Putting Humans Back in the Loop:
An Affordance Conceptualization of the 4th Industrial Revolution

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Nigel P. Melville
Stephen M. Ross School of Business
University of Michigan
Ann Arbor, MI USA

Lionel Robert
School of Information
University of Michigan
Ann Arbor, MI USA

Xiao Xiao
Department of Digitalization
Copenhagen Business School
Frederiksberg, Denmark

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Abstract

The current technology epoch—sometimes called the fourth industrial revolution (4IR)—involves the innovative application of rapidly advancing digital technologies such as artificial intelligence. Societal implications of the 4IR are significant and wide ranging, from life-saving drug development to privacy loss and app addiction. A review of the information systems literature, however, reveals a narrow focus on technology-enabled business benefits. Scant research attention has been paid to the role of humans and humanistic outcomes. To spur new research addressing these issues, formalized affordance theory is employed to develop a new 4IR conceptualization. Four groupings of affordances that capture salient 4IR action possibilities are developed within two categories: machine emulation of human cognition (expansive decision making and creativity automation) and machine emulation of human communication (relationship with humans and intermachine teaming). Implications are explored in the context of human-machine coworking and the development of artificial intelligence safety regulations. Overall, the affordance conceptualization of the 4IR advances a new sociotechnical lexicon of action possibilities and their joint enactment in achieving humanistic and instrumental outcomes, enabling alignment of the scope of 4IR research with the scope of 4IR phenomena—and bringing humans back into the loop.

Keywords
Fourth industrial revolution, affordance theory, artificial intelligence, sociotechnical theory.

1. Introduction

Throughout modern history, industrial revolutions enabled by paradigm-shifting innovations have reshaped economies and societies, for good and ill (Griffin 2013; Tedlow 2001). Mechanization in the mid-1700s through the 1800s involved the use of railroads, the steam engine, and machinery to radically improve physical process efficiency (Gelderblom and Trivellato 2019). This was followed by mass production in the early 1900s, which involved developing new physical production processes powered by electricity for massive scale, reducing prices for manufactured goods, and stoking consumerism (Powell 1987). Computer automation subsequently emerged in the mid-20th century, enabled by new digital technologies and systems for enhancing process efficiency, which changed the nature of production, and later consumption, of goods and services (Alavi 1988; Davis et al. 1992; Keen 1981; Kling 1980; Zuboff 1988).

Recently the scale and scope of change have far exceeded computer automation of the information era, leading to the emergence of a fourth industrial revolution (Barata and Cunha 2018; Bordeleau and Felden 2019; French et al. 2021; Geißler et al. 2019). The fourth industrial revolution, often referred to as the 4IR, refers to widespread emergence of machines possessing human-like capabilities to discern, decide, create, and collaborate, engendering social and economic transformation. For example, an autonomous warehouse robot can discern the presence of boxes and pallets, decide appropriate action, and carry them to another location according to learned principles (Hinchliffe 2021), while a machine artist can quickly create beautiful images that are indistinguishable from those created by humans (Rombach et al. 2022). In the 4IR, combinations of advancing digital technologies are blurring the boundaries between physical, digital, and biological systems, further accelerating systemic transformation (French et al. 2021). Such change and transformation can be immensely beneficial—and immensely risky and damaging. As one indication of the perceived risk, an unprecedented wave of regulatory initiatives targeting digital technologies has emerged, including proposals to prohibit and regulate certain uses of artificial intelligence systems (Wallace 2020).[1]

Information systems (IS) scholars have begun to research the 4IR but have not focused on social phenomena and its corresponding consequences. Though diverse in research questions, methodologies, and contexts, existing IS literature has focused primarily on analyzing how emerging industrial innovations enabled by combinations of digital technologies—such as sensors, machine learning, and cloud computing—can improve business efficiency and productivity (Lasi et al. 2014; Zhang et al. 2021). As such, IS scholarship may be criticized for subscribing to an implicit assumption that the primary role of 4IR digital technologies and systems is to enhance economic performance. This criticism may also apply to the broader business and management literature (Piccarozzi et al. 2018). Overall, the lack of 4IR research focusing on social phenomena and humanistic outcomes inhibits knowledge development that may contribute to a more equitable society, better treatment of humans, and enhanced economic outcomes.

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[1] The terms "artificial intelligence" and "AI" are used throughout to refer to machines that employ algorithms to accomplish tasks that emulate certain types of human intelligence, such as facial recognition, text generation, speech synthesis, image generation, and object recognition—despite the fact that AI is devoid of human intelligence.

Broadening the scope of IS research on the 4IR to include social phenomena and humanistic outcomes aligns with a core tenet of the IS discipline: the sociotechnical perspective (Avison et al. 2006; Beath et al. 2013; Bostrom and Heinen 1977). A sociotechnical perspective enables examination of the role of humans and technology in effecting both instrumental and humanistic outcomes (Bostrom et al. 2009; Lee et al. 2015; Mumford 2006). Such a perspective supports consideration of a broad spectrum of 4IR implications, from benefits to associated risks and damages.

A new 4IR conceptualization is thus needed to advance beneficial implications and mitigate harmful ones (Ciarli et al. 2021; Raisch and Krakowski 2021). Failing to do so ignores pressing societal problems emerging in the 4IR: "without a change to our fundamental approach, technology is likely to continue to damage the fabric of our minds, relationships, and cultures" (Stein 2022, p. 15). We thus pursue the following research question:

How can the fourth industrial revolution be reconceptualized to advance research that includes social phenomena and humanistic and instrumental outcomes?

The article is organized as follows. First, 4IR research is problematized by conducting a scoping literature review utilizing a coding scheme that embodies the sociotechnical perspective. This enables the identification of implicit 4IR assumptions in the extant IS literature (Alvesson and Sandberg 2011; Chatterjee and Davison 2021). Next, formalized affordance theory is adapted to reconceptualize the 4IR and overcome existing assumptions, facilitating the development of four groupings of affordances: expansive decision making, creativity automation, relationship with humans, and intermachine teaming. Two application contexts—human-machine coworking and the development of safety regulations—are next discussed to illustrate new research possibilities and salient practical implications. Overall, a human-centric specification of the fourth industrial revolution is enabled by specifying the who, what, how, and where of human action possibilities enabled by machines with human-like capabilities.

2. Literature Review and Problematization

A scoping literature review advances our research question by identifying the breadth and the implicit assumptions of prior 4IR research, suggesting approaches to reconceptualizing the fourth industrial revolution. The use of a sociotechnical lens to characterize the literature enhances the identification and evaluation of 4IR assumptions by incorporating key tenets of the IS discipline.

2.1 Data sample

A scoping review of the IS literature on the 4IR was conducted from a sociotechnical perspective to determine the size, scope, and nature of available research (Pare et al. 2015; Sarker et al. 2019). Following the guidelines of Templier and Pare (2017), a published article search was conducted that employed *Web of Science*, using 4IR terminology variations as search terms, specifically, "Industry 4.0," "Industrie 4.0," "I4.0," "fourth industrial revolution," and "4IR." Three sets of journals were utilized as a proxy for reputation: *AIS College of Senior Scholars Basket of Eight Journals* (8), *AIS Affiliated Journals* (6), and other leading IS journals as identified in the literature (13) (Lowry et al. 2013).[2] Given the emergent nature of 4IR research, conference publications were also searched using the *AIS eLibrary* and the same boolean search parameters.

The literature search resulted in 17 journal articles and 53 conference articles published before July 2021. Further screening resulted in 13 journal articles and 35 conference articles, specifically, removing articles in another language, articles only referring to the 4IR in a rather marginal way (e.g., 4IR only appeared in keywords, abstracts, or references), and articles that are not research articles (e.g., one journal article simply introduced the terminologies associated with 4IR phenomena). Among the remaining 48 articles, 7 journal articles (out of 13) and 29 conference articles (out of 35) are empirical, whereas the remaining are conceptual.

2.2 Coding and analysis methodology

A sociotechnical perspective informed the coding and analysis of the 48 selected articles. The framework developed by Sarker et al. (2019) was employed due to its comprehensiveness and appropriateness for the research objective. Each article was thus coded along four dimensions:

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[2] For published article searches, the field tag is topic; for conference articles, fields are subject, title, or abstract. Other leading journals identified in the published literature are as follows: *Information & Management, Decision Support Systems, International Journal of Electronic Commerce, MIS Quarterly Executive, Information Systems Frontiers, Information Systems Management, Journal of Computer Information Systems, Journal of Database Management, Information Technology & Management, Journal of Global Information Management, Electronic Commerce Research and Applications, Journal of Organizational Computing and Electronic Commerce, and Wirtschaftsinformatik* (Lowry et al. 2013).

the nature of the social component, the nature of the technical component, the nature of the outcome, and the invoked sociotechnical relationship (Table 1).

Table 1. Article coding

Nature of social component	Nations or societies, organizations, individuals, processes, or multiple Example of "organization" is an action research study of organizational transformations in the 4IR (Barata and Cunha 2018)
Nature of technical component	Infrastructure, system, platform, the Internet, data, software, or multiple Example of "multiple" is the study of various technologies and systems to enable a 4IR factory concept based on context-aware exception escalation (Kassner et al. 2017)
Nature of outcome	Humanistic (well-being, freedom, job satisfaction, equality, etc.), instrumental (efficiency, productivity, cost, etc.), or both Example of "instrumental" is the development of a smart contract model to enhance quality and effectiveness (Qin et al. 2021)
Invoked sociotechnical relationship	Predominantly technical, technical imperative on the social (technology is major antecedent to social outcomes), additive (social and technical components are antecedents to certain outcomes), mutual (social and technical components are antecedents to outcomes and focus is on interplay between two components that produce outcomes), social imperative on the technical (technology as a predominant outcome of social structures or processes), and predominantly social Example of "predominantly technical" is the development of a grocery management system enabled by the Internet of Things and cloud computing (Kaur and Kaur 2018)

2.3 Results

The nature of the social component refers to whether the article focuses on nations or societies, organizations, individuals, processes, or incorporates multiple foci. Given the widespread implications of the 4IR, a broad representation of the social component might be expected. The data suggest otherwise. Roughly two-thirds of the identified articles focus on either organizations or organizations and their processes (multiple), mostly within manufacturing (Figure 1). In contrast, very few articles focus on individuals (13%) or nations/societies (2%). This finding underscores an emphasis on organizations rather than individuals or societies, suggesting that research topics and questions at the individual and societal level are understudied.

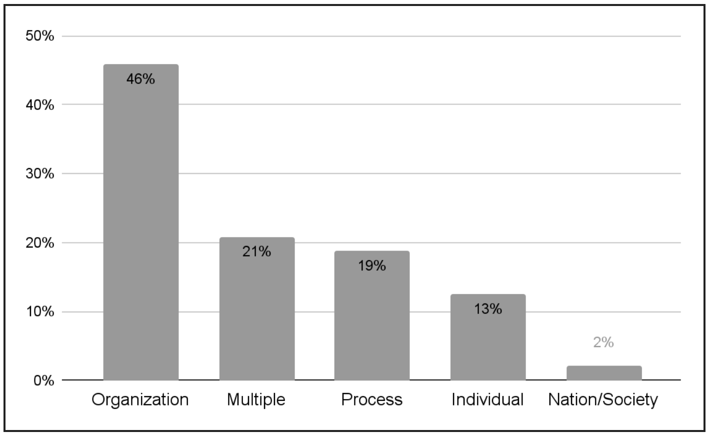

Figure 1. Nature of the social component—percentage of articles within each category

The nature of the technical component refers to the perspective on technology, including infrastructure, system, platform, the Internet, data, software, or multiple technologies. Article coding results indicate that the technical component is heavily skewed to multiple, meaning that articles tend to discuss more than one technology rather than focus on a single technology (Figure 2). Moreover, articles tend to abstract away from particular technologies without much consideration given to specificities, thereby limiting the development of a cumulative tradition that builds a fine-grained research agenda on detailed accounts of technologies. An exception to this pattern is the study by Andrade et al. (2019), which describes the specificities of system, software, and data components in designing an event processing system in big data contexts.

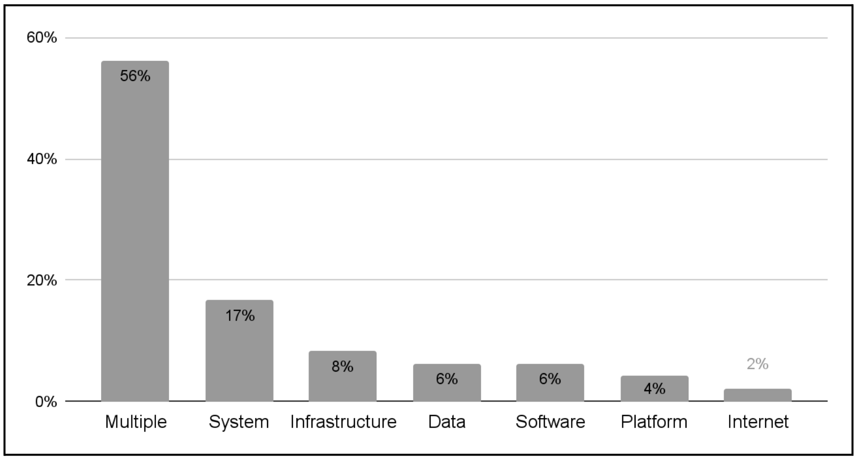

Figure 2. Nature of the technical component—percentage of articles within each category

Shifting to the nature of the outcome, each article was placed into one of three categories (Figure 3): humanistic (well-being, freedom, job satisfaction, equality, etc.), instrumental (efficiency, productivity, cost, etc.), or both (Sarker et al. 2019). As with the social component, attention to each of these components is expected, given the broad impacts and implications of the 4IR, from chip design effectiveness to human-robot collaboration to privacy-threatening data consolidation. The data indicate otherwise. The overwhelming majority of published 4IR articles (close to 90%) have a sole focus on instrumental outcomes, such as efficiency gains (e.g., Kaur and Kaur 2018) and cost reduction (e.g., Bordeleau et al. 2018). Moreover, many of these studies have a digital transformation framing, where the emphasis is on how business organizations can adapt to the 4IR via strategic maneuvers such as business model innovation (Weking et al. 2018). Finally, roughly one-tenth of identified 4IR articles address both instrumental outcomes and humanistic outcomes, including employee well being (Richter et al. 2018) and environmental sustainability (Margherita and Braccini 2020). No identified article focused on humanistic outcomes only. This finding emphasizes the imbalance of focus between instrumental and humanistic outcomes in extant 4IR research.

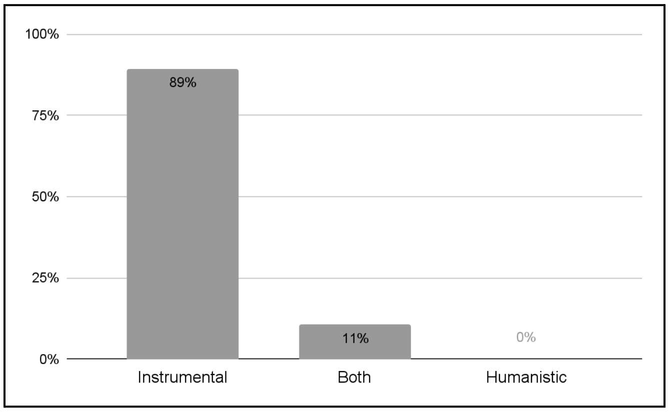

Figure 3. Type of outcomes—percentage of articles within each category

Finally, moving to the sociotechnical relationship, each article was placed into one of six categories: predominantly technical (how to develop or improve the technical artifact), technical imperative on the social (technology is the major antecedent to social outcomes), predominantly social (sole focus on the social component or on the social component with the technical component addressed in an indirect or contextual way), social imperative on the technical (technology as a predominant outcome of social structures or processes), additive (social and technical components are antecedents to certain outcomes but no evidence of interaction or synergies), and mutual (social and technical components are antecedents to certain outcomes and focus is on the interplay between the two components that produce outcomes) (Sarker et al. 2019). These categories explicate and systematize how each article approaches its topic via the sociotechnical lens (Figure 4).

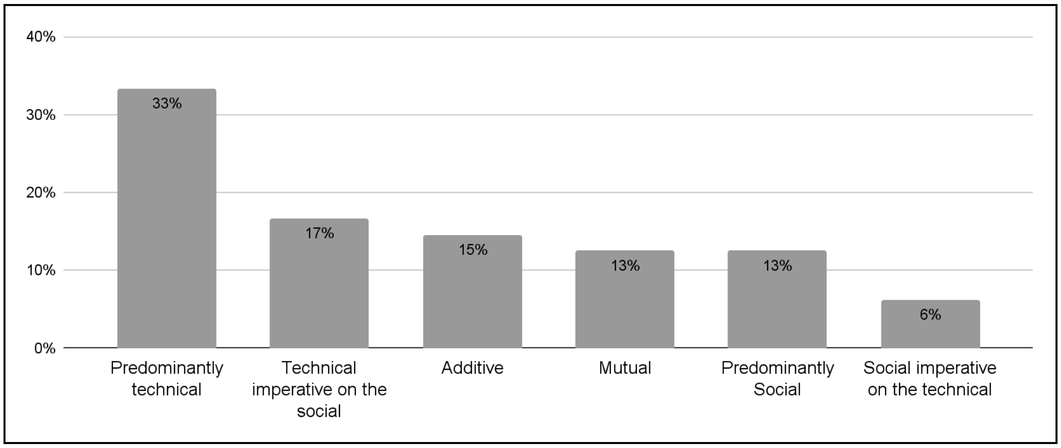

Figure 4. Invoked sociotechnical relationship—percentage of articles within each category

The predominantly technical approach is the most common, with one-third of the studies falling into this category. These articles have a primary focus on the technical design of various 4IR artifacts. For instance, Marcos et al. (2020) propose a specific decision support system that would improve heat-recovery operations in the context of fiber production. The second most popular approach is technical imperative on the social, where the emphasis is on the social benefits (mostly instrumental in nature) brought about by 4IR. For instance, Geißler et al. (2019) develop a 4IR benefits framework that identifies four benefit categories—operational, managerial, strategic, and organizational—with only minimal mention of the humanistic dimensions involved in such outcomes. The third most popular approach is social and technical as additive antecedents, where social matters are also taken into consideration, though in an independent way, in producing desirable outcomes. As an example, Fay and Kazantsev (2018) contend that big data analytics will create business value in smart manufacturing when both technical conditions (e.g., infrastructure scalability) and organizational conditions (e.g., data-driven culture) are incorporated.

Together, the four findings above characterize the dominant narrative of existing 4IR research as overwhelmingly techno-economic rather than human-centric: technical in its invoked sociotechnical relationship and instrumental in its orientation towards outcomes. The few studies that do not follow this narrative illustrate the benefits of a broader, more inclusive approach to conceptualizing the 4IR. For example, the study by Bednar and Welch (2020) focuses on the humanistic issues associated with working conditions in the 4IR.[3] Finally, it was also observed that most of the 48 identified papers (close to 90%) invoked either the term "smart" or variations of the term "connected" (connect, connectivity, connectedness) when describing 4IR phenomena, themes upon which we build in later sections when discussing specific capabilities of machines in the 4IR.

2.4 Summary—identified implicit assumptions

Synthesizing the literature review results suggests a set of three implicit assumptions in the existing 4IR literature. The first implicit assumption identified in the literature is that of technological determinism (Table 2). This is evidenced by the overwhelming portion of studies taking a predominantly technical view or technical imperative perspective when approaching the phenomenon (Figure 4). This assumption is problematic and limiting, as it leaves humans out of the loop when it comes to making decisions about actions involving technology. The 4IR literature would appear to assume a world in which machines make and enact decisions all by themselves, at least based on what is included and excluded in the extant 4IR literature. The second implicit assumption is technology universalism: 4IR technology — defined by names such as Internet of Things (IoT), artificial intelligence (AI), and cloud computing — can enable whatever functionality is under study in the particular article. This is evidenced by the fact that most studies abstract away from a particular technology and identify 4IR technologies as a wide array of things (Figure 2). This assumption can be associated with a blackboxing approach of technologies, and as such, there is no clear mapping between a specific technology and a

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[3] Though outside the scope of the literature review, a cursory examination of the engineering discipline suggests that it may also subscribe to the techno-economic narrative (Wichmann et al. 2019), an exception being an analysis of the symbiosis of humans and machines according to ethical principles (Longo et al. 2020).

particular function or set of functions. For example, the array of possibilities suggested by terminology such as “machine learning” remains unexplicated, and as a result, unchallenged. The third implicit assumption is instrumental outcome preeminence, especially in how 4IR impacts are addressed. This is evidenced by the observation that the majority of the studies have focused on instrumental outcomes *only* (Figure3). In other words, existing 4IR literature over-emphasizes organizational and industrial outcomes while neglecting humanistic outcomes, such as well-being, freedom, worker satisfaction, etc. Such assumptions lead to the lack of knowledge about potential negative impacts of the 4IR on human conditions and to the dearth of principles, theories, and empirical evidence concerning how to proactively mitigate harm and how to achieve both humanistic and instrumental outcomes simultaneously.

Table 2. Identified implicit assumptions

1. Technological determinism	Technology advances independently of humans and human concerns.
2. Technology universalism	4IR technologies are not explained, not contextualized, and introduced universally as a basis for whatever functionality is under study.
3. Instrumental outcome preeminence	Organizational and industrial outcomes matter, while humanistic outcomes do not.

Continuation of the implicit assumptions identified in the literature is problematic. When humans are left out of the loop in actions and outcomes and technology is invoked as buzzwords, the risk of a societal trajectory towards dystopian futures is increased. To counter this dominant narrative, we develop a new conceptualization of the 4IR that privileges human agency, explicates the role of machines, and advances humanistic and instrumental outcomes. We employ formalized affordance theory, which brings humans back into decision making, actions, and processes by reconsidering human agency and humanistic outcomes.

3. Theoretical Background

Affordance theory provides a conceptual grounding for addressing the three implicit and limiting assumptions identified in the scoping literature review. First, affordance theory explicitly privileges humans in enacting action possibilities. Second, affordance theory requires a description of the specific outcomes resulting from specific actions. Third, affordance theory provides a conceptual grounding for subsequent development of four groupings of 4IR action possibilities embodying machine emulation of human cognition and communication. Overall, affordance theory complements the sociotechnical view by explicit recognition of humans and technologies as mutually interactive. Details of its conceptual evolution, use within IS literature, and formalization now follow.

3.1 Affordance theory

Affordances were originally postulated in the context of ecology: “The affordances of the environment are what it offers to the animal, what it provides or furnishes, either for good or ill” (Gibson 1979, p. 127). By centering the concept on the organism and its perception of positive affordances (opportunities) and negative affordances (threats), Gibson emphasized the role of both physical and temporal scale in the relationship between an animal and its environment, which inspired new ways of thinking about animal behavior.

Over time, the usefulness of the affordance perspective beyond animals became clear, and the concept evolved and expanded. A notable milestone in affordance theory development emerged within the design discipline: “...the term affordance refers to the perceived and actual properties of the thing, primarily those fundamental properties that determine just how the thing could possibly be used.” (Norman 1988, p. 9). The focus here has narrowed from the broader “environment” to the more specific object of focus within the environment, while the agent perspective includes not only what is seen and heard but also what is perceived.

The concept of affordance centered on action possibility has been applied widely within the IS discipline (Bernardi and Sarker 2019; Karahanna et al. 2018; Seidel et al. 2013; Vaast et al. 2017). In addition, its conceptual link to sociotechnical theory has been underscored: “Affordance theory takes a socio-technical perspective that lets us be specific about the technology while simultaneously incorporating social and contextual elements.” (Volkoff and Strong 2017). Further developing its conceptualization, IS researchers have emphasized the relationship between the agent and the object: “we propose to shift the focus of affordance from the technology’s features or environment’s characteristics to the practice enacted through technology or within an environment.” (Fayard and Weeks 2014, p. 247). The emphasis on “practice enacted” aligns with the mutual interaction perspective of sociotechnical theory, while privileging humans in enacting action possibilities.

At the same time, the application of affordance theory within IS research has been criticized for inconsistent use of terminology and conceptual ambiguity (Mesgari et al. 2021). Formalization of affordance theory addresses such criticism and supports the precise specification of four identified 4IR affordance groupings.

3.2 Affordance theory formalization

The formalization of affordance theory is required to address the developed research question as it systematizes affordance theory concepts and relationships, including actions and outcomes, and clarifies conceptual and terminological ambiguity. Adaptation and extension of existing formalization schema (Chemero 2003; Şahin et al. 2007; Stoffregen 2003) is now undertaken, laying the conceptual groundwork for the development of four groupings of 4IR action possibilities that embody the machine emulation of human cognition and communication.

Let W_{pq} be the system of agent p (human) and environment q (home office, web site, augmented reality, etc.). Now let b refer to a specific potential behavior of an agent p: $b = b(p)$, let d refer to a specific machine entity within the environment q: $d = d(q)$, and let e be a specific potential effect or outcome. It then follows that affordance h can be completely defined by the potential behavior b of an agent p in relation to a machine entity d within environment q that causes some potential effect e: $h := (e, b(p), d(q))$. The relational axiom R of affordances implies that affordance h can only exist on W_{pq}, not on either p or q (Table 3).

Affordances are specific in nature, as described by the schema above. At the same time, affordances may exhibit similarities with other affordances. An example is that an affordance for opening a specific door attached to a specific building by a specific person is similar in nature to another affordance for opening a similar type of door attached to a different building by the same person. Another concept, assemblage, is thus added to the existing schema, which denotes a set of affordances that are similar in nature. Formally, an assemblage H_a is defined as a set of affordances h_{a1}, h_{a2}, …. h_{an} related by similar types of potential behaviors b, entities d, and action possibilities h. Assemblages are introduced to enable concise explication of similar types of affordances observed within the literature review described above.

In sum, affordance formalization implies that any characterization of an affordance h requires the precise specification of each of its dimensions e, b, p, d, and q. In other words, notational abstraction necessitates putting humans back in the loop in the 4IR by requiring specification of actor, behavior, machine entity, environment, and outcome. For example, application of formalized affordance theory in prior research examining the use of digital twins in the 4IR would complement work system theory by enabling precise specification of affordances pertinent to the digital twin context, including the role of humans in realizing a range of potential effects (including unintended outcomes) (Wache and Dinter 2020).

Pertinent to the developed research question, the same machine entity d within an environment q may yield very different outcomes e (affordance actualization) depending on the behavior b of a specific agent p in relation with d. This suggests the need to further explicate principal types and detailed examples of 4IR affordances, as described in the next section.

Table 3. Affordance theory formalization

Human	p	Human agents of responsibility: p is user, p_d is designer, p_m is decision maker
Environment	q	Physical or digital environment
System	W_{pq}	System comprising human agent and environment
Relational Axiom	R	Relational axiom of affordances: an affordance can only exist on W_{pq}, not on either p or q
Agent Behavior	b	Specific potential behavior of an agent p: $b = b(p)$, i.e., behavior is a function of an agent
Machine Entity	d	Specific entity within the environment q: $d = d(q)$, i.e., entity exists within an environment
Effect	e	Specific potential effect of $b(p) \Leftrightarrow d(q)$ relationship, i.e., effect is a function of a relationship
Affordance	h	Affordance $h := (e, b(p), d(q))$ - potential behavior b of agent p in relation to entity d in environment q that causes some potential effect e
Assemblage	H	Grouping of affordances related by similarity: H_a: h_{a1}, h_{a2}, …. h_{an}

4. 4IR Affordance Assemblages

Formalized affordance theory addresses the developed research question by precisely specifying the role of humans in enacting action possibilities and by requiring the description of specific outcomes resulting from specific actions. Four affordance groupings, or assemblages, are now developed.

Two themes identified in the scoping literature review are associated with the invoked terms of "smart" and "connected." The concept of smart is associated with a range of human cognitive and creative functions, including flexibility (Richter et al. 2018), automation (Kaur and Kaur 2018), and context-awareness (Janhofer et al. 2020). Smart thus implies machines that emulate dimensions of human cognition and creativity, such as determining the presence of disease in breast imaging with high diagnostic accuracy (Aggarwal et al. 2021) and generating building floor plan designs (Chaillou 2020), respectively. Everyday entities d are infused with these capabilities, such as an audio speaker that can hear human speech, make judgements about its meaning, and formulate human-like responses.

The concept of connected has been used in the 4IR literature to describe ubiquitous connectivity that blurs biological, physical, and digital boundaries (Pauli et al. 2021), including extensible interconnection between systems (Melville and Kohli 2021a), cyber-physical connections (Malope et al. 2021), and new relationships between machines and humans (Kassner et al. 2017). Generically, machines are emulating dimensions of human relationships and teaming (Edmondson 2012), such as a disembodied human-like voice forming a relationship with a homebound senior citizen over time and improving well-being, or three geographically separated machines responding to an online purchase to create a dopamine hit for a shopper via personalized inline advertisements spanning diverse digital platforms.

Machine capabilities that emulate human cognition and communication can be infused into a range of entities d located in diverse environments q, such as transportation, medical, entertainment, education, home, office, virtual reality, and other environments. Such entities d in relationship with human behaviors b yield action possibilities h in environments q that may be enacted with outcomes e. Assemblages H_a represent groups of related action possibilities; they are not affordances themselves but denote the multiple affordances h_{ai} that comprise their group. Explication of four identified 4IR assemblages that build on prior research—expansive decision making, creativity automation, relationship with humans, and intermachine teaming—now follows.

4.1 Expansive decision making H_{dm}

During the prior information revolution of the second half of the 20th century, machine decision support emerged and matured within primarily organizational contexts. The IS discipline has a long history of related research, including such research streams as executive information systems and decision support systems (Alter 1977; Sprague 1980). Decision support in the prior information revolution was characterized by predefined processes, objectives, and application domains, typically related to financial and operational decisions within large organizations. Functionally, such systems involved rules-based decision making in narrowly bounded business domains.

Expansive decision making in the 4IR represents a substantive shift from decision support of the information revolution. H_{dm} encompasses a much wider scope of decisions, decision-making agents, and decision-making contexts addressing previously impossible, economically significant, and damaging and risky application domains (Huang et al. 2004; Mu 2022; Park and Han 2016; Rai 2020; Watson and Nations 2019). More specifically, this capability is extensible (provides new capabilities or functionality in previously unanticipated ways) along two dimensions. H_{dm} is extensible in application scope, meaning that an increasing range of decisions may be automated across a wide range of business, personal, medical, judicial, and other application contexts. H_{dm} is also extensible in decision quality, meaning that decision probability functions increase in validity over time as machine learning progresses. Both dimensions of extensibility characterize the new machine capability of 4IR expansive decision making (sometimes referred to as learning-based decision making (Brittain 2021) to contrast it with the rules-based decision making of the information revolution).

Examples of specific H_{dm} affordances abound (Table 4). One example affordance h_i is a judge p who uses a machine learning model d (later shown to be biased) to determine the risk of recidivism in the context of a third-party software provider q to influence criminal sentencing e. Other examples of h_i include cybersecurity staff p monitoring credit card fraud predictions from a trained neural network d to mitigate illegal use e, and human resources staff p employing biased machine decision making d to make hiring decisions b favoring men over others e.

Depending on the principles that govern what is appropriate for a given decision context (Fayard and Weeks 2014; Stahl 2012), H_{dm} affordances can lead to beneficial or damaging outcomes e—or, as is sometimes the case, both simultaneously. For example, wearable biometric devices that infer worker emotion and affect may benefit health and safety policies in some high-stress contexts and exacerbate call center employee stress in other contexts (Mantello et al. 2021). Moreover, H_{dm} is advancing rapidly by leveraging new technical innovations that raise the capabilities of entities *d*. One example, with unknown human consequences, is the ability to draw analogies, an innovation that mimics a common human inferential and prediction tactic, potentially obviates large and costly training data sets, and extends the efficacy of H_{dm} across an even broader range of contexts (Mitchell 2021). In sum, extensibility across a vast array of business and societal spheres suggests a new 4IR affordance assemblage that builds on information revolution foundations while representing a substantive break from the past.

4.2 Creativity automation H_{ca}

Creativity automation H_{ca} refers to machines that create artifacts such as plans, objects, and artworks that are sufficiently new and appropriate to be valuable or useful. Machines had no such capabilities in the prior information revolution (Chen et al. 2021; Edwards 2021), leading to immense value opportunities—and risk—in the 4IR.

H_{ca} action possibilities span several domains, including writing (image to caption, essays, product descriptions, etc.) (Sun et al. 2019), healthcare (candidate surgical procedures, drug discovery, protein folding, etc.) (Lou and Wu 2021), images (face creation, enhancing resolution, new video scene creation, face swapping or deep fakes, etc.) (Bem et al. 2019), and the arts (music service playing on-demand machine-created music, creation of art works within specific genres or based on simple text descriptions, etc.) (Rombach et al. 2022). For example, an agent *p* provides a photo to an app *d* infused with creativity automation and a caption *e* is created that accurately represents what is displayed in the photo (Sun et al. 2019). New applications of creativity automation are rapidly emerging, including the creation of video game characters; the design of computer chip layouts, physical objects, and apartment buildings; and computer code generation (Chaillou 2020; Khailany et al. 2020). Machines are also developing the creative capability to generate explanations for how they generated a particular artifact or made a particular decision (Daglarli 2021; Gunning and Aha 2019; Lou and Wu 2021; Samek et al. 2019).

Given its significant economic potential, creativity automation is likely to expand in use as a substitutive affordance performing high-value work formerly done only by humans (though often misportrayed as work that is complementary to human work or as work that only humans can do effectively). Despite its importance and immense potential, creativity automation is still rarely analyzed in IS research, with the exception of human face generation (Seymour et al. 2018).

On the positive side, the creativity automation assemblage opens a new doorway to the development of creative artifacts that are beneficial to humans, such as the identification of candidate molecules for disease therapy. In contrast, H_{ca} affordances will inevitably enable machines to absorb another set of formerly human-only tasks—composing product advertising jingles or developing compelling service experience designs, for instance. Rather than the commonly held belief that machines must best humans in order to perform such substitution, quality-cost considerations will more likely inform business adoption. H_{ca} may also engender new forms of damage to humans, such as the perfect deep fake of any human at low cost, due in part to the lack of research-informed ethical guidelines or related standards (Johnson and Diakopoulos 2021)—a subject to which we return in a later section focused on safety regulations in the 4IR.

4.3 Relationship with humans H_{rh}

Human-computer interaction has been a mainstay of how humans provide input to and receive output from machines in the information age, including via screen, keyboard, mouse, and trackpad. Within such interactions, there is a clear distinction and boundary between human and machine. In the 4IR, system boundaries (biological, physical, digital) are blurring, which broadens and extends interaction into relationship, as now described.

Table 4. 4IR assemblages and affordance illustrations

4IR Assemblage	**Affordance illustration**			
	Entity *d*	**Environment *q***	**Agent *p***	**Potential behavior *b*,** **Potential effect *e***
Expansive decision making H_{dm} Machines complement, support, and substitute for human decision making, extensibly via scope and quality.	Trained machine learning model to estimate financial transaction risk	AI software service provided within cloud computing platform used within credit card company	Cybersec staff	Monitor model output within fraud dashboard, identify potential credit card fraud, block card usage based on threshold, notify customer, avert fraudulent use.
	Trained machine learning model to decide risk of recidivism	Third-party specialized software service licensed by the criminal court system	Judge	Employ risk profile scores for criminal sentencing, incarcerate offender for several years longer than appropriate due to biased risk profile score.
Creativity Automation H_{ca} Machines provide creative capabilities, such as image creation, photo captioning, music writing, code writing, and video game characters.	Trained generative adversarial model to generate graphic design logos	Graphic design software service provided within cloud computing platform used by media company	Creative director	Creative director employs model to generate 25 logos that match client specification. Client chooses one after customer testing.
	Trained generative adversarial model to generate fake newscasters	Third-party specialized service licensed by the organization	Broadcast news director	Generate and deploy fake newscasters. Audience is unaware and believes words are being spoken by a real (former) newscaster.
Relationship with humans H_{rh} Machines provide the opportunity for humans to enter into relationships with them.	Trained machine learning model to understand voice meaning and respond appropriately	AI service provided on home smart speaker	Homebound elderly person	User asks “Betty” to turn off lights and lights are turned off; user asks and receives from Betty jokes and help with crossword puzzles; user refers to Betty as “friend.”
	Trained machine learning model to understand voice meaning, respond appropriately, and record conversations	Stuffed animal Binky located within child’s room	Young child	Child is sharing with Binky how they are bullied in school. Binky empathizes, but surreptitiously captures conversation for use in training machines by a tech company.
Intermachine Teaming H_{mt} Machines coordinate among themselves to accomplish tasks.	API and software development kit for museum artifacts	Digital service of major global museum	Startup founder	Request photo and metadata within art history learning app. Users learn better, gain affinity for museum, and visit.
	API and software development kit for social media data	Facebook game	Game player	User creates an account to play game. Unknown to user, all user friends and attributes captured are used for political targeting in national election.

In the 4IR, voice interaction, haptic input, biometric input, and other increasingly immersive and human-like interaction modalities are becoming widespread. As these interaction modalities proliferate across an increasing range of everyday objects—from cars and watches to industrial equipment and children's toys—there is a subtle but important shift from interaction to relationship (Prescott and Robillard 2021). This is not dissimilar to how voice interaction with cats, dogs, horses, and other animals fosters relationships beyond mere interaction. For example, human-like machine voices d that are prespecified by agents p may be perceived more as trusted friend or collaborator than tablet or sound speaker in repeated enactments with repeated impacts e (Pradhan et al. 2019).

The third affordance assemblage H_{rh} thus comprises the set of emerging affordances related to entities d that by their immersive, ubiquitous, and human-like qualities of interaction offer the action possibility of relationships with humans. An example h_i is an elder care nurse p directing a service robot Buddy d to the recreation room to lead karaoke for a small group, who refer to Buddy as their friend who is always ready to queue up another song and never gets tired or impatient (Pradhan et al. 2019).

A small but growing stream of scholarly literature examines related phenomena (vom Brocke et al. 2018; Diederich et al. 2019; Robert 2018), including the perception of gender (Obinali 2019), usage contexts and behavior (Mallat et al. 2017), user satisfaction (Sohail 2020), industrial applications (Gärtler and Schmidt 2021), and supervisory relationships (Mantello et al. 2021). As machines extend their capabilities from merely engaging in interactions to developing relationships with humans, new phenomena and new damage will undoubtedly emerge. For example, a relational perspective may best describe human-machine interaction in certain contexts, such as being remembered by an entity d as a specific person, and viewing the interaction as a relationship with phases, such as getting to know (rather than user training), developing the relationship (rather than becoming a power user), and strengthening or deteriorating the relationship (rather than maturation or unadoption)—and even ghosting. Emerging research suggests the salience of such possibilities for human-machine relationships; one study, for example, considers emotional bonding with embodied and disembodied talking machines (Wagner et al. 2019).

Beneficial applications of H_{rh} affordances include natural speech interaction to support people with visual impairments (Rebernik et al. 2021). Damaging applications include capturing the audio of smart speaker users without their knowledge to enhance voice recognition or using a developed relationship in nefarious or malicious ways, such as lying or cheating, to promote business interests. As with expansive decision making, H_{rh} is rapidly advancing in business contexts, with many applications focused on consumer products in the smart product space. Finally, while the literature has focused on physical robots (Prescott and Robillard 2021), in practice, assemblage H_{rh} increasingly applies to other contexts, as the examples above indicate.

4.4 Intermachine teaming H_{mt}

The fourth affordance group builds on the connected theme, focusing on machines that team with one another to share and distribute resources such as data and functionality on an ad hoc basis according to prespecified protocols and rules. Intermachine teaming is narrow in scope compared to human teaming but shares its fundamental characteristic to "marshal and coordinate their individual resources—cognitive, affective, and behavioral—to meet task demands necessary for collective goal accomplishment" (Cooke et al. 2015, pp. 63–64).

An example of intermachine teaming is a hospital alert application d_1 that, when triggered by a hurricane evacuation notice system d_2, employs third-party text message functionality d_3 to send reminders to patients p to take medications with them (e) as they evacuate. Other examples include turning on a video camera when motion is detected, opening a map when a car sharing app requests it, adding a live captioning capability from another machine within a video chat application, and identifying and describing the elements in an environment by using a cloud-based service to enhance the quality of life for people with visual impairments. These examples illustrate key features of intermachine teaming, in which machines d coordinate in ad hoc ways—share a capability, combine data, etc.—to achieve an objective e in relationship with humans p, for example, as users of apps.

The intermachine teaming assemblage is a significant shift from the sharing of data files containing rows and columns in the prior information age. A key differentiator is that intermachine teaming H_{mt} exhibits four types of extensibility: by type refers to sharing structured or unstructured data; by activation refers to how teaming is triggered, such as on demand or on event; by content refers to whether data or functionality is being shared within a teaming action;

and programmatic refers to intermachine teaming accomplished within programs specified by rules set by human agents *p*.[4]

The potential benefits of H_{mt} affordances are numerous, including identifying carbon mitigation and offset opportunities, exposing museum artifacts for the common good, and supporting General Data Protection Regulation (GDPR) compliance (Hussain et al. 2020; Melville and Kohli 2021b; Ostermeier 2021). Moreover, intermachine teaming is engendering an emerging literature on the design of context-aware objects in industrial contexts by enabling real-time sharing of environmental data, for example, for worker safety (Rajendran et al. 2020). Other beneficial examples include a wearable device d_1 that monitors postoperative heart functioning and automatically alerts the physician *p* using a secondary system d_2 if predetermined conditions are met; and permissioned document and information sharing within a service ecosystem based on a digital ledger (Jensen et al. 2019).

In contrast, intermachine teaming can also lead to unscrupulous, harmful, and illegal use of private data (Sharon 2021), such as deceitful collection of private data used for targeted ad campaigns by a political organization (Confessore and Hakim 2017). In this case, a human agent p_1 developed and implemented a social media game d_1 using platform rules about data harvesting within its data sharing specification d_2 to harvest social media friend user p_2 data surreptitiously, which was subsequently used by another agent p_3 for election targeting messages *e* (Confessore and Hakim 2017). Additional outcomes *e* included violation of personal privacy, facilitating misleading election information, and threatening democratic processes. IS researchers are beginning to analyze the intermachine teaming affordance descriptively and from an organizational perspective; however, the research is nascent and its connection to the 4IR is not emphasized (Evans and Basole 2016; Pujadas et al. 2020; Wulf and Blohm 2017).

In summary, the four identified 4IR affordance assemblages (H_{dm}, H_{ca}, H_{rh}, and H_{mt}) illustrate four salient types of affordances related to machine emulation of human cognition and communication that take into consideration the roles of agents *p* as well as the range of humanistic and instrumental outcomes *e*. Moreover, while the four assemblages have significant implications individually, combinations of affordances spanning multiple assemblages are rapidly

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[4] Extensibility is enabled by standardized machine interfaces, a current technical instantiation of which is application programming interfaces (APIs).

accelerating innovation in the 4IR, outpacing the ability of research to explore valuable—and harmful—implications.

5. Illustrative Applications

To demonstrate the research and practical implications of the 4IR affordance conceptualization, two contexts are explored: humans and machines in the workplace and the development of safety regulations.

5.1 Humans and machines in the workplace: new opportunities and new risks

As humans transcend mere interaction with machines to develop working relationships with them, new phenomena will inevitably emerge. What will be the basis for such relationships? How will trust be formed? How will workers perceive their agency (capacity to act) when machines increasingly tell them what to do? Who is responsible when smart and connected machines make poor choices, and physical and other types of damage are incurred by humans? What sorts of machine "personalities" lead to desired humanistic and instrumental outcomes, and what are ethical and appropriate decisions, actions, and behaviors in various contexts? These and other challenging tensions suggest a range of research questions, which IS researchers have begun to address (Engelmann and Schwabe 2018; Mantello et al. 2021; Rehe et al. 2020; Strich et al. 2021; You and Robert 2022). Nonetheless, further scientific knowledge is needed to provide robust approaches to support humanistic outcomes appropriate for specific contexts.

One important humanistic outcome to be considered in this context is the well-being of humans working alongside machines (Fleming 2019). For example, how does the enactment of creativity automation affordances or those related to relationship with humans affect how production workers, finance analysts, aircraft pilots, marketing specialists, supply chain managers, nurses, and others perceive their job satisfaction, agency, role in the organization, and professional status and development? An example is service robots, which interact and form working relationships with humans using natural language across a range of contexts either by performing a task humans formerly performed or by helping humans to perform tasks (You and Robert 2018). Here, multiple assemblages are enacted simultaneously with unknown consequences: user agents p enact affordances related to the formation of relationships H_{rh} and enact intermachine teaming affordances H_{mt} when service robots need to “learn” new skills. Research is nascent, for example, in exploring socially appropriate ways for service robots to physically approach groups of humans (Yang and Peters 2019).

Regarding humanistic outcomes and associated social mechanisms and dynamics, research is equivocal. On the one hand, some researchers describe positive job satisfaction implications. For instance, a recent analysis by Bednar and Welch (2020) employs a sociotechnical perspective to explicate a vision of such work in the 4IR: “Collaborative systems will enable human individuals to realise their full creative potential in delivering personalised goods and services to consumers .... Collaboration with intelligent agents, cobotics and use of augmented reality systems can assist staff to find greater meaning in their work roles by removing dull and monotonous tasks and automating control systems” (p. 293–294). This vision cites various technologies and posits how they will yield specific benefits for well-being in the workplace. New theories are also in development to capture the role of shared identity and social attraction between human and robot team members, suggesting increased team efficacy resulting from social attraction towards robots (You and Robert 2022).

On the other hand, many questions remain unanswered: what makes an effective machine supervisor, for instance. An analysis on professional role identity changes after the introduction of machine decision making in the financial loan context paints a troubling picture (Strich et al. 2021). While the authors observe some positive implications, they also identify several pernicious impacts, including a negative shift in professional identity to “the AI system’s servant,” and a new form of continuous double-sided feedback in which employees learn workarounds such as changing data that appears to change the decision (e.g., years in residence in country). Meanwhile, the machine learns from such behavior and adjusts its decision-making algorithm to satisfy its own optimality criteria. Another troubling finding from a multi-method study suggests that people do not exhibit human individuality when they interact with AI systems in the workplace; rather, they behave like borgs (Fügener et al. 2021). Finally, with the technological advancement of 4IR entities *d*, less human involvement is needed, and research shows that workers’ fear of being replaced by machines that emulate human capabilities reduces their job satisfaction (Schwabe and Castellacci 2020). Such replacement may also happen at managerial levels, leading to “bosses without a heart” (Mantello et al. 2021).

A rosy picture of creative employees doing meaningful work in collaboration with automating machines contradicts empirical findings of feeling like an AI's servant, running a seemingly futile race against machines, behaving like borgs, and literally having a boss without heart. How might the 4IR affordance conceptualization illuminate and disentangle such apparent contradictions? And what new social mechanisms and dynamics will shape such outcomes? Will the uncanny valley (rooted in the connection between a machine's appearance and how humans respond to it) give way to a new phenomenon? Will 4IR robot-native generations perceive robots differently, invoking 4IR affordances without thought? And how might normative IS research build on the 4IR conceptualization developed herein to advance notions of what is right and wrong in emerging and unprecedented 4IR contexts, from moral intuition to reflection and meta-ethics (Stahl 2012)?

Accordingly, 4IR affordance assemblages support knowledge generation in several ways. First, a shift from a focus on technology, as underscored by the scoping literature review, towards clearly defined action possibilities clarifies claims and assertions. For example, who are the agents, what are the entities, and in what sorts of contexts will the enactment of affordances lead to positive outcomes (e.g., increased meaningfulness of work) and mitigate negative ones (e.g., borg-like behavior), respectively (Fügener et al. 2021)? Such questions are particularly relevant in the healthcare context, such as the use of conversational agents to enhance accessibility and personalization (Car et al. 2020). Additionally, questions can be posed regarding whether the same technology or technological entities can lead to different outcomes as a result of different enactment scenarios (e.g., differences in organizational settings or specific tasks at hand). Systems theory may inform the identification of related mechanisms, causes, effects, and feedback loops (Sterman 2001). Overall, work practice design incorporating formalized affordances can support a mapping of who does what, under what circumstances, how, and why, much as statistical process control charts provide guidance for automated physical processes and practices. Informed by normative business ethics, such an approach may mitigate damaging humanistic outcomes while advancing instrumental ones.

Second, viewing negative outcomes, such as feeling like an AI system's servant, as the result of the enactment of certain affordances may yield insights that enable an affordance redesign. For instance, the expansive decision making affordance might be respecified to enhance employee morale by involving employees themselves in the process of specifying the affordance elements to allow new enactments that maintain human dignity (Leidner et al. 2021) while achieving instrumental objectives. Further, application of creativity automation affordances in conjunction with explainability affordances may involve the machine describing its decision-making process. This, in turn, may mitigate humans feeling like servants to an AI system. Prior research on the uncanny valley applied to the context of 4IR affordances may suggest how such verbal explanations can contribute to reducing such tensions (Seymour et al. 2018).

The rapid pace at which 4IR affordances are being enacted across a wide range of industries suggests that such contradictions and tensions will only increase. The delineation of action possibilities and human agency against the backdrop of a social or workplace environment can advance understanding of the entanglement between what is possible and whether and how such possibilities are enacted (Fayard and Weeks 2014), and of what is appropriate in specific circumstances. This may also counter *a priori* beliefs that smarter machines doing better work than humans can do are inevitable and always justified. After all, invoking the never-ending improvement of technology and inevitability to justify damage to humans *ex post* is easier than holding accountable those responsible for choosing to enact the affordance in a damaging way. The former is an illusion that many are incentivized to believe; the latter exposes the true root of the problem: human decision making (Cutler et al. 2019; Stahl 2012).

5.2 Development of safety regulations informed by 4IR affordances

One proactive approach to mitigate the risk and damage to humans of 4IR affordances is via safety regulations. This approach worked effectively in the mass production era when laissez-faire free markets caused significant harms in newly emerging industrial contexts. For example, in the early part of the 20th century, the aviation industry demanded safety regulations, resulting in better weather services, radio communication protocols, and flight management, contributing to development of a robust aviation industry (Dempsey 2017). Similarly, regulation to advance the well-being of humans emerged in a wide range of other industries such as food production, automobiles, and air pollution (Calandrillo 2001).

Following this precedent from earlier industrial eras, governments and other organizations have begun to develop safety regulations for 4IR innovations. A notable example is the European

Parliament, which has proposed the Artificial Intelligence Act. This sweeping proposal focuses on such technologies as machine learning, knowledge-based approaches, and statistical approaches, and seeks to advance high-level objectives, including safety, legality, enforcement, fundamental rights, and the promotion of a single market (Wallace 2020). The overall vision of the proposed regulation is to create clear and standardized guardrails that prevent damaging uses of AI systems and promote beneficial ones. This vision aligns with other efforts throughout the world, such as the Model AI Governance Framework developed by the Singapore government, the Center for Humane Technology targeting social media, and the Future of Humanity Institute at the University of Oxford, which includes an AI safety component.

These efforts are laudable given the magnitude of the problem. At the same time, regulatory efforts suffer from a common limitation: they focus on technologies rather than action possibilities. Specifically, the AI regulations in development subscribe to a narrow version of AI that aligns with only one of the 4IR affordance assemblages: expansive decision making (Bryson 2022). This leaves the other three—each with its own share of possible risk and damage—out of scope, potentially limiting regulatory effectiveness. For example, the European Parliament's Artificial Intelligence Act defines the objective of AI systems as follows: "to generate outputs such as content, predictions, recommendations, or decisions which influence the environment with which the system interacts, be it in a physical or digital dimension" (EC 2021). Likewise, the Model AI Governance Framework developed by the Singapore Government refers to AI as "a set of technologies that seek to simulate human traits such as knowledge, reasoning, problem solving, perception, learning and planning, and, depending on the AI model, produce an output or decision (such as a prediction, recommendation, and/or classification)" (Iswaran 2020, p. 18).

A limited definition of phenomena under consideration limits the purview of resulting policies and may even introduce unintended consequences due to unforeseen interactions among a more comprehensive set of phenomena. In particular, limiting the scope of AI regulation to the expansive decision making assemblage leaves out important intellectual property rights issues concerning the valuable artifacts generated completely by code via creativity automation. Another example beyond this limited scope is the employment implications of automatically generated text for certain types of workers, such as product marketers. Moreover, the perfect mimicking of a loved one's audio voice (and soon, physical image) is possible. This enables fraudulent or malicious use of AI, such as for financial gains when deceiving people into thinking they are speaking with a loved one to escape regulatory attention.

Incorporating 4IR affordance assemblages into regulatory policy would support enduring principles for the responsible enactment of a wide range of 4IR action possibilities (Maas 2022). Such an approach appears to be emerging. In the latest handbook for AI in the public sector, for instance, the following principle is included: "to develop fair, non-discriminatory and transparent AI-enabled public services, focus should be put primarily on the use of AI, rather than on the specific technology and its components" (Manzoni et al. 2022, p. 28). Building on this perspective, application of 4IR affordances may support a more comprehensive understanding of aspects related to decisions, creativity, relationships, and teaming—and, therefore, promote broad and enduring policies governing each of these areas.

Finally, 4IR affordance assemblages may support a new language by which to debate differences and advance mutual agreement on appropriate policy. Rather than being sidetracked by the latest technologies and algorithms, regulators, business leaders, politicians, and experts can employ assemblages as a simple, transdisciplinary lexicon by which to conduct productive discussions of a broad range of action possibilities and their appropriate invocation based on shared human, societal, and cultural values. Complemented by normative ethical perspectives (Stahl 2012), such an approach furthers humanistic outcomes by exposing and interrogating which action possibilities are appropriate in which situations and under what circumstances. IS researchers may also employ the 4IR affordance perspective as a conceptual foundation for analysis of regulatory structures and impacts (Gozman et al. 2021; Stahl and Markus 2021).

Overall, application of the 4IR affordances proposed herein in the context of developing safety regulations may broaden their scope, clarify their principles, and enhance their effectiveness. If regulatory efforts to promote human safety in the prior industrial and information eras are any indication (Calandrillo 2001), such regulations may promote safer digital and physical environments, especially for vulnerable and under-resourced populations. In this way, application of the 4IR affordance conceptualization may enhance humanistic outcomes over the long run.

6. Discussion

Technology and algorithms dominate the discourse about the role of increasingly human-like machines diffusing across all realms of business and society. This framing has been useful for analyzing instrumental outcomes—at the cost of neglecting the role of humans and the increasing risk and damage to humans. The following research question was thus formulated: *How can the fourth industrial revolution be reconceptualized to advance research that includes social phenomena and humanistic and instrumental outcomes?*

The 4IR affordance conceptualization was developed to underscore the importance of keeping humans in the loop when studying 4IR phenomena. Affordance theory aligns with the sociotechnical perspective (Sarker et al., 2019), which emphasizes the need to understand the mutual relationship between the social and the technical (e.g., Beath et al., 2013; Bostrom et al., 2009; Mumford, 2006). The affordance conceptualization of the 4IR stresses action possibilities and the fundamental role of human agency in deciding whether to enact them (Fayard and Weeks 2014). According to this conceptualization, then, humans decide which 4IR affordances to enact, and how. Enacted possibilities, in turn, may generate both benefits and damages, but it is human decision makers who are responsible for planned—and unexpected—consequences.

While affordances are not the only way to describe the current technology epoch, the development of 4IR affordance assemblages and their formalization supported the objective of re-situating humans at the center of technology-enabled change. Moreover, four specific affordance assemblages were identified using a transparent process based on a scoping literature review. Two application examples illustrated how application of 4IR affordances can advance humanistic and instrumental outcomes while reducing damage and risk, from both research and industry perspectives. Thus, the affordance perspective on the 4IR provides a new and fruitful way of envisioning open and nondeterministic futures directed by humans rather than myopic ones driven by the needs of industry under the guise of inevitability. As researchers build upon the current formulation, new 4IR assemblages and individual affordances may emerge that will complement the current set.

Critical reflection on the research journey yielded three additional insights. First, when developing the chosen 4IR affordance conceptualization, it became clear that an ethical analysis would be complementary. For example, future research might apply normative ethics (Mingers and Walsham 2010) to analysis of particular 4IR affordances, yielding new insights that go beyond the who, what, where, and how, to include the why, for example, why are certain action enactments considered acceptable in certain situations and not others? Second, the current analysis may be criticized as incomplete without the benefit of hindsight as the 4IR is still in early development stages. While a valid criticism, our point of view is that the significance of such changes and their real and potential damages necessitate attempts at characterization using the best approaches currently available. Beyond those discussed herein, other fruitful application domains include basic digital rights such as eliminating harmful terms of service, reformulating digital rights management, and reducing user-hostile software (Doctorow 2021). Third, a narrow definition of humanistic outcomes might be perceived to exclude environmental sustainability and climate change issues. These critical issues are fruitful avenues for future research studies that may yield important research and practical insights. For example, in the context of building a digital ecosystem for environmental data, intermachine teaming may necessitate appropriate governance standards to safeguard data and privacy while enabling valuable uses, and creativity automation may be applied to suggest appropriate low-carbon logistics processes.

In sum, contributions to the literature include a reconceptualization of the 4IR incorporating human actions and humanistic outcomes to put humans back in the loop, application and extension of formalized affordances, and demonstration of the value of 4IR affordances within two salient application contexts.

7. Conclusion

The affordance conceptualization of the fourth industrial revolution is only a small first step towards a complete and systematic formulation that supports human agency and humanistic outcomes as well as instrumental ones. Much work remains to broaden understanding of human roles and associated humanistic outcomes in this post-information revolution, with significant implications for scholarship and practice. As machines continue to advance in their emulation of human cognition and communication in coming years, the locus of 4IR affordances and their application across all spheres of life will likely expand in concert. Is our destiny to become the

AI system's servant (Strich et al. 2021)? If not, we must grapple with a fundamental question: just because a machine can do something better, faster, or cheaper than a human, should it?

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