. For the homeless respondents, with a median age more than double that of the student respondents, the low coverage in financial services is a strong indicator of a banking system that renders them financial invisible.

Taking the results from RQ1 and RQ2 together, and noting the crucial differences between the two groups in terms or heat exposure and technology interaction, we argue that the digitally invisible are objectively different from the digitally connected and that RQ3 is answered in the affirmative: the concept of the "digitally invisible" is empirically supported for the small number of research participants in our convenience samples. If new data sources and forms relevant for policy analytics are generated by the movements, choices and preferences of individuals such as those in our comparison group of student respondents, the movements, choices and preferences of the homeless individuals in our research will appear with lower volume in those same databases, rendering them digitally invisible.

Conclusion

Policy analytics can allow us to view society and its individual elements with increased clarity, and to peer into very large and complex systems. When we think of what policy analytics can tell us about society, with the aim of improving public policy formation, the question we have focused on here is whether there are important elements of the picture that are invisible to us because of the very lenses we are using. As policy analytics has been made possible by advances in technology, are there people and problems in society that are rendered *digitally invisible* because that same technology is unable to discern the pale shadows that the digitally invisible cast under the policy analytics spotlight? Our purpose here is to explore this possibility with reference to a particular population in a specific setting in an attempt to consider potential remedies.

Do the digitally invisible exist? One possibility is that we are like Lord Bowen's philosopher—"the blind man in the dark room looking for a black cat that isn't there" (Evans, 1968, p. 522). One explanation for digital invisibility is that they can not be seen because there is nothing there to see. Following the findings of a part of the digital divide literature that the divide has generally been bridged in its pure "access" sense, homeless individuals in the United States have very good coverage in terms of mobile phone usage. And public libraries and other access points provide computer resources and Internet access, leveling the digital playing field and lowering cost barriers. The concept of the digital divide still occupies many researchers, and remains a useful concept for considering equitable access to Internet communications, and the ability of citizens to equitably participate in civic dialog. Yet with the development of new types of Internet-connected technology based not on active participation but instead revealed through passive data contributions, we propose the concept of the digitally invisible as distinct from the digital divide. Whereas the digital divide implies a barrier that separates those with the ability to access information and influence content from those who cannot, new forms of data transfer and accumulation through passive mechanisms such as digital traces left from mobile and IoE devices, and transaction cards, give rise to a distinction that can emerge in the data as between individuals whose actions contribute those traces and individuals who do not. And since it is through these new forms and sources of data that policy analytics can have impact on policymaking in ways potentially more powerful as we shift emphasis from policy based on explicit citizen inputs to policy based on observed behavioral patterns, the concept of the digitally invisible is important for researchers and policymakers to be aware of.

If the digitally invisible exist, but the lenses we are using make it impossible for us to see them, what are the implications for policy when the evidence collected fails to detect key targets that are invisible to the network of sensors, card readers, cell towers, and servers? The consequences of the digitally invisible for an accurate understanding of the whole system and a robust policy analytics system are that policy responses will be oriented toward the digitally connected and fail to respond to the needs of the digitally invisible. Meanwhile, those same digitally invisible individuals may be among the most vulnerable to the hazards and impacts that monitoring networks and public infrastructure are designed to protect against. The consequences for public policy responses designed to protect vulnerable populations from extreme heat events include the misdirection of heat relief resources and the failure to provide public infrastructure that can minimize adverse health outcomes from exposure.

Minimizing the health impacts of extreme heat is a public problem addressed by a range of government and nongovernment entities through a wide spectrum of policies and programs. Many of these initiatives can be informed and enhanced by leveraging policy analytics. For example, scholars (including ourselves) have proposed targeting response activities to vulnerable or disproportionately impacted communities and individuals identified through retrospective epidemiological analysis of large health data sets. Municipalities maintain archives of vulnerability and impact maps to aid them in the identification of communities that would most benefit from additional investment. Emerging technologies and data capture strategies make it possible to generate novel insights into urban environmental conditions and exposure at a very fine resolution—for example, through crowd-sourced temperature measurements from smartphones. As the world and our cities become increasingly equipped with sensors connected to real-time information and decision-making systems, we imagine that the intricacy and complexity and which data are used to make policy and programmatic decisions about extreme heat preparedness and response will grow. But it is unclear where this movement will leave the digitally invisible, some of whom may be the most vulnerable to the impacts of extreme heat.

For those without a smartphone; without a bank account or credit card; without regular and ubiquitous Internet-connected computer access; living beneath and beyond the network of sensors, monitors, and data capture points, their existence is being rendered increasingly invisible, with policy developed using a policy analytics approach biased against them, even if unintentionally. As a result, policymaking is blind to their existence and policy based on incomplete evidence will not reflect their reality or their vulnerability. This blindness would be troubling in a traditional policy analysis system. In a policy analytics environment, such blindness is potentially debilitating for a robust and complete understanding of the system if we fail to acknowledge and internalize it.

At this stage of the policy analytics movement, there are limited examples of its use in any robust or intensive way. Thus our argument cannot extend to "here are examples of where policy analytics has been biased against the digitally invisible," but rather that the concept of the digitally invisible should inform any advances in policy analytics, to adopt some of the insights of post-positivism while taking advantage of the capacity that such analytics offers. We thus argue for contextual awareness and humility, acknowledging that a policy analytics approach is powerful and potentially of great public benefit, but that it offers only a partial picture of a reality that is influenced by the values we bring to the analysis. In our exploration of applying policy analytics for understanding exposure to extreme heat events, we have identified some challenges regarding the digitally invisible and how to understand the nature of the problem. We recommend being vigilant in looking for those who are hidden and will do the same in our future work.

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Notes

1. While we acknowledge that some small proportion of the homeless have freely chosen to live without a fixed residence, significant material possessions, or being embedded in modern systems (Sundeen, 2012), our focus here is on the homeless who live within the affluence of general society and who would prefer, if given the opportunity, to live in stable housing, but—for reasons related to poverty, mental health, or addictions—are not adequately housed. For the intentionally homeless who do so to attain a certain lifestyle, independence, and freedom, or for socio-technical refuseniks who purposely withdraw from modern society as a choice, we contend that these acts repudiate the social contract and thus abrogate their right to have an impact on modern governance (Gough, 1967). It is also important to note the distinction between the "street homeless" and those (as in our participant group) who have regular access to homeless shelters (Jencks, 1995)—as the former tend to have much worse wellness (Kryda & Compton, 2009).
2. PRM is a private faith-based social service charity working to end homelessness and hunger in the greater Phoenix area. See http://phoenixrescuemission.org/solutions/.
3. This response was complicated by a PRM policy that requires program participants to relinquish their mobile phone and other devices upon entering the program ("Clients are not allowed to have phones, paging devices, computers, radios, MP3 players, or nonapproved medications." See http://

phoenixrescuemission.org/wp-content/uploads/2015/03/PRM-Intake-Application-071815.pdf). While some respondents said they did not have a mobile phone, it was later clarified that they were referring to the PRM policy. Data reported here refer to mobile phone ownership outside of the influence of the PRM policy.

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