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The digital is different: Emergence and relationality in critical realist research

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ABSTRACT

When analyzing empirical phenomena, the implicit or explicit assumptions we have of relationality guide what we take as the primary units of analysis and how we study them. This paper investigates and expands on the notion of relationality and relational explanations in the Critical Realist (CR) paradigm of Information Systems (IS) research. As digital technologies are becoming increasingly adaptive to the social and socio-technical structures they are embedded in, it is necessary to expand the field's conceptual tools in its study of digital phenomena. Therefore, to explain why the digital seems more tightly coupled to social phenomena than other types of technologies, the concept of transformational emergence is introduced. The key argument is that the malleability of digital entities entails that they are disposed to transform by emergence, which is key to understanding the constitutive relationality between the social and the technical in contemporary digital phenomena. This has fundamental implications for CR-based theories in the IS field, most notably Affordance theory and Representation theory.

1. Introduction

The field of Information Systems (IS) has been defined by its knowledge aim of investigating how digital technology can be developed, implemented, used, and managed in social arrangements in ways that serve and benefit them (Grover & Lyytinen, 2015). This definition necessitates a relational understanding of the socio-technical, in that neither technologies nor social arrangements are investigated and accounted for in isolation, but in relation to each other (Sarker, Chatterjee, Xiao, & Elbanna, 2019). What a relational understanding entails and what relationality means, however, is contested and depends on the a priori assumptions researchers implicitly or explicitly subscribe to (Cecez-Kecmanovic, 2016). Relations can be understood as interactions, as causes and effects, as spatiotemporal positionings, as intentions or projections people make on the world, or perhaps as something more fundamental to the constitution of reality (Markus & Poduska, 2018; Orlikowski & Scott, 2008; Schatzki, 2019). When analyzing the phenomena we observe, assumptions of relationality guide what we take as the primary unit of analysis (Schultze, 2017). Such assumptions can frame phenomena as effects of relatively stable entities that interact, which would indicate that we should primarily analyze these entities, or that entities themselves and their effects are primarily constituted by the relations they are in. The latter would imply relations as the primary unit of analysis.

In this conceptual paper, we aim to approach the issue of relationality by clarifying and expanding on the notions of relational explanations and emergence in the critical realist (CR) paradigm of IS. The position of CR has been portrayed within recent IS debates as first and foremost a substantialist paradigm (Cecez-Kecmanovic, 2016; Schultze, 2017; Schultze, van den Heuvel, & Niemimaa,

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2020); a meta-theory that affords theorizing socio-technical phenomena as consisting of relatively stable social and technical entities that interact in some pattern (Leonardi, 2013). In the philosophy of CR, there is a tradition of analytically separating between entities and the relations these entities are in, thereby distinguishing agency from structure, subject from object, and the observer from the observed (Archer, 1998; Porpora, 2018; Wynn & Williams, 2020). This line of argument has strongly influenced CR-based theorizing in IS: on socio-technical structures (Wynn & Williams, 2012), affordances (Volkoff & Strong, 2017), representations (Burton-Jones & Grange, 2012), and technological identity (Faulkner & Runde, 2019). These are all theorizations that include relational explanations, but they put little emphasis on how entities are formed by the relations they are part of. There is, therefore, a tendency to treat digital technologies as relatively stable entities formed by design, rather than by effects of the relations they are part of.

Assuming separation and stability can be problematic when studying contemporary digital phenomena. While relationality has long been central in theorizing socio-technical phenomena (Bateson, 1970), which digital phenomena is a form of, current technological developments has pushed the issue into the forefront of theoretical debates (Riemer & Johnston, 2017). The last decade's development and diffusion of mobile, social, immersive, experiential, and machine-learning based digital technologies is challenging our notions of the socio-technical (Baskerville, Myers, & Yoo, 2020; Yoo, 2010). In analyzing contemporary digital phenomena, it can be difficult to establish clear boundaries between the agencies of people and the agencies of machines, as the lines between them are blurred (Riemer & Johnston, 2017). Social media platforms provide a telling example; they are characterized by how their content is structured, ranked and disseminated in complex and intertwined mixture of algorithmic and human actions (Bucher, 2018). This is related to a development where digital technologies are increasingly adaptive to patterns of data from both use and external sources (Lyytinen, Nickerson, & King, 2020). The use of machine learning and data analytics entail that technologies learn and change over time. These technological shifts make it necessary for IS research to expand the field's conceptual tools in its study of the socio-technical, both within and outside the CR paradigm.

To address the issue of relational explanations in CR and how technological developments nudges us to update these explanations, we ask the following research question: *How does critical realism effectively theorize digital phenomena characterized by adaptiveness and emergence?* To approach this question, we do the following: First, understanding digital phenomena as socio-technical, we clarify the relational understanding of the technical and the social in current CR theorizing in IS by reviewing the concepts socio-technical structures and technology identity. We also show how the assumptions of this theorizing has implications for two well-established CR-based theories in IS: Affordance Theory and Representation Theory (Burton-Jones & Grange, 2012; Volkoff & Strong, 2017). We then relate these concepts to the philosophical concept of *relational emergence*, the realist concept for wholes that are more than their parts due to their specific composition and interactions (Elder-Vass, 2011). The concept is crucial for understanding how critical realist explanations of observable phenomena depends on describing both entities and the constitutive relations they are in.

Second, while emergence is a well-established concept in CR (Bhaskar, 1998; Bygstad, Munkvold, & Volkoff, 2016; Elder-Vass, 2017; Gorski, 2016; Lawson, 2016; Mingers & Standing, 2017), we offer a novel theoretical contribution by introducing the term *transformational emergence* into Information Systems theorizing. Building on the philosophy of Anjum and Mumford (Anjum & Mumford, 2017), we pose that the malleability of digital technologies entails that they transform as they interact with other entities and that this transformation causes the formation of the emergent structures they are part of. While the concept originates from outside CR philosophy, it offers a compatible approach to conceptualize the blurred lines and adaptability of current socio-technical phenomena.

The paper is structured as follows: After an overview over prior CR conceptualizations in IS literature, we discuss the concepts of relational emergence and socio-technical structures. Building on these concepts, we develop, define, illustrate, and discuss transformational emergence. We argue that the concept explains how the causal capacities of digital technologies change as the data changes, and we conclude by discussing some of the implications of the theoretical contribution to the IS field.

2. Critical realism and digital phenomena

2.1. Socio-technical structures

CR research takes a structural view of humans and technologies; they are studied as elements positioned in relations to each other, relations which recursively form and are formed by their interactions. For example, organizations are seen as socio-technical structures, where some of the components are people, some technologies or other material artefacts, and these structures shape and are shaped by organizational elements like rules, roles, and practices (Wynn & Williams, 2012). CR is distinct from stronger relational theories and meta-theories, however, as its ontology also allows for intrinsic properties and characteristics (Elder-Vass, 2011). This means that an entity – like a human or a technology – may be shaped both by its relations to other entities and by its internal structure.

'Structure' can be an ambiguous term; it can refer to concepts as disparate as the totality of relations within a society, to a specific group of entities with specific properties (Elder-Vass, 2011, 2017; Porpora, 1989; Wynn & Williams, 2020). CR studies tend to use 'structure' following the latter definition, as a distinct composition of elements that is relatively stable (Wynn & Williams, 2020). The term is used similarly to terms like assemblages or configurations in other paradigms, but CR scholars tend to put more emphasis on stability than the alternative terms connote (e.g. DeLanda, 2016; Suchman, 2007). A structure, therefore, is a general term that encompasses all kinds of compositions, for example, technological structures (compositions of technological elements, like the parts of a computer organized by their interrelated positions and interactions) and social structures (compositions of people organized by social elements, like language, capacity relations, and so forth). We use the qualifier 'socio-technical' to describe compositions where social and technical elements are the primary elements of analysis, which also cover the structures of digital phenomena where the technologies under explanation are primarily digital.

Following this take on structures, CR studies have analyzed digital phenomena through how the composition of socio-technical structures conditions action (Strong et al., 2014), how socio-technical structures and the interactions within them transform wider societal structures (Essén & Värlander, 2019), and the recursive relation between the room of possibilities afforded by a socio-technical structure and the actions taken within them (Henfridsson & Bygstad, 2013). CR researchers have generally been interested in explaining the causes of observed phenomena like digitalization outcomes or firm's abilities to perform digital innovation (Henfridsson & Bygstad, 2013; Wynn & Williams, 2020). When explaining what causes such phenomena, CR researchers have worked to identify the socio-technical structures causing the phenomena and the mechanisms working within them, meaning the way the elements in the structure interact over time to produce an outcome (Bygstad et al., 2016; Wynn & Williams, 2020). To understand the particular understanding of relationality in CR theorizing, however, we turn to a concept discussed in recent literature that accentuates the topic: technology identity.

2.2. Technology identity

With identity, we mean what something is and what makes it different from other things; what is a software application, and what makes *this* application different from *that* application? Questioning the identity of technology goes into the core of relationality. Take, for example, the AirBnB accommodation booking platform (www.airbnb.com). Is the platform what it is in virtue of being a concrete piece of implemented software that is running in a cloud environment and accessible through the internet? Or is the AirBnB platform what it because of the meaning people individually and communally ascribe to it? The CR position is affirmative to *both* of these alternatives. As the CR scholars Faulkner and Runde have argued in several seminal papers, technologies get their identities both from social function and technological structure (Faulkner & Runde, 2012, 2013, 2019). The former denotes how a technology is relationally constituted by how it is understood and used in a social structure, while the latter is the way a technology exists as a bounded set of material or digital elements that are organized in some way (Faulkner & Runde, 2013, 2019). In other words, technology gets its identity from both its technological structure and the social structure it is situated in.

Social function is collectively assigned by members of social groups, in that a technology is given meaning through its use in a specific social structure. As Faulkner and Runde exemplify it, a Magnetic resonance imaging (MRI) machine in a hospital is assigned meaning - social function - through how it is used and understood in the practices of radiographers, physicians, patients, and so forth. On the other hand, technological structure is immanent to the technology itself; it is "composed of constituent parts that are organized in some way" (Faulkner & Runde, 2013, p. 807). Using the MRI example, this type of machine is made up by several elements that are organized and interact according to some design. Through this technological structure, the machine has the capacity to take MRI images, whether or not this capacity is used appropriately in practice.

Technology is positioned in social structures through this dual nature of technological structure and social function; positions are reproduced and transformed, like other social positions, through peoples' ongoing practices. But they are not socially determined, "for the assignment of function to an object to be sustained that object must generally possess the characteristics and capabilities required to perform that function" (Faulkner & Runde, 2013, p. 809). In other words, the identity of a technology both have dependent and independent aspects in relation to the social structure it is situated in. The enduring structure of the technology entails that it can stay the same while the social position changes, or conversely, the social position can stay the same, while the technological structure changes.

Faulkner and Runde separate between material and digital technologies, in that material technologies have spatial properties like mass and volume, while digital technologies, do not. The underlying structure of all digital technologies are bitstrings, sequences of 1s and 0s. Like other technologies, they get their identity both from their technological structure and from their function in social communities, and these two aspects shape each other. But because digital technologies do not have "the spatial attributes associated with material technological objects" (Faulkner & Runde, 2013, p. 811) they can have different roles and functions from other types of technologies. For example, because they can exist within different material bearers (i.e., different computers, smartphones, etc.), digital technologies can be easily copied and moved around at relatively negligible cost, compared to other types of technologies (Faulkner & Runde, 2019). In turn, this means that digitality may lead to different types of social structures with different types of dynamics than when other technologies are put in play.

Although digital technologies have different characteristics than material technologies, Faulkner and Runde emphasize their structural stableness and continuity (Faulkner & Runde, 2019). For example, the AirBnB booking platform is what it is – in terms of technological structure - because it exists over time as a structure of bitstrings. This structure may be gradually changing over time through development and design changes, but it stays stable enough to constitute the same object. Shifts in identity, per Faulkner and Runde, is therefore typically a question of how the technology's position in the social structures it is changing (Faulkner & Runde, 2013). As a globally accessible and used platform, AirBnB can have different functions and meanings assigned to it, which can change over time, while its internal technological structure, following Faulkner and Runde, stays relatively stable.

2.3. Assuming stability and its implications for representation and affordance theory

As we have shown, current CR-based perspectives in IS provide a rich vocabulary to study digital phenomena as socio-technical structures. The vocabulary is built on an assumption that technologies are what they are (at least partly) because of the relations they are in, but that such relations are relatively stable. The internal structures of the technologies are also assumed to stay stable over time. CR-based IS theories, in other words, accentuate stability in the way they conceptualize digital phenomena. This has implications for two of the most prominent CR-based theories of IS: Representation Theory (RT) and Affordance Theory (AT) (Burton-Jones &

Grange, 2012; Volkoff & Strong, 2017).

RT analyses digital technology through their capacity to represent external objects (Recker, Indulska, Green, Burton-Jones, & Weber, 2019). In its simplest form, RT predicts that the faithfulness of a digital technology's representations - how faithful its digital representations are to the physical things they represent - is correlated to how useful the technology is to its users. RT, as originally developed by Wand and Weber (1995), takes an inside-the-technology view to information systems and its properties, by focusing on data models or the modelling language these models were generated from (Burton-Jones, Recker, Indulska, Green, & Weber, 2017). Recent additions to the theory have moved it in a socio-technical direction, in line with other current CR-based perspectives in IS, where the representational capacity of technology is seen as impacted by interactions with users. Users do not merely use a technology's representations in their activities, they also modify the technology to make the representations more faithful over time (Burton-Jones & Grange, 2012). However, the basic assumption of RT has stayed the same; the deep structure of digital technology, the structure that makes its representations meaningful, is a relatively static structure of models that are implemented at design time to map entities in the world (Recker et al., 2019; Wand & Weber, 1995). Data is conceptualised as state changes in these models; an entity is an entity, and the influx of data means that some property in the entity model changes.

There exist several strands of AT, but in contemporary IS research, the most prominent conceptualization is based on CR (Volkoff & Strong, 2017). An affordance is here defined as the "the potential for behaviours associated with achieving an immediate concrete outcome and arising from the relation between an artefact and a goal-oriented actor or actors" (Volkoff & Strong, 2017, p. 235). The proponents of AT stress that the definition is relational; the affordance belongs neither solely to the actor nor solely the artifact but to the relation between them (Thapa & Sein, 2018). An affordance is, therefore, viewed as emerging from a socio-technical structures, as perceivable potentials for interaction in a structure consisting of technologies and people (Bygstad et al., 2016). Research on affordances has shown how they evolve over time. For example, a digital infrastructure affording recombination can recursively afford more recombination as the affordance is actualized and the infrastructure expands (Bygstad et al., 2016), and people change technologies over time leading to the rise of new affordances in the socio-technical structure (Essén & Värlander, 2019). However, the basic assumption underlying these conceptualizations of change is that the affordance exists as a stable potential between the designed features of the technology and the human user (Volkoff & Strong, 2017).

Assuming stability both in and between entities has proven useful and generative in developing CR-based theories in IS, demonstrated, for example, by the popularity of the affordance concept in IS literature (e.g., Thapa & Sein, 2018). As we will argue, however, assuming stability over time in the bitstrings constituting contemporary digital technology is problematic when it comes to the adaptive applications and platforms we observe today. The last decade's development and diffusion of mobile, social, immersive, and experiential, and machine-learning based digital technology challenge notions of stability, as they are increasingly adaptive to patterns of data from both use and external sources (Lyytinen et al., 2020). The CR vocabulary of IS provides a rich toolbox for analyzing socio-technical structures. But as the phenomena under study are changing, we need to update the foundations the toolbox is built on. To move this argument forward, we first turn to the concept of *relational emergence*. This concept provides an understanding of why CR researchers focus their studies on structures and their mechanisms. Structures are constituted by parts that interact in some way, and because they interact the way they interact, new properties *emerge*. Relating this to identity, technologies have their technical capacities because of their technological structure, and their identity emerges as these capacities interact with other entities in social structures.

3. Relational emergence

3.1. Causal capacities

To explain the relational theory of emergence, we start with the concept of causal capacities (also called causal powers). A capacity is generally taken to mean the ability to affect or change something in the environment (Mingers & Standing, 2017). The theory of capacities is often contrasted to a positivist theory of causation. While the latter see causation as regularity between changes in atomic units, the theory of causal capacities argues that causality is immanent; entities have their causal capacities in themselves (Mumford & Anjum, 2011). There is something about glass that makes it prone to break if hit by a stone. Or to take an experiential example; if you play tennis, you exercise mental and physical capacities to be able to swing the racket in a way that makes the ball go in a specific direction. Even though this experience might not account for external (or internal) causal capacities that have created the dispositions for wanting to play tennis, or the physical mechanisms of a ball-trajectory-in-air, our experience of being agents in the world tells us that we can affect things outside of ourselves through our capacities.

Table 1

Key concepts for describing relational emergence.

Concept	Definition
Socio-technical structure	A relatively stable composition of entities/structures, where the defining entities, relative to the causal capacity under explanation, are people and technologies
Emergent causal capacity	A causal capacity existing in the structure, not in its individual parts
Mechanism	The composition and interactions between the parts of a structure causing an emergent capacity
Causal structure	A socio-technical structure's mechanisms and causal capacities

3.2. Mechanisms and emergence

In the critical realist view, capacities are constituted by *mechanisms*: compositions and interactions between the parts of the thing that possesses the capacity (Elder-Vass, 2015, 2017). A computer is made up of components organized and interacting in a specific way, that produces the capacity to store data and execute instructions in it. A soldier is made up of person, gear, and gun, interacting in a way that produces the capacity to shoot-to-kill. Both the computer and the soldier are structures; they are made up of interacting entities (which themselves are structures down to the quantum level). A structure is thus a specific and relatively stable composition of entities. A structure's causal structure is the totality of mechanisms constituting it, together with its resultant causal capacities (See Table 1).

When a structure has properties and capacities that only exist because of the composition and interactions of its parts (its mechanisms), it is termed as *emergence*. This means that the whole that is created by the composition of entities is something more than its individual parts. Emergence is in this sense a structural concept. At the same time, emergence occurs temporally; a structure continually comes to be and changes – it emerges - over time. Social and socio-technical structures are not finite or teleological, they do not end up in defined or static states but continue to evolve and transform as their parts interact in different ways over time. To take the example of the University of Oslo, it is made up of students, professors, buildings, books, and so forth. It emerged temporally from the first part of the 19th century and it continues to emerge over time, with new features like the capacity to educate online. But more centrally for this argument, the university emerges structurally as the interactions between the students, professors, buildings, and books produce the capacity to educate in the specific way it does.

We follow Elder-Vass in describing this as a “non-mysterious” emergentist account of causal capacity (Elder-Vass, 2017). The soldier can shoot, the computer can compute, and the university can educate because they are composed of the parts they are composed of, that interact in the way they interact in. The textbook example of emergence is water, with its causal capacity to put out fire. An explanation of this capacity must either state that water has the capacity to put out fire or refer to the specific composition of H₂O interacting in the way it does. Referring to water as a sum of Hydrogen and Oxygen can in no circumstances explain the capacity, as either of these atoms would instead make the fire fierier. The interactional composition between them is a necessity for explanation. The same goes for a social structure. As Elder-Vass argues, you cannot explain a manager's ability to fire his employee without referring either to the existence of an organization that contains them both or to the actual composition and interactions of the organization (Elder-Vass, 2011).

3.3. Socio-technical structures

Until recently, the structures investigated in CR-based social science have primarily been characterized as social structures, that is, structures composed primarily of people, organized through social means (e.g., through language, rules, power). There has been less interest in technologies and how they partake in emergence. As in other fields of social science, this interest is shifting. As Elder-Vass has argued, most or all social structures contain technologies (Elder-Vass, 2017) and these matter in how they work and the capacities they have. As already shown in the example of the computer and the soldier, it is not just the composition and interactions of people that make up a structure; it is also made up of the technologies within it. Elder-Vass exemplifies this with a quartet playing classical music (Elder-Vass, 2017).

A quartet is a structure of people and instruments organized in a specific way that together create harmonious music (Fig. 1). There is no way of explaining the output of the type of harmonious music specific to quartets without either referring to the quartet as having immanent capacities or to the musicians and instruments and the composition of relations between them. There are in other words necessary spatial and interactional relations between players, between player and instrument, and between instrument and instrument for the quartet's causal capacity. This theoretical movement towards a priori symmetry between technologies and human agency is

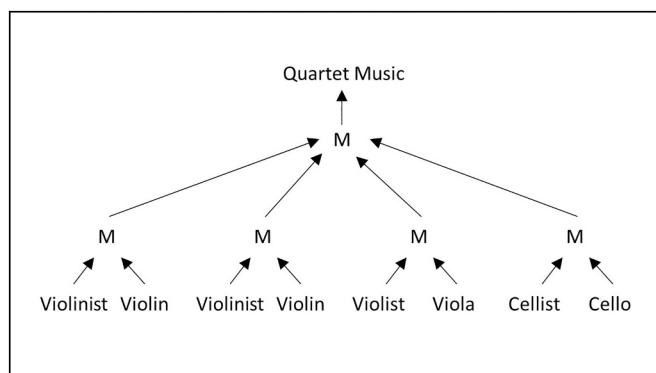


Fig. 1. A quartet structure: a causal structure with the capacity to produce quartet music. M with arrows denotes mechanisms that produce a causal capacity. Each player with instrument, specific player-instrument structures, can cause music. These structures interacting together can cause quartet music.

crucial. It means that technologies are not merely tools utilized in social structures, but active parts in the emergence of them.

In the example, the basis for harmonious music is an inseparable structure of people and instruments. It is not inseparable in the sense that musician or instrument does not exist outside of the structure, but in the sense that neither quartet nor music would exist if it had not been for the musicians and the instrument interacting in the way they did. Classical concerts held on Zoom or similar platforms during the Covid-19 pandemic illustrate how such spatial and interactional relations can be digitally mediated and still produce an emergent capacity of quartet music. As such, similar capacities – i.e., playing quartet music – can emerge out of differently configured structures – i.e., musicians physically present with each other or digitally mediated. However, when such concerts experience network latency and interactions get out of sync, the capacity is no longer present, as the necessary interactional and spatial relations of the structure are not there.

If we accept that quartet music is real, we must also accept quartet structures as being real. In the quartet, specific causal capacities of the violin are being triggered because of the overall structure. However, although they get tuned before use and worn over time, neither capacities nor other qualities (like the material form) of the parts change radically because they partake in the quartet. The meaning and role of the violin are dependent on use; if musicians stopped using violins altogether and the complete set of violins of the world were placed in museums, they would signify something else than they do today. But they would retain their material form (given correct humidity and temperature in the museums).

4. Transformational emergence

4.1. Defining transformational emergence

A violin's qualities and causal capacities are quite stable as it partakes in producing the emergent capacities of the quartet. However, emergence can also entail transformations in its constituent parts. A transformation entails a qualitative change in the properties or causal capacities of an entity. If an entity is transformed because it is constituent to an emergent structure, we propose calling it *transformational emergence*, building on Mumford and Anjum's transformational theory of emergence (2017). Such transformations can happen in the process of forming the structure or as an effect of the structure's emergent capacities. Returning to the textbook example, the philosophers Mumford and Anjum exemplify transformational emergence with water: "A hydrogen atom has a vacant space on its outer shell of electrons and an oxygen atom has two vacant spaces. When they have bonded, they can be understood as sharing electrons, thereby completing the outer shells of all the atoms – two of them being hydrogen – which thereby forms a stable molecule. The three 'parts' have thus each changed in order to form the whole" (Anjum & Mumford, 2017).

Mumford and Anjum argue that all emergence, not just of water, must be explained by transformations (2017). An interaction means that the causal capacity of one entity acts with the causal capacity of another entity. If disposed to it, interactions between these entities do not just entail a mutual triggering of the parts' respective capacities, but transformations in them. Emergence can thus be explained as interactions causing transformations that lead to new capacities. For example, languages exist because people exercise their linguistic abilities in interactions with each other. However, a specific language, like English, exist as a living language because its users have developed the ability to speak and write in the English language. The emergent existence of a language structure is thus the result of transformations in its users' causal capacities. Put in other words, if the "circuits" of your brains did not transform through interactions with English-speakers during upbringing or training, it would be hard to explain why you could read this text, or how the English language could exist at all.

In CR philosophy and research, there is often made an analytical separation between "upward" and "downward" causation (Mingers & Standing, 2017). Upward causation points to emergence, how the constituent parts of a structure cause emergent capacities. Downward causation denotes how the structure as a whole – when it has come into being – affects its constituent parts (Mingers & Standing, 2017). Social function, as an element of technology identity, is a good example of downward causation. *Because* of the makeup of a social structure - its practices, positions, understandings, and so forth - a technology is assigned meaning and function in this structure. Transformational emergence, however, is distinct from earlier CR use of the emergence concept, as it entails that upward and downward emergence occur at the *same* time (Anjum & Mumford, 2017). The English speaker transforms as she learns the language through participation in a language structure - i.e., downward causation - at the same time this transformation causes the language structure to exist - i.e., upward causation. Transformational emergence, in other words, can therefore describe cases where it necessary to emphasize the mutual constitution of the structure and the entities making up the structure.

We do not follow Mumford and Anjum in that all emergence necessarily entails transformations in all constituent parts. In the quartet example, the human constituents have transformed to be able to play in exact coordination, while the instruments have been tuned to be in harmony with each other. However, we do not attribute the causal capacity of the quartet primarily to these prior transformations. It is their combined composition and interactions that are necessary for the emergent causal structure of the quartet to exist. This leaves the relational theory of emergence as sufficient to explain it. However, we propose that transformations are essential to understanding the type of empirical cases observable today, where digital technology is more adaptive and coupled to the social structures they are embedded in. Explaining such digital phenomena requires a theory of emergence which is both relational and transformational. Because, while the violin can be separated from the quartet, digital technologies cannot be equally separated from the structures they are part of.

4.2. Transformational emergence and digital technology

As a thought experiment to exemplify transformational emergence, we can envision an image sentiment recognizer (Fig. 2). This is

a digital technology for recognizing images showing positive content; for example, an image depicting children playing in the sun would by many be labeled as positive. The envisioned digital technology has two modes: a learning mode and a recognition mode. While in learning mode, a set of images labeled as showing positive content is fed into the technology and used to train a machine learning model. After training is complete, the technology enters recognition mode. In this mode, it takes a random image as input, uses the trained model to match for patterns, and displays a binary output on a screen denoting whether it has recognized an image with positive content or not.

The screen also displays a button. Two people sit by this screen, and every time a new output is displayed, they discuss whether the input image has positive content or not and compare their judgment to the recognizers' output. If they reach a consensus that the technology has produced a false negative - an image containing positive content has not been recognized as such - one of them presses the button. If the button is pressed, the image is added to the original training data set, and the technology enters learning mode. The new data set is now used as input to retrain the model. As this process iterates, the technology becomes more and more reliable at recognizing images which these two people find positive. We can also imagine that after some time discussing image after image, their taste for what is positive content is also changing, which contributes to the choices they make in deciding what a positive image is.

This thought experiment depicts an emergent structure, composed of a digital technology and people interacting in a way that produces the technology's causal capacity to recognize images with positive content. The recognizer technology itself has stable mechanisms: given training data, it is disposed to recognize patterns in images. *But initially, it does not have the causal capacity to recognize positive content*; this only comes as the capacity transforms through the emergence of the structure.

If you were to place the trained technology in another context with other people, it would be less apt at recognizing images these find positive. Its causal capacity and its meaningful relevance are in other words tied to the structure. This contrasts with the example of the quartet: while the position of a violin in a web of meaningful relations, or its role in producing harmonious music, is produced in a structure, the causal capacities of the separate violin is quite stable. The vibration of the violin's strings causes oscillations in the air around it, interpreted by humans as sound, whether it is part of a larger social structure or not. However, the digital technologies responsible for performing sentiment recognition would not be able to produce meaningful output outside of the overall structure, as it transforms through interactions in order to do what it does. Thus, theoretically, transformational emergence is defined as *the becoming and existence of wholes that are more than their parts, due to transformations in the parts caused by the composition and interactions between them*.

4.3. Illustrating transformational emergence of digital phenomena

Transformational emergence can be further illustrated through the example of AirBnB. Its digital platform has the causal capacity to show users ranked listings of accommodations that are targeted to their inclinations and intentions. Drawing on AirBnB's engineering and data science blog,¹ we can see that this capacity cannot be reduced to be the result of predefined algorithms. Rather, AirBnB relies heavily on machine learning techniques, where statistical patterns in data lead to personalized ranking of accommodations. For example, deep neural networks are used to infer the preferences of users based on patterns between search results and bookings,² which shapes users experience of the platform.

AirBnB's capacity to rank accommodations affords user interactions, user interactions cause transformations in data, and transformations in data produce the capacity to rank accommodations. To use AirBnB's own example, they have the capacity to show users wanting to rent family-friendly homes close to popular sights in Beijing relevant accommodation options.³ This capacity cannot be reduced to AirBnB's technological structure or designed features alone. Rather, we can conceptualize it by relational and transformational emergence. It is relational, as it is caused by a myriad of interactions of people and technologies. It is also transformational, as the structure of data behind the users' recommendations - in the form of knowledge graphs and search indexes produced through machine learning - is continuously changing through these interactions. Every time a user interacts with AirBnB, by clicking a search result or booking an accommodation, data that represents this interaction is collected, which in turn enables AirBnB to provide results relevant to the user. This means that the bitstrings constituting AirBnB's technological structure is constantly transforming, which again is constantly transforming its technological capacities.

5. Discussion

The research question asked in the introduction was: *How does critical realism effectively theorize digital phenomena characterized by adaptiveness and emergence?* To approach this question, we have shown that in earlier CR studies, technology has been seen as inscribing social structure or mediating it (Mutch, 2009, 2013), there has been a focus on discrete entities and their capacities and properties (Mutch, 2013), and technologies have been seen as mostly stable outside of their social positions (Faulkner & Runde, 2012). We have argued that emergence, in both its relational and transformational conceptualization, is key to both understand and develop the CR paradigm of IS. For CR to stay a relevant paradigm in the field, it needs conceptual development to support accounts of contemporary developments where the digital and the social is becoming increasingly intertwined through the use of adaptive digital technologies. Digital technologies do not have the same restraints as material technologies, they are made up of bitstrings that can be

¹ <https://medium.com/airbnb-engineering>

² <https://medium.com/airbnb-engineering/improving-deep-learning-for-ranking-stays-at-airbnb-959097638bde>

³ <https://medium.com/airbnb-engineering/contextualizing-airbnb-by-building-knowledge-graph-b7077e268d5a>

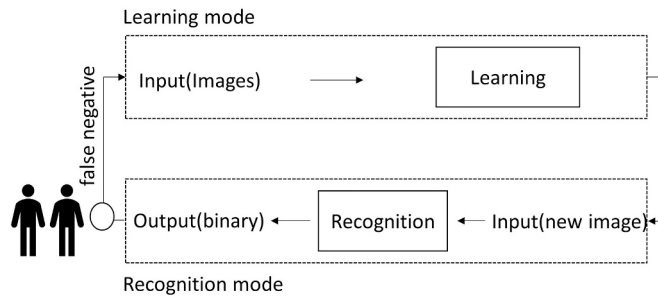


Fig. 2. Thought experiment. The stable mechanisms of an image-recognition-users-structure are causing the transformational emergence of a causal capacity.

easily manipulated into arbitrary sequences or changed out with other sequences, as long as they follow a structure compatible with the computational device that processes them (Faulkner & Runde, 2019). The technologies of the digital realm are therefore not as stable as the technologies of the physical realm; they are malleable technologies that have a potential for being transformed in relations with other technologies and people.

The theory of relational emergence is central to CR research. A structure is a set of related entities, and such structures can have properties and capacities that are not reducible to the structure's parts. This guides CR researchers to study mechanisms, the composition and interactions between the parts of a structure that cause such emergent capacities and properties. This implies that both the entities of the socio-technical structure need to be understood – for example, the capacities of the individual technologies in use – and the interactions that relate the different entities together. We have argued that in terms of emergence, there is a key difference between the digital and the non-digital, which has been accentuated as digital technologies have become more adaptive to patterns in data. While structures involving the latter is typically explainable by *relational emergence*, structures involving digital technology can be formed by *transformational emergence*. Interactions of humans and technology have caused emergent causal capacities long before homo sapiens became sapiens: a person and a sharpened stone have different abilities than a person alone. What is special about the digital is therefore not emergence, but that the causal capacities of digital technologies can transform and become what they are by partaking in emergence. By sharpening, the possible causal capacities of the stone are shaped *before* action. In contrast, the possible causal capacities of the digital technology are shaped *in* action by transformations in data.

We have explained the relational nature of CR theorizing of digital phenomena through Faulkner and Runde's work on technology identity (2012, 2013, 2019). Their arguments can be understood through relational emergence. A technology's capacities interact with entities in a wider socio-technical structure, and through these interactions, its identity emerges. This entails that as a technology is used in new ways, its identity can change, even while the bitstrings that constitute its technological structure stay stable. This understanding of technological identity can be expanded to account for adaptable digital technologies by using the theory of transformational emergence.

Faulkner and Runde emphasize digital technologies that are developed by an intentional designer (2013). Microsoft Word, for example, is made up by a set of algorithms – a structure of executable bitstrings – that give rise to its technological capacities. The bitstrings that make up and matter for adaptive digital technologies like AirBnB, however, are to a large extent the data these platforms have amassed through interactions with a large set of users. The reason why AirBnB can provide you with a relevant accommodation offering is as much due to this data as the designed algorithms. This means that the technological identity of AirBnB partly emerges through the transformations in data that occur every time a user interacts with it. In other words, it is not merely social function that emerges through relations with the wider structure, but also its technological structure. This shows how the relations of digital phenomena are potentially more constitutive than in other forms of socio-technical structures.

Digital phenomena are socio-technical structures with emergent causal capacities. Digital technologies differ from other forms of technology because they can transform as data from interactions in the overall socio-technical structure is added to or change them. Neither the overall causal capacity of such a structure nor the transformed capacities of the transformed digital technologies constituting it, can be separated from the whole. The emergent capacities would not exist if the whole did not exist. By accepting the reality of emergent capacities and that these capacities are dependent on the whole, we follow the relational understanding of CR theorizing. Such a perspective allows us to study how the constitutive relations between the social and the technical has come into being, by investigating the mechanisms of how relations and transformed capacities come together (Wynn & Williams, 2020). In other words, a CR perspective that builds on transformational emergence provides us with a conceptual toolbox to examine digital phenomena part by part and understand the depth of the relations that constitute an emergent whole.

5.1. Implications for representation and affordance theory

The theory of transformational emergence has implications for how substantive theory in IS can be developed and made more relevant in explaining digital phenomena. This brings us to RT and AT, as two prominent CR-based theories in the field (Burton-Jones & Grange, 2012; Volkoff & Strong, 2017).

The theory proposed in this paper allows us to question the assumptions of RT, and by doing this, develop it further. First, we argue

that the capacity to produce representations is not a property of a digital technology alone, but an emergent capacity of the socio-technical structure its part of. Second, representations in adaptive digital technologies are not determined by pre-given models or algorithms but emerge through the numerous interactions and transformations that occur in the socio-technical structure. By engaging with these two points, RT could be developed into a more relevant theory for current IS research. Since both RT and the theory proposed here are based on a CR view of the world (Burton-Jones & Grange, 2012), they share an underlying assumption that there exists a reality outside of our conceptualizations of it, and consequently, that some representations are more faithful than others to this reality (Bhaskar, 2016). These assumptions stand in contrast to stronger relational theories like sociomateriality or radical forms of social constructivism (Orlikowski & Scott, 2008). The transformational emergence of digital capacities, however, presents an apparent contradiction, in that a representational capacity can both be emergent through complex processes and more or less faithful. We believe that engaging with this contradictory nature is fruitful for further developments of RT, instead of going to the extremes of reducing the phenomena to a one-to-one relationship between reality and representation, or to discard the notion of faithfulness all together.

Our argument in relation to AT can be put in similar terms, not least because the affordances of digital technologies are tightly coupled to their representational capacities (Burton-Jones & Grange, 2012). Since the properties and capacities of a socio-technical structure can be emergent, so can its mechanisms. Recalling that a mechanism is defined as the composition and interactions between the parts of a structure producing a causal capacity, mechanisms can transform as the compositions' elements change. Therefore, when technologies and practices change over time, the affordances that bind them together change with them. In other words, an affordance is something that can emerge as a property of the socio-technical structure over time. When an affordance has emerged, it conditions behaviour within the structure, which recursively can lead to new structural change. Digital technologies transform through interactions, which explains how affordances can evolve.

AirBnB illustrates this point, as it affords the user to pick accommodation X at time 1, but accommodation Y at 2. Although both affordances are of the same type at a higher level of abstraction, accommodation choosing, they are not the same specific affordance, as they condition the user towards different behaviours which leads to different immediate outcomes. The explanation behind this transformation of the affordance must be traced back to transformations in data, which again are effects of the socio-technical structure at large. The theory of transformational emergence gives, in other words, a more dynamic view of how affordances come to be and transform over time. Presumably, no-one designed social-media platforms like Facebook to have a misinforming affordance (Volkoff & Strong, 2017). It is an affordance that has emerged over time, through interactions leading to transformations leading to changed affordances, which has strengthened some paths of action and made others less likely.

5.2. Implications for further research

We believe that the arguments of this paper can be used to challenge and develop other theories within IS, as our assumptions of socio-technical structures need to be revised as technologies change. Although we have only exemplified this with some directions for AT and RT, we believe additional research could develop this line of argument in more depth. Research on AT, for example, could empirically trace how transformations in data concretely lead to new affordances. Exploring the particular mechanisms behind such transformations will in turn have design implications; if we predict that affordances will change over time, design needs to take the mechanisms of such changes into consideration.

Related to this point, the theory has implications for methods. Data is transformed in multiple ways: by 'translation' into different data structures (Faulkner & Runde, 2019), by deterministic and learning algorithms, and by users' direct manipulations (Alaimo & Kallinikos, 2022). Modern microservice architectures add to the complexity; the road from input to output is typically marked by data being transformed through distributed infrastructures of digital technologies before they are rendered to and impact end-users. Understanding both the internal transformations of data and the socio-technical structure these transformations partake in constructing, requires methodological developments.

In some digital phenomena, researchers have internal access to the technologies themselves, and can analyze algorithms by their data traces. In other cases, where technology is studied from the outside, scholars from fields like IS, media studies and sociology are developing reverse-engineering techniques, where potential transformations are inferred based on manipulating input to the technologies and correlating this to its output (Bucher, 2018). We propose that the theory of transformational emergence can provide an ontological grounding for this type of methodological development, necessitating that researcher draw together emerging data-centred methodologies with more "traditional" methods for the study of social phenomena.

6. Conclusion

In this paper, we have proposed the following: First, the causal capacities associated with technology are often structurally emergent; they are properties of the socio-technical structure the technology is embedded in, not of the technology itself. Second, to understand such emergent capacities in cases of adaptive digital technology, we need to study the mechanisms of how data is transformed and how these transformations impact and are impacted by interactions with other elements in the socio-technical structure.

Our argument has two main contributions to IS research. First, emergence provides an explanation to how relationality is understood in CR research. People and digital technologies are distinctly different and have separable existences, exceeding their relations between them. At the same time, many of the capacities and properties we associate with both people and technologies are emergent properties of the structures they form together. Our assumptions about relationality – especially between people and

technology – form how we understand, investigate, and theorize empirical phenomena (Cecez-Kecmanovic, 2016; Sarker et al., 2019; Schultze, 2017; Schultze et al., 2020). This paper clarifies what taking a CR perspective on the socio-technical entails.

Second, with transformational emergence, we have provided an extension to the CR strand of IS research. As artificial intelligence and machine learning technologies are becoming ubiquitous, this can provide a step on the way to achieve a conceptual grasp of how we as humans and they as machines together form structures with emergent capacities. CR provides IS researchers a rich conceptual toolbox to understand digital phenomena (e.g., Faulkner & Runde, 2019; Volkoff & Strong, 2017). By building transformational emergence into the foundations of this toolbox, CR-based researchers are better placed to develop explanations and theories of digital technologies that are becoming increasingly adaptive and autonomous.

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