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Emergence in Design Science Research

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Abstract. Designing artifacts is a pivotal activity in Information Systems (IS) research. Beside the development process, the evaluation of artifacts is important as it allows the application of scientific methodologies to generate and accumulate knowledge. Commonly, the evaluation of an artifact is conducted in terms of the artifacts usefulness, utility or performance. Although those evaluation metrics are important, they do not allow conclusions on a more fundamental question, namely "What are fundamental components of an artifact?". Since Information Technology is becoming increasingly complex, identifying fundamental components becomes more important. To address this important topic, we draw from emergence theory to enhance artifact evaluation. We argue that emergence is a well-suited perspective that can be used to identify crucial components of an artifact. We provide a conceptual notion that can be applied to evaluate artifacts in the light of emergence and demonstrate conceptually how to apply this framework.

Keywords: Emergence, Design Science Research, Confirmatory Composite Analysis (CCA), IT Artifact Evaluation, Innovation

1 Introduction

Designing artificial objects is a pervasive human activity that significantly contributed to the evolution of humankind. For instance, the invention of a wheel to transport objects is considered a milestone in human history. In Information Systems (IS) research, designing objects receives the same attention as it allows to develop models, concepts, or artifacts to solve organizational and social problems (Hevner et al., 2004). Since designing artifacts is a crucial part of the discipline, design science research (DSR) emerged as a distinct research paradigm (Hevner et al., 2004; March & Smith, 1995; Simon, 1969; Walls et al., 1992) which in contrast to natural science, is concerned with the artificial (Simon, 1969).

A pivotal activity in DSR is the evaluation of design to demonstrate the utility or the usefulness of an artifact (Hevner et al., 2004; Venable et al., 2016). To ensure rigor, extant literature provides different approaches to guide DSR. Examples include the proposition of research guidelines for DSR (Hevner et al., 2004), research methodologies (Peffers et al., 2007), frameworks to evaluate artifacts (Venable et al., 2016) and the notions to develop and test design theories (Gregor & Jones, 2007; Niehaves & Ortbach, 2016).

Since Information Technology is becoming increasingly complex (Simon, 1962), the evaluation of artifacts is becoming more challenging. Existing and emerging technology including mobile technologies and wearables (Barfield, 2016) and the dissemination of Individual IS (Klesel, 2019) further intensify the complexity of systems and challenges the evaluation of IT artifacts. Against this background it seems necessary to have an evaluation criterion at hand that allows the evaluation of an artifact in a most fundamental way, namely to identify and evaluate indispensable components of an artifact. This perspective is closely related to reductionism that seeks to reduce something to its very basic entities (Clymer, 1994). It is also in line with Popper who argues that the primarily objective of science is the proposition of generic statements (Popper, 2002).

So far, existing literature mainly focuses on specific evaluation matrices such as performance, utility or fit (Hevner et al., 2004) to evaluate an artifact. Consequently, fundamental questions like "*What components are required to address a specific objective?*" cannot be answered systematically so far. This lack has some considerable implications: First, without knowing fundamental design elements, a researcher is forced to include a great number of design components in the evaluation process. Alternatively, one can rely on heuristic approaches (Gregory & Muntermann, 2014) in dynamic environments. However, this approach might limit a systematic knowledge generation process (e.g., theory development). Second, with an exclusive evaluation of the overall performance of an IT artifact, design components which are not contributing to the performance of the artifact could be overseen. This leads to non-economic evaluation processes and the consideration of design components with little relevance (i.e. design gimmicks). Finally, without sufficient knowledge about fundamental elements, a refinement and an exploration of superior designs are challenging.

To address this issue, we posit that the principle of emergence provides an important enhancement to evaluate IT artifact. Emergence theory suggest that higher-level objects can be worth "*more than the sum of its parts*" (Ablowitz, 1939; Henseler, 2015). Consequently, we argue that emergence is well-suited to be used as an assessment criterion. As soon as an emergence phenomenon has been revealed, the designer is able to recognize super-summing effects. Hence, an IT artifact can be considered useful if the whole is worth more than the sum of its parts. In order to use emergence for design theorizing, we propose a conceptual model that primarily focuses on the synthesis of an IT artifact and inherits the idea of emergence.

2 Artifact Evaluation in DSR

At the core of DSR is the IT artifact (Hevner et al., 2004; Lee et al., 2015; Orlikowski & Iacono, 2001). Generally, an artifact is understood as something that can be transformed in a material or artificial existence, such as a model, an instantiation or a process (Goldkuhl, 2002; Gregor & Hevner, 2013). It is also assumed that most artifacts have a certain degree of abstraction (Gregor & Hevner, 2013). However, most of them can be easily transferred into a more concrete form for instance transferring programming code (e.g., an algorithm) into enterprise software (Gregor & Hevner, 2013). In line with previous literature, we further understand an artifact as a composition of related components and parts (Walls et al., 1992). This understanding is in line with General System Theory (GDT) (von Bertalanffy, 1968). According to GDT, an IT artifact can be generally understood as a composition of specific components which are, thus, "*part of*" an IT artifact (c.f. Figure 1). Moreover the artifact seeks to address specific goals. Hence, the concept also includes cause-effect relationships between the artifact and the intended goals.

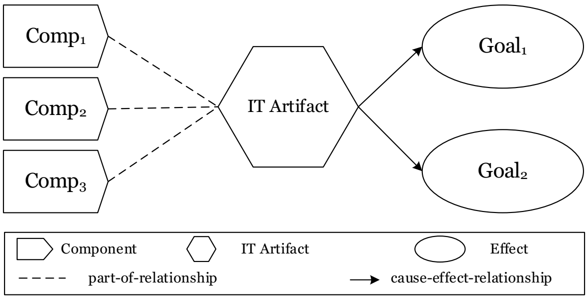

Figure 1. Conceptualization of an IT artifact

The evaluation of artifacts is crucial in DSR and should be rigorously demonstrated (Hevner et al., 2004; Venable et al., 2016). For this purpose, extant literature provided different approaches including methodologies (Peffers et al., 2007), guidelines (Hevner et al., 2004), frameworks (Venable et al., 2016), or theory-driven frameworks (Niehaves & Ortbach, 2016). In DSR, evaluation metrics are manifold including the evaluation of performance, reliability, usability or fit (Hevner et al., 2004). With regards to explanatory design theories, which focus on the environmental effects of an artifact (Baskerville & Pries-Heje, 2010; Niehaves & Ortbach, 2016), the evaluation can be implemented through the inclusion of a desirable or undesirable dependent variable. With regards to the generic conceptualization of an artifact, evaluation processes oftentimes focus on the goal or on specific components. For example, Peffers et al. 2007 reports that *"[a system] was found to be flexible and effective in this field of application*". Similarly, DSR investigating the explanatory aspects of an artifact are focusing on single effects and their effects. For example, Niehaves and Ortbach 2016 investigated the effects of media richness.

3 Emergence in DSR

3.1 Emergence Theory

Emergence arose from the Latin verb '*emergo'* which means to bring to light, to arise or to come forth and generally describe how an entity comes into existence (Vintiadis, 2016). The idea of emergence can be tracked back as far as Aristotle on the principle of entelechy, where he argues that the principle of growth is responsible for the qualities or form, that emerge within time (Clayton, 2006). Generally, a property can be described as emergent if "*it is a novel property of a system or an entity that arises when that system or entity has reached a certain level of complexity and that, even though it exists only insofar as the system or entity exists, it is distinct from the properties of the parts of the system from which it emerges.*" (Vintiadis, 2016). In other words, emergence can be described as "*more is different*" (Anderson, 1972) or "*less is different*" (Butterfield, 2011) respectively.

The concept of emergence can be found in various domains. For instance, an orchestra composted of various musicians and various instruments can evoke an emergent phenomenon. By overlaying different tones from different instruments, an orchestra is able to affect emotions which can only be addressed by means of a composition of various instruments playing at the same time. In contrast, listening to the notes and instruments separated from each other will not cause the same effects. This example demonstrate that an emergence effect may occur and that the whole is more than the sum of its parts. Note that the composer (i.e., the designer) can add or drop instruments in order to change the composition. Dropping to many instrument will lead to a point where some emotions cannot be affected anymore. Similarly, adding new instruments will not affect new or more intense emotions.

This phenomenon is also object of scientific debates. For instance in 2002, Malcom Gladwell published a book where he coined the term '*Tipping Point*'; an idea to describe "*mysterious changes*" (p. 7) who lead to completely new phenomena (Gladwell, 2002). Throughout his book, he proposes a variety of examples from daily life, including the emergence of new fashion trends or the outbreak of a disease (Gladwell, 2002). In academia this phenomenon has been discussed as *emergence* (Bar-Yam, 2004; Bedau & Humphreys, 2008; Clayton, 2006; El-Hani & Pihlström, 2002; Vintiadis, 2016). Examples from research are manifold. A common cited example for emergence is the characteristic of water (i.e., liquidity and transparency), as it emerges from the properties of oxygen and hydrogen (Bedau & Humphreys, 2008). Another example from biology is the emergence of *life* itself as an interplay of chemical and biological properties.

Extant literature has named central assumptions in order to describe an emergent phenomena, namely *irreducibility*, *unpredictability*, *novelty*, and *holism* (Bedau & Humphreys, 2008). *Irreducibility* refers to the idea that an emergent phenomenon is autonomous with regard to the basic concept. In other words, it is not possible to reduce an emergent phenomenon. It is nevertheless assumed that there is a relation, which is commonly described as *supervenience* (i.e. the emergent phenomenon is distinct but depends on the more fundamental phenomena). *Unpredictability* assumes that with knowing the complete theory of basic phenomena it is not possible to predict emergence of an emergent phenomena. Another assumption is *novelty* which holds if a new conceptual or descriptive phenomenon is introduced. Finally, it is assumed that emergent phenomena appeal to holism. In other words, emergent phenomena only exist in a conglomerate of various more basic phenomena.

Previous IS literature acknowledged different perspectives of emergence (Hovorka & Germonprez, 2013) and its role for artefact mutability (Wessel et al., 2016). In specific, three different forms of emergence have been distinguished (Hovorka & Germonprez, 2013): (1) associative emergence, (2) combinatorial emergence and (3) emergence as process.

Associative emergence occurs if "*constituent parts are associated or aggregated such that the properties of the whole can be predicted by attending to the properties of the constituent parts*." (Wessel et al., 2016, p. 4) It is about deriving the whole out of its parts. The properties of the parts (components) are in focus. The whole is static and the properties of the parts are transformational.

Combinatorial emergence holds if "*constituent parts are combined or fused such that the properties of the whole are distinct from the properties of the parts, and the parts themselves are transformed*." (ibid., p. 5). Contrary to associative emergence the properties of the parts are static in that form of emergence at the beginning. The focus is about the combination of different parts (components) which lead to an effect that is finally transforming the parts themselves and also lead to a new whole. Therefore, the transformational effect of combining parts is focused.

Finally, **emergence as a process** "*focuses on patterns, timing, and intensity of interactions of constituent parts. Interactions may be planned or inadvertent*." (ibid., p. 6) It is about the process and not about the parts and the whole of their relation. So this complementary form of emergence is not supposed to help understanding the whole and the parts with regard to understand their interaction.

3.2 Application of Emergence in DSR

We depart from the notion that emergence can be used to investigate whether the composition of technological components cause emergent effects in a sense that the "*whole is more than the sum of its parts*" (Henseler, 2015). For an illustration, we use the framework shown earlier (c.f. Figure 1). Consequently, two scenarios can be distinguished:

(Genuine) Emergent phenomena: a desired or undesired effect can only be caused through the higher-level phenomenon (i.e. IT artifact). Hence, there is an exclusive relationship between the artifact and a goal (c.f. Figure 2). In reverse, lower-level components are not able to cause the effect. If this scenario occurs an emergent phenomenon occurs. At this point of time, a researcher can recognize the artifact as a new entity.

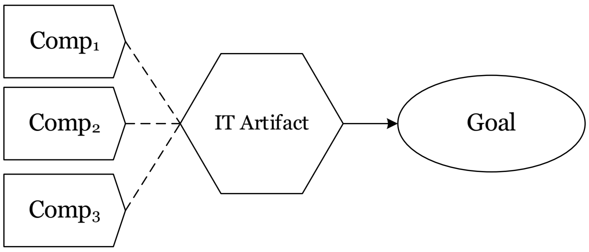

Figure 2. Emergent Phenomena

Resultant phenomena: a desired or undesired effect can be explained through one or more lower-level phenomena (here: components) and the higher-level phenomena. In other words, to achieve the goal, the composition of components is not required, as the effect (i.e., the goal) could also be caused by single component (c.f. Figure 3). Based on the principle of parsimony, it is recommendable to use only a component instead of a complex artifact. Hence, the composition of an artifact is not required necessarily.

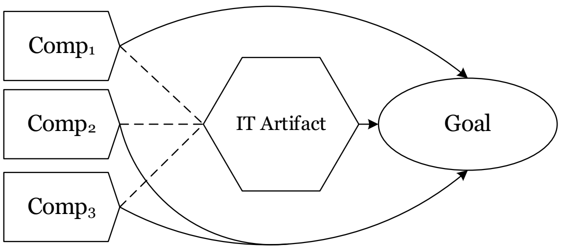

Figure 3. Resultant Phenomena

3.3 Application of Emergence

Emergence can be of use in various scenarios: First, it can be used to demonstrate that a specific configuration of components is able to cause a desired or undesired goal (c.f. Figure 2). This perspective is primarily of interest for new and disruptive innovations. Nevertheless, it might also be of interest for technologies that are known but without extensive theorizing. Second, it can be used to demonstrate that the extension of artifact components is meaningful as it influences a specific goal (c.f. Figure 4). This scenario ("*emergence through artifact extension*") commonly occurs when IT artifacts are redefined or extended including contemporary technologies. For example, if mobile technologies are extended with a GPS system, they address new goals (e.g., location dependent services).

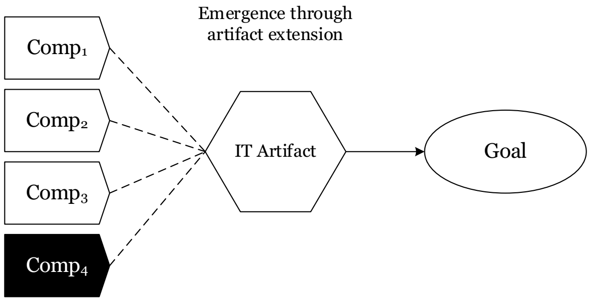

Figure 4. Emergence through artifact extension

Finally, emergence can also be used, to identify new effects. For example, if an IT artifact is applied in a new environment, or analyzed from a new perspective that allows the demonstrate that an artifact has an influence on a yet unknown goal or effect, emergence can also be used for justification (c.f. Figure 5). Again, this scenario is most likely with regards to technologies that are already studied.

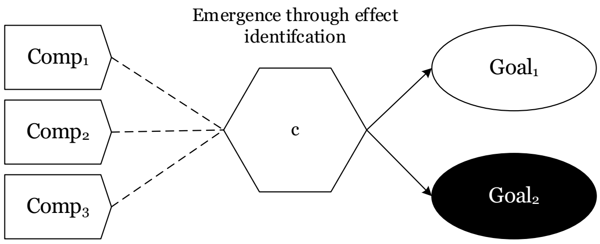

Figure 5. Emergence through effect identification

4 Discussion

Previous literature argued that emergence is related to artifact mutability in IS design theories (Gregor & Jones, 2007; Wessel et al., 2016). We agree that emergence is an important aspect of a design theory. However, it seems that emergence is not only relevant with regard to artifact mutability but can also be considered a general perspective for the evaluation of design theories. In fact, the proposed conceptualization is well-aligned with the anatomy of a design theory (Gregor & Jones, 2007). First, the *purpose and scope* is defined by the inclusion of goals. For instance, one may use this framework to build a system that enables social presence. Second, *constructs* are included in two ways: components and goals.

Components are manifold including text-, audio-, and video-elements. Goals are commonly captured as latent factors such as user satisfaction. Third, the *principle of form and function* can be provided in terms of a graphical representation of a new composite-theory (similar to the framework above). Forth, the *artifact mutability* can be included through the inclusion or exclusion of components. Fifth, *testable propositions* are included both from a component to an artifact as well as from an artifact to several goals. Finally, *justificatory knowledge* can be included to inform the inclusion or exclusion of components. In summary, the conceptual notation inherits the fundamental requirements of an IS design theory and refers to emergence as an evaluation criterion.

Due to the generic nature of emergence as an evaluation criterion, it is not limited to a specific methodology or a distinct research paradigm. Quite the opposite, it is perfectly suited to be part of existing research methodologies (Peffers et al., 2007) or can be used as an evaluation lens in existing DSR guidelines (Hevner et al., 2004). Emergence can also be included in the evaluation of design theories (Gregor & Jones, 2007). Since the notion used here, is well-aligned with the notion of a design theory, it can be easily applied within the development and evaluation of design theories. With regards to empirical methodologies, emergence can also be of use in both qualitative and quantitative approaches. The assessment of an emergence effect can, thus, be demonstrated by means of expert interviews or focus groups. Moreover, quantitative approaches including Structural Equation Modeling can be used by means of composite models and confirmatory composite analysis in specific (Henseler et al., 2014; Schuberth et al., 2018).

In order to reveal emergent effects, it seems that some form of experimental research is most promising. In line with existing literature that highlighted the usefulness of experimental research in design science (Kampling et al., 2016), emergence is also likely to be investigated within an experiment. A systematic manipulation of components and the continuous investigation of an effect, experiments seems to appropriate for this perspective.

From a theoretical perspective, our framework prepares the ground for more research that is concerned with the synthesis of an artifact as it emphasize the role of design components. We hope that focusing on components helps to enhance design research in IS as it relates directly to the artifact. Hence, this research also contributes to an ongoing discussion about the role of artifacts in IS research and the conceptual distance (Orlikowski & Iacono, 2001). The investigation of emergent effects caused by artifact design is, thus, closely intertwined with an artifact. Using a conceptual notion as used above (c.f. Figure 1) has also the potential to communicate DSR. Following Gregor and Jones (2007), it is crucial to find an effective communication in DSR. Both the conceptual notion and the use of emergence as an evaluation criterion that can be used to communicate DSR.

Extant literature in DSR argued that radical innovation has rarely been achieved in IS research so far (Gregor & Hevner, 2013). Although we agree that disruptive innovations including the world wide web are rare indeed, we also acknowledge that literature oftentimes miss an objective criterion to justify innovation. Emergence has the potential to contribute to (artifact) innovation by providing transparent criterion that helps researchers (and designers) to justify a new artifact. We proposed three different avenues to use emergence (i.e. emergence in general, emergence through effect identification, and emergence through artifact extension) that are all equally useful to justify a new class of artifacts. Note that detecting an emergent effect still needs a careful justification to argue for a (disruptive) innovation. It is more likely, that emergence enhance the objective criterion to justify what Gregor and Henver (2013) call "*improvement*" or "*exaptation*".

The emphasize on design components also contribute to knowledge development and theory integration. If a new artifact is recognized (i.e. by means of an emergent effect), other researchers can built upon this knowledge and further evaluate the composition in different scenarios. This practice is commonly known in handicraft professions and production industry where the fundamental components of a receipt (e.g., for the composition of a drink) have been identified and continuously refined. Having a conceptual notion in place that focuses on the component and emergence as an evaluation criterion, this practice can be adopted for IS research.

The application of this framework has several implications for practice: First, having evaluation results in place that provides evidence for the emergence of a desired or undesired effect, a designer (e.g., software architect) is able to include those fundamental components in order to address this issue. Based on that, practice can further enhance the components and add context-specific components.

Second, in line with the identification of fundamental components, a designer is also able to identify components that do not contribute to a specific effect. For example, brandings or customer gimmicks could enhance the appearance of an artifact, but do not contribute to a desired effect (e.g., satisfaction with the artifact). Nevertheless, it needs a careful justification whether to keep or getting rid of a specific component.

Finally, emergence can be used to justify a new class of systems (i.e., a new artifact). Therefore, it can be seen as guidance within design processes. Both academia and practice oftentimes struggle to justify that something new was developed (Gregor & Hevner, 2013). The concept can be used to demonstrate the uniqueness of a design configuration, which in turns help practitioners to demonstrate the quality of a new artifact.

5 Limitation and Outlook

Based on the scope of this article, there are several issues that opens the door for future research. First, the focus of this paper is on emergence in order to demonstrate that the composition of components leads to effects which could not be addressed by means of single components ("*the whole is more than the sum of its parts*"). We acknowledge that emergence theory has other components that are not included in this perspective. For instance, the aspect of unpredictability has not been included since unpredictability makes a design process nearly impossible. In other words, it is impossible to design an artifact for unpredictable objectives. However, with the raise of big data and heuristic theorizing (Gregory and Muntermann 2014), this aspect could be of further interest and requires further investigations.

Second, as this paper is conceptual in nature, future research is able to investigate the strength and weakness of various methodologies with regard to the implementation of this approach. As for now, different approaches could benefit from this perspective. Methods that are designed for hypothesis testing might benefit from the close relationship to IS design theories. Confirmatory composite analysis (Schuberth et al., 2018) which is well aligned with this persepctive is most promising. In this line, future research could investigate different methodologies and elaborate specific requirements to use emergence as a criterion.

Third, we put emphasize on combinatorial emergence. Therefore, the remaining two facets have not been investigated in detail. Both associative emergence and emergence as a process are important perspectives for IS research in general and DSR in specific. There are promising perspectives to investigate those remaining aspects with existing concepts and methodologies in DSR. As a starting point, emergence as a process could be integrated in DSR methodologies (Peffers et al., 2007) that are designed for process-driven design endeavors.

Finally, we proposed emergence as a useful criterion in the evaluation process. We acknowledge that in various scenarios, the identification of something new is not top priority. In fact, designing Information Systems that requires a high degree of security, are less interested in the emergence of new effects but are exclusively focuses on security. This might also be true for systems that are designed for high performance or high level of batch processing. Thus, emergence might not be relevant for all technologies. Nevertheless, for a broad spectrum and end-user systems in particular emergent effects are of relevance and should be in line with existing metrics (e.g., usability). If a new effect emerge and another (important) effect diminish, a major potential of this approach is weakened. Consequently, future research should investigate how the interrelationship between existing effects and emergent effects are.

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