Replication of design theories: Reflections on function, outcome, and impact

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Abstract

The replication of existing research studies and theories is considered a foundational pillar of knowledge accumulation and an important instrument of discourse across research disciplines. Although replication has a long tradition in natural and behavioural science research, the design science research (DSR) community is yet to adopt it, especially the replication of design theories. However, it is unclear how the DSR community could benefit from the replication of design theories. Similarly, the goal of design theories is to obtain utility instead of truth raises questions regarding the transferability of replication into the DSR domain. Against this background, this study reflects on the function, outcome, and impact of replications, to understand whether the replication of design theories is possible and necessary. The study proposes that replication can be an important catalyst for reuse and knowledge accumulation in DSR because it provides evidence on the boundaries of design theory. Specifically, replication can increase or decrease the level of confidence and projectability associated with design theory.

KEYWORDS
design science research, design theory, knowledge accumulation, replication research, theory abstraction

1 | INTRODUCTION

Replication serves an important purpose in science as it serves to question previous results and theories (Dennis & Valacich, 2014; Lindsay & Ehrenberg, 1993). In the case of successful replication, replication increases confidence in the validity of the existing study results, as well as in the ability of a theory to describe, explain, or predict. In contrast, an unsuccessful replication can decrease this associated confidence, triggering further investigation or even leading to the 'weeding out' of theories and guiding the development of new ones (National Academies of Sciences, Engineering, and Medicine, 2019).

A field that regularly replicates their studies can prevent replication crises. A replication crisis is a state in which a large portion of the knowledge base is suddenly called into question because of the inability to replicate extant and highly regarded studies and theories, which, in turn, calls into question any research that has been built upon this knowledge base. In psychology, the inability to replicate many fundamental studies and theories has led to the declaration of such a crisis (Baker, 2015; Schooler, 2014; Stroebe & Strack, 2014); however, this crisis is neither rare nor exclusive to psychology. Baker (2016) reported that in a survey of more than 1500 researchers, around 90% of respondents from various fields (including chemistry, biology, engineering, medicine, and environmental studies) stated that their field had or could have a replication crisis.

Consequently, there has been a recent push for replication in the information system (IS) research discipline. One of the first initiatives in this vein was to launch the *AIS Transactions on Replication Research* (*TRR*) journal in 2014 as well as the publication of the 'Replication Manifesto' (Dennis & Valacich, 2014). By having a journal dedicated to publishing replication research and additional tracks at conferences (AMCIS, 2018), the IS community has seen the publication of more replication studies than ever before (Brendel, Diederich, & Niederman, 2021). Various calls for more replication research have also been published (Brendel et al., 2020; Niederman & March, 2015; Olbrich et al., 2017) and the *TRR* and *Management Information Systems Quarterly* (*MISQ*) came together to conduct an IS replication project (Dennis et al., 2020). Overall, it is safe to assume that replication is an important tool for all branches of science, including IS research.

The concept of replication has recently been introduced in the design science research (DSR) community, and an early stage discourse has been initiated (Brendel, Lembcke, et al., 2021; Niederman & March, 2015; Olbrich et al., 2017). Currently, the literature is clear on how and why to replicate analysis, explanation, prediction, explanation, and prediction theories (Gregor, 2006) (i.e., truth theories); however, design theories, which strive for utility, have yet to be addressed (Brendel, Diederich, & Niederman, 2021; Brendel, Lembcke, et al., 2021). We do not see an immediate threat to the DSR community in terms of the looming prospect of a replication crisis. Following vom Brocke et al. (2020), the DSR community has rarely built upon existing design knowledge and instead has opted to develop stand-alone artefacts and design theories. Consequently, if replication devalues an existing artefact/design theory, it would not lead to a ripple effect because only a limited number of studies would be called into question. However, as the DSR community strives to develop a culture of design (Kruse & Seidel, 2017; vom Brocke et al., 2017) and knowledge accumulation (vom Brocke et al., 2020), the threat of a replication crisis may significantly increase in the future. Hence, the topic of replication should be discussed to understand whether it is necessary to prevent a future replication crisis and what other contributions are possible for the DSR community. As a result, this opinion paper focuses on the similarities and differences between truth theory and design theory replication, to build a conceptual framework to answer the following questions:

> Is the replication of design theories possible?
> Why might such replication be necessary?

To answer these questions, we have conceptualised what happens during the replication of a design theory (i.e., function of the replication), what the results of such a replication would be (i.e., outcome of the replication), and what the implications of a replication may be (i.e., impact of the replication). This conceptualization has been based on an analogy between the replication of truth theories and the role of replication in science (adapting scientific progress in Popper's view of science [1959, 1963]), highlighting that the pursuit of utility instead of truth changes the application and interpretation of replication. In this context, we build a case for the replication of design theories and discuss their implications for the IS community, especially DSR scholars.

2 | NATURE OF DESIGN SCIENCE RESEARCH

This section outlines how the concepts of artefacts and design theories are understood in this study. Furthermore, we provide an outline of how knowledge accumulates in DSR.

2.1 | Design theories and artefacts

In general, artefacts are objects that are intentionally created to accomplish a certain purpose (Hilpinen, 1992); this purpose is to solve a problem (i.e., the difference between a current and a desired future state [Goldkuhl, 2012; Hevner et al., 2004]) while fulfilling a set of requirements. In IS research, artefact types include constructs, models, methods, and instantiations (Hevner et al., 2004). Furthermore, design theory is a theory of means-end relations; that is, a projectable means-end relation proposition (Goldkuhl, 2012; vom Brocke et al., 2020), which can be used as a guideline to develop artefacts that are intended to reach the desired end. In this context, Jones and Gregor (2007) conceptualised design theory anatomy as consisting of six essential components that formalise the knowledge gathered during a research project.[1]

Design theory can be used to develop artefacts that are intended to solve multiple similar problems, which are called problem classes (Iivari, 2015). A problem class groups problem instances by removing the details regarding the context of single problem instances, and therefore describes the included problem instances in terms of shared characteristics (e.g., requirements). A problem class can contain multiple sub-problem classes; correspondingly, a problem instance describes a single, situated, and specific problem (Iivari, 2015; Lee et al., 2011). Figure 1 provides an illustration of the relationship between problem class, problem subclass, and problem instance. As an example of this relationship, the problem of balancing the spatial vehicle supply and demand in car-sharing is a sub-problem of the problem of balancing supply and demand in any item-sharing system (e.g., scooter-sharing, bike-sharing, power-bank-sharing,

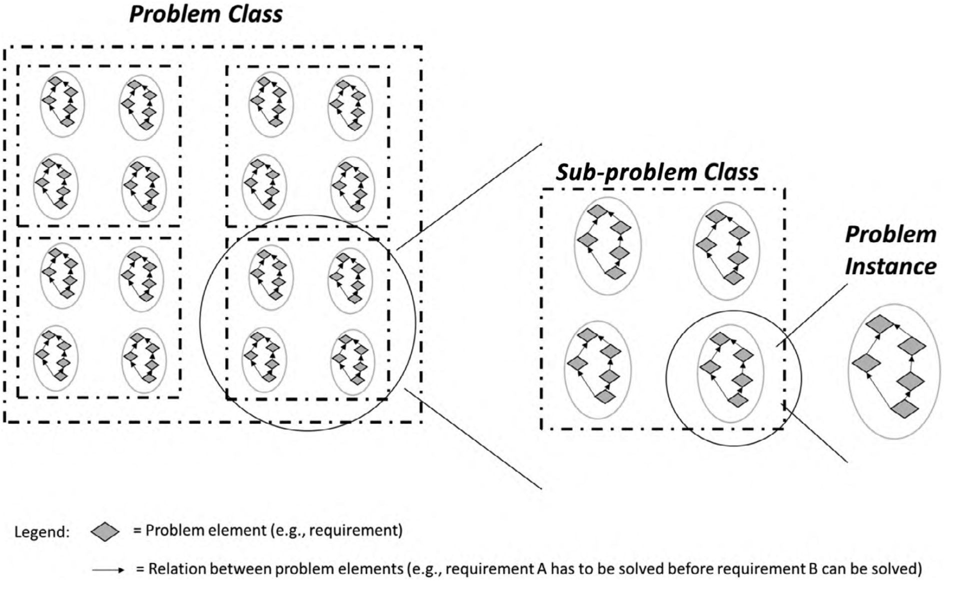

FIGURE 1 Design theories in the solution and problem spaces. Note that a problem class can also be a sub-problem class of an even larger class. In addition, a problem class can consist of several sub-problem classes, which in turn can consist of many sub-problem classes. Furthermore, any problem class consists of several problem instances

and umbrella-sharing). In this context, the car-relocation problem of a French free-floating car-sharing business in Paris constitutes a problem instance.

To describe the relationship between design theory, an artefact, and the actual problem, we adapted Venable's (2006) concept of a solution space and a problem space.[2] According to the terminology provided by Jones and Gregor (2007), the solution space is concerned with the principles of form, function, and related technology, which are called solution components, whereas the problem space includes the requirements, stakeholders, and goals (i.e., purpose and scope) of a problem, which are called problem elements. The connection between both spaces is a testable proposition of design theory (e.g., solution component A addresses/solves problem element B). Hence, design theory describes which solution components address which problem elements of a problem instance or class are to be solved (see Figure 2).

Finally, the utility of design theory lies in its ability to guide the development of an artefact that can solve the problem instances (and sub-problem classes) of the addressed problem class (see Figure 3).

2.2 | Accumulation of design knowledge

DSR develops various types of knowledge, including conceptualising (definitions and categories), normative (stating desirable values and goals), and prescriptive (means-to-ends relations) knowledge (Goldkuhl, 2012). Each of these contributions adds to either a descriptive or prescriptive knowledge base (Gregor & Hevner, 2013). Ideally, researchers use knowledge bases to better understand a problem, develop design theories, and/or solve problems via innovative artefacts (vom Brocke et al., 2020). By reusing, refining, extending, and building upon existing knowledge, researchers can gather new knowledge, leading to the accumulation of design knowledge. In essence, using existing knowledge to guide (1) building artefacts aimed at solving relevant problems, and (2) evaluating the utility of these artefacts leads to studies with new discoveries and implications for incorporating existing knowledge (Niederman & March, 2012).

Vom Brocke et al. (2020) described the changes in design knowledge during a DSR project and studied movements in a three-dimensional space that consisted of projectability, fitness, and confidence. Projectability describes how well the design knowledge can be applied to different problem classes. A low level of projectability means that design knowledge applies to a very specific problem class (or even to only one problem instance), whereas the opposite indicates that it applies to a more general problem class. Fitness describes how well design knowledge solves a problem. A low level of fitness indicates that it only solves parts of a problem (e.g., some requirements are not fulfilled, but it 'is better than nothing'), whereas the opposite indicates that the entire problem is solved (e.g., all requirements are fulfilled to full satisfaction). Finally, confidence addresses the quality of the evaluations: a high level of confidence indicates a low probability that the design knowledge will not apply to the problem class (projectability) and/or solve the problem (fitness).

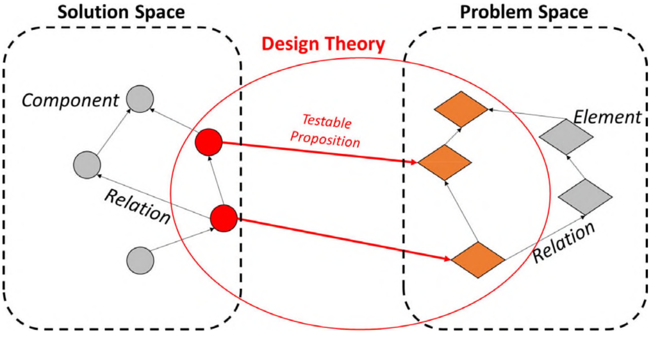

FIGURE 2 Design theories in the solution and problem spaces. Note that not all the solution components in a solution space must be used as part of the design theory. Similarly, not all elements of a problem space must be addressed (e.g., if they are not yet known or are irrelevant to the problem instance or class)

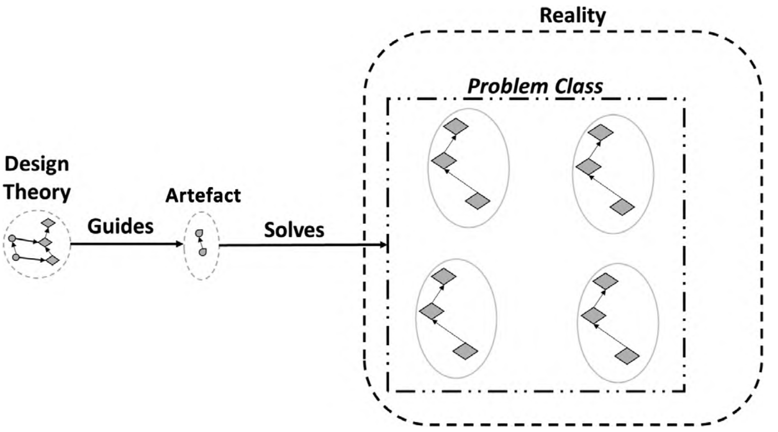

FIGURE 3 Relation of a design theory to the corresponding problem class and reality. Note that the artefact is positioned outside of reality because it must be implemented to become part of reality. The general relationship between design theory and related artefacts (i.e., a design theory can be used to guide the implementation of an artefact) does not require an implementation to exist

Within this three-dimensional space, vom Brocke et al. (2020) identified generalisation (increasing projectability), abstraction (increasing projectability and simultaneously decreasing fitness), amplification (increasing fitness), and contextualization (increasing fitness and simultaneously decreasing projectability) as the four movements of design knowledge during a DSR project (see Figure 4). The dimension of confidence depends on the evaluation process applied during these movements; therefore, changes in confidence are not directly related to movement. Finally, it is desirable to develop design theories with a high level of projectability and fitness, associated with a high level of confidence.

3 | REPLICATION RESEARCH

The following sections summarise the current literature on replication, and specifically address the place of replication in science and analyse the current discourse regarding replication in DSR.

3.1 | Replication in science

The aim of replication research is to test the validity of original studies and theories, enabling scientific consensus on proposed knowledge (Berthon et al., 2002; Dennis & Valacich, 2014; Schmidt, 2009). Following Weber (2012) and the minimalist view of Niederman's theory (Niederman, 2021), a 'truth' theory is defined as a system of entities that have relations with each other, describing a section of reality via boundaries[3] and allowing the formulation of a hypothesis about the current and future states of reality. In this regard, a theory allows naturally occurring causes and effects to be described or predicted (Gregor, 2006; Iivari, 2015). Hence, replication studies contribute to research by testing the validity of existing theories. This is done by examining the correctness of the proposed entities, relations, and derived hypotheses by entirely or partly reconducting the original study (Berthon et al., 2002; Dennis & Valacich, 2014).

Thus, replication research fulfils the role of falsification within the context of scientific progress (e.g., scientific methods). According to Popper (1959, 1963), theories must be easily falsifiable. Hence, theories must be phrased in

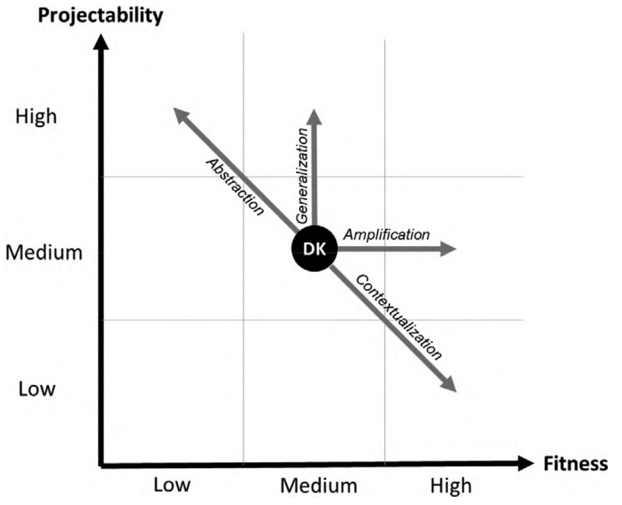

FIGURE 4 Movements of design knowledge (vom Brocke et al., 2020). DK, Design Knowledge

such a way that they can be shown to be false; otherwise, the findings of any test can neither support nor refute the original proposition, making it unscientific. Together, these assumptions lead to a scientific process that consists of (1) proposing a theory, (2) refuting a theory, and (3) improving or replacing a theory to better describe, explain, or predict the investigated phenomena (Salovaara & Merikivi, 2015). This approach to science is commonly associated with 'scientific realism'[4] (Leplin, 2007).

Unlike Popper, who was sceptical of any positive or supportive findings from theory testing, other researchers have adopted a more 'nuanced' view of science (National Academies of Sciences, Engineering, & Medicine, 2019). In this view, a positive (negative) outcome of replication increases (decreases) confidence.[5] Replications can help understand the boundaries within which a theory applies, as they may probe the resilience of the theory within new populations, technologies, or methods. Additionally, they may suggest contextual factors (i.e., boundary conditions) that affect the replicated theory.

For conducting replication studies, the experimental research disciplines (e.g., natural sciences) have developed individual classifications and approaches for replication studies (Gómez et al., 2014; Greulich & Brendel, 2019). Nonetheless, they all share the idea that replication does not change the original study or theory (what 'regular' research would do) but instead tries to provide evidence or counter-evidence for the original form of the theory; that is, to increase or decrease confidence (Brendel et al., 2020). In the context of IS research, a prominent categorization is provided by Dennis and Valacich (2014), which covers most of the classifications of other sciences.

1. *Exact replications* share the same context and method as the original study. All treatments, methods, measures, and so forth, are identical to those in the original research. Furthermore, the context remains the same; therefore, if the original study involved employees of a Chinese automotive company, the replication study must do the same as well (Dennis & Valacich, 2014).
2. *Methodological replications* apply the same method as in the original study but in a different context. For instance, the original study may ask employees of a Chinese automotive company, whereas a replication study may ask Canadian undergraduate students (Dennis & Valacich, 2014).
3. *Conceptual replications* investigate the same context but apply different methods. They seek to answer the same research question and test the same hypotheses using different measures, treatments, contexts, and/or analytical methods. For example, in a replication study, the wording of items used to measure key constructs may be altered (Dennis & Valacich, 2014).

Furthermore, a theory normally does not address a single phenomenon,[6] but rather a group of phenomena (i.e., the explanation space); for instance, the technology acceptance model (Venkatesh et al., 2003) addresses technology acceptance-related phenomena in mobile apps or accounting systems in different industries (e.g., finance, automotive, and transportation). These considerations are illustrated in Figure 5.

According to this logic, a replication study has the function of adding or subtracting phenomena from the explanation space of a theory (see Figure 6). A successful exact or conceptual replication provides evidence for the claim that a phenomenon is part of the explanation space of a theory (it cannot be subtracted), whereas an unsuccessful replication provides evidence that a phenomenon might not be part of the explanation space of a theory (it can be subtracted). A successful methodological replication provides evidence for the addition of a phenomenon to the explanation space, whereas an unsuccessful replication provides evidence that a certain phenomenon cannot be added to the explanation space of a theory. Hence, the four outcomes of the replication study can be formulated as follows:

1. *Successful addition*: The function of adding a phenomenon was successful, meaning that the explanation space of a theory was extended and confidence in the theory was increased.
2. *Unsuccessful addition*: The function of adding a phenomenon was unsuccessful, indicating that a theory has its limitations in terms of what it can and cannot describe, explain, or predict. Nonetheless, this also leads to an increase in confidence because of evidence for the formulation of the original theory.
3. *Successful subtraction*: The function of subtracting a phenomenon was successful, revealing new theoretical limitations and decreasing confidence.
4. *Unsuccessful subtraction*: The function of subtracting a phenomenon was unsuccessful, leading to an increase in the confidence that the explanation space was correctly defined.

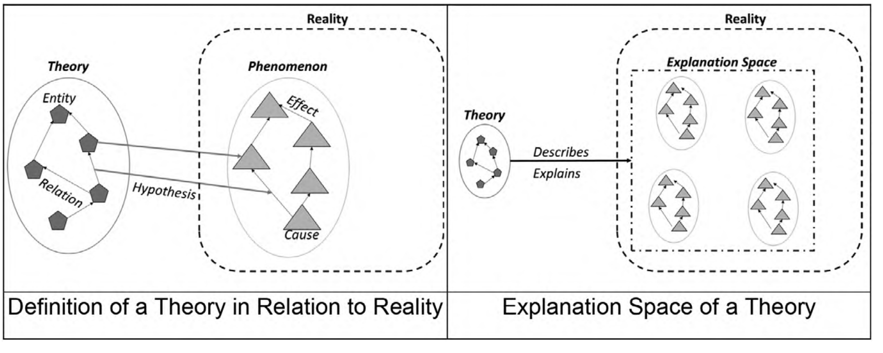

FIGURE 5 Truth theory and reality

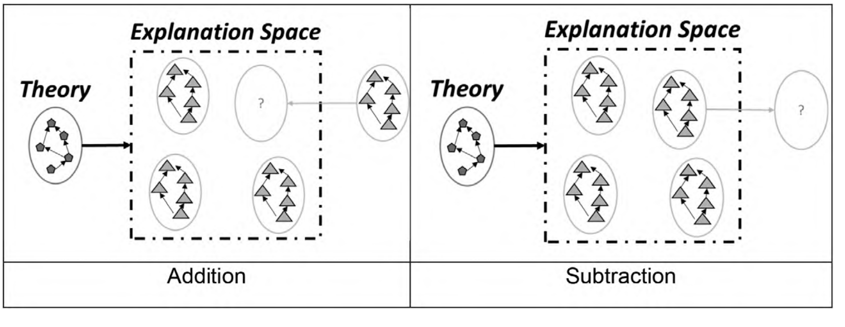

FIGURE 6 Functions of replication

Based on Schmidt (2009), the outcome of a replication study that leads to a decrease in confidence can have various causes ranging from sample errors to missing internal validity, and even fraud.

Overall, the impact of a single replication study on the overall confidence of a theory can be small; however, multiple studies can change its overall state (Ioannidis et al., 2017) (illustrated in Figure 7). First, repeated unsuccessful addition and subtraction attempts lead to a stable theory, meaning that a theory has reached a high level of confidence to be correct, consistent, and true. Second, a mix of outcomes leads to an unstable theory (i.e., a lower level of confidence), which requires further investigation. Finally, repeated unsuccessful addition and successful subtraction attempts lead to a refuted theoretical state, meaning that there is a very low level of confidence, which indicates that the theory is false.

Based on previous observations, we propose that replication studies interact with a theory in three sequential ways (see Figure 8): (1) function, (2) outcome, and (3) impact. This function describes the attempt to add or subtract phenomena from the explanation space. The outcome addresses the change in the size and boundaries of the explanation space caused by replication. The impact of a replication study on a theory is a potential change in the overall state of that theory, which could render a theory stable, unstable, or refuted.

3.2 | Replication research in design science research

There are calls to consider replication in DSR (e.g., Niederman & March 2015; Olbrich et al., 2017); however, it is still unclear how replication research fits within the context of DSR. Because utility and truth are vastly different research outcomes, it is difficult to apply the existing concepts and procedures to DSR. Hence, based on the literature review of Brendel, Lembcke, et al. (2021), we analysed the extent to which the DSR community has already engaged in a discourse on how to replicate DSR studies.

Lee and Hubona (2009) suggest that the replication of design theory should address the underlying assumption that design theory prescribes an artefact that solves a certain type of problem. If this relation can be replicated for an instance of the type of addressed problem, the design theory is considered true; otherwise, it is considered false. This concept follows the logic of problem-solving (Simon, 1969), meaning that a design is only useful when it solves related problems. A similar view was expressed by Braun et al. (2015), who adds that a transparent design process is

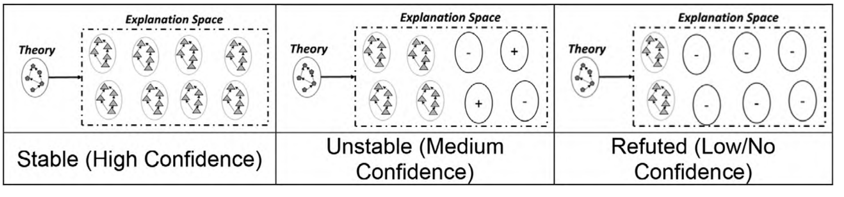

FIGURE 7 Possible states of a theory

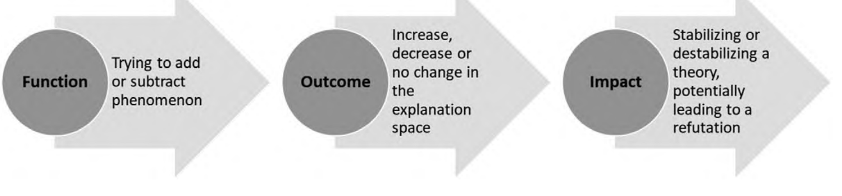

FIGURE 8 Interaction between replication and theory

a prerequisite for replication. We can see from this discussion that replication is considered to have a possible impact on the solution components proposed to solve the problem elements of a problem class.

As an alternative to this strict view of design theory as a problem-solving truth statement, Wynn and Williams (2012) and Olbrich et al. (2017) note that every test of a design theory is simply a snapshot, and that replications in different contexts can lead to different outcomes, making the replication results difficult to interpret. Olbrich et al. (2017) propose the concept of problem classes as a central part of the replication in DSR. According to this line of thought, replication in DSR involves testing the validity of the associated problem class (i.e., testing the boundaries of the present problem class). This stream of literature points to the role of replication within the boundaries of problem instances and classes covered by existing design knowledge.

Similarly, Baskerville et al. (2017) explore the term 'reliability' in the different ways in which single or multiple applications of a design theory can lead to evidence for or against the claim of a design theory to solve a certain problem class. Similarly, van Aken (2004) proposed two different types of testing: (1) 'a-testing' is the evaluation of the artefact in the original context and (2) 'b-testing' is the subsequent (re)evaluation of the artefact in other contexts (i.e., problem instances), and sees b-testing as similar to replication. Al Turki et al. (2012) propose that repeated successful replication of a design in various contexts leads to a state of routine design.

Against this background, we conclude that the literature in this regard is in its early stages (in terms of the goals and possible contributions of replication to mature design knowledge), as the path leading from replication studies, the possible outcomes, and their related impacts remain underexplored. For example, it remains unclear at present how replication studies and their outcomes can lead to the specification of overarching problem classes, and thereby to more abstract design knowledge. With a focus on problem-solving and utility, design researchers would also benefit from a better understanding of how replication studies and their possible outcomes can contribute to achieving higher levels of utility.

4 | FRAMING REPLICATION IN DESIGN SCIENCE RESEARCH

In accordance with Popper's idea of scientific progress, in combination with the concept of confidence (National Academies of Sciences, Engineering and Medicine, 2019), proposing new theories and refuting existing theories via replication to guide the development of new theories is a cycle that drives our knowledge closer to the truth. A similar cycle of progress can be applied to the context of design theory development. The existing design theory can be improved or replaced by an entirely new design theory that formulates mean-end relations that reach higher levels of utility. In this context, replication can provide the necessary tool to assess the current level of utility of a design theory and what should be improved. This leads to the development of a new design theory and the assessment of its level of utility via replication, which guides the development of a new design theory (see Figure 9).

When confidence in a theory (T1) is close to zero and is therefore considered to be refuted, an improved theory is proposed that is closer to the truth (T2).[7] This cycle of refuting and proposing new theories moves knowledge much closer to the core of truth. Nonetheless, a theory is either true (or at least considered true) or false (or at least considered false) (Popper, 1959, 1963). After replication, the results may indicate that parts of a theory can be considered true, but these parts are now included in a new or refined theory (Popper, 1959, 1963). Similarly, in accordance with the epistemology of pluralism and co-existing scientific paradigms (Kellert et al., 2006; Kuhn, 1962), multiple theories can be considered true, but a theory on its own must be consistent to be considered true within its paradigm (Kuhn, 1962). Furthermore, believing that objective truth is reachable is a question of epistemology, but moving closer to truth remains the undisputed goal of most epistemological views.

In comparison, utility is non-binary and on a scale. Design theory can provide guidance for implementing artefacts that are highly useful, slightly useful, or not useful, and everything in between.[8] The DSR is built on the premise that finding utility is an iterative search process for improvement. Therefore, design theories can be compared with the possibility that one theory provides more utility than the other.[9] Two design theories can propose two different artefacts as solutions for the same problem class; however, when they are applied, one of them provides a higher level of utility than the other, whereas the less useful theory cannot be considered 'false' or 'refuted'. This assessment is subjective because the existence of a problem and the utility of a solution can be assessed differently by stakeholders (Goldkuhl, 2012). Nonetheless, finding contradictory evidence for a design theory (i.e., showing that it does not provide the expected and desired level of utility) starts the theory development process (e.g., from DT1 to DT2), after which the resulting design theory provides a higher level of confidence. However, we assume that it is unlikely that a state of 'highest utility' can be reached; that is, under no circumstances is there a more useful design theory for any problem instance within the problem class.

According to the design theory framework developed by Jones and Gregor (2007), many elements of design theory can mirror the elements of 'truth' theories. A design theory, in the context of solution and problem spaces (Venable, 2006; vom Brocke et al., 2020), describes the connection between artificial solution components and problem elements. In comparison, truth theories describe the connection between entities/relations and causes/effects. Design theory proposes that a certain solution component (or a group of components) solves a certain element of a problem (or a group of elements), which is comparable to a hypothesis in the context of truth theory. Using the vocabulary of design theory, we formalise the relationship between the principle of form and function and the requirement (as part of the purpose and scope) in the form of a testable proposition, which is similar to how a hypothesis makes a truth theory testable. A design theory proposes that certain means will lead to desired ends, which can be tested as an artefact, assembled according to the design theory, and provide a solution applicable to all instances of the problem class (Jones & Gregor, 2007; Olbrich et al., 2017); in other words, the principles of form and function guide in solving all problem instances within the addressed problem class. This is similar to the truth theory claim that a theory describes, explains, and/or predicts all the phenomena of its explanation space.

In summary, the similarities between utility theory (i.e., design theory) and truth theory lie in the concept of addressing a group of real-world occurrences (problems or causes/effects). Both types of theories are formulated

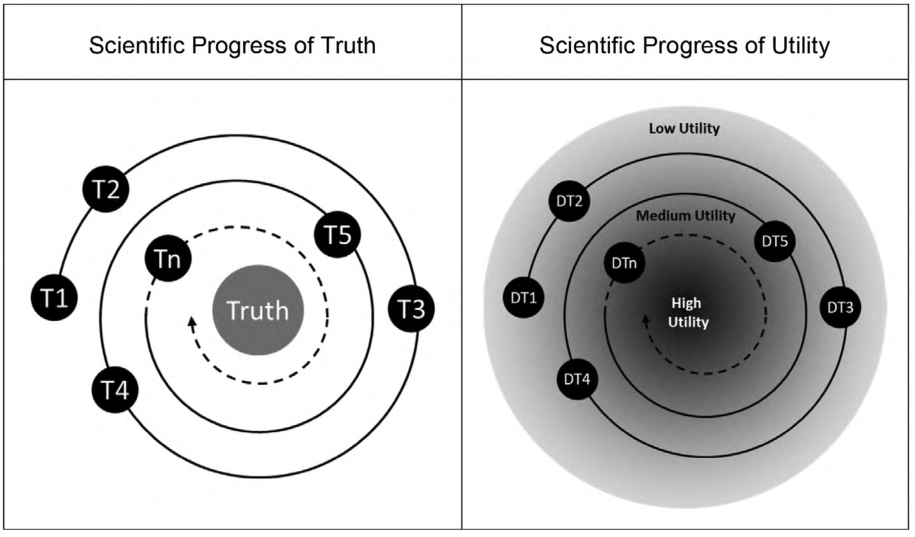

FIGURE 9 Comparing the scientific Progress of truth theories and design theories. T, Theory; DT, Design Theory. Note that we depict an idealist process. Paradigm shifts, technological advancements, or methodological errors might lead to total rearrangements of the positions of theories (e.g., a prior theory can be considered true instead of a newer one) and design theories (e.g., the high level of utility was attested because of asking the 'wrong' set of stakeholders)

such that multiple occurrences can be described, explained, and/or predicted (truth theory) or solved (design theory). This relationship can be replicated to provide evidence of or against it. Based on these similarities and to provide an initial understanding of replication in DSR, the interactions between replication and design theory (e.g., function, outcome, and impact) are discussed in the following subsections.

4.1 | Function and outcome of replication in design science research

Analogous to truth theories, the function of replication in DSR is to add or subtract problem instances from the problem class of a design theory (see Figure 10). To add a problem instance to the problem class, a replication study attempts to apply design theory to a problem instance that is outside the boundaries of the current problem class. When the design theory leads to the implementation of a useful solution, the problem instance (and all instances considered similar, forming a sub-problem class) can be added to the problem class. On the other hand, if the application of design theory does not lead to the desired level of utility, the problem instance cannot be added, and the boundaries of the original problem class are supported. For instance, a design theory for a decision support system for car relocation in a car-sharing system can be applied to a similar problem of bike relocation in a bike-sharing system. When the decision support system improves the relocation operations of the bike-sharing system, the design theory can be applied not only to car-sharing but also to bike-sharing. Conversely, when the decision support system does not improve operations, the design theory remains applicable to car-sharing, and bike-sharing can be considered outside the boundaries of the problem class of design theory.

Similarly, by applying design theory to a problem instance described as part of the problem class, a replication study can test the testable proposition (e.g., can the principles of form and function be applied to the problem, resulting in the desired level of utility?). If the design theory leads to the implementation of a useful solution, the problem instance remains in the problem class (i.e., the process of subtraction is not successful). However, if the solution is not useful, the problem instance (and all instances considered similar to it) is removed from the problem class (i.e., the attempt at subtraction is successful), as it does not support the boundaries of the original problem class, thus indicating that it is not applicable. For example, design theory can be used to design a customer-based vehicle relocation system for car-sharing (i.e., customers are asked to relocate a car for a monetary incentive), which can be applied to the sub-problem class of luxury car-sharing systems. If customers are unwilling to relocate because monetary incentives do not motivate them, the problem class of design theory is reduced by the sub-problem class of luxury car-sharing. Otherwise, if customers are motivated by monetary incentives, the problem class of design theory remains unchanged.

Against this background, the function of replication research is quite similar in DSR compared with other research paradigms. Similar to truth theory replication research, there are four possible replication outcomes:

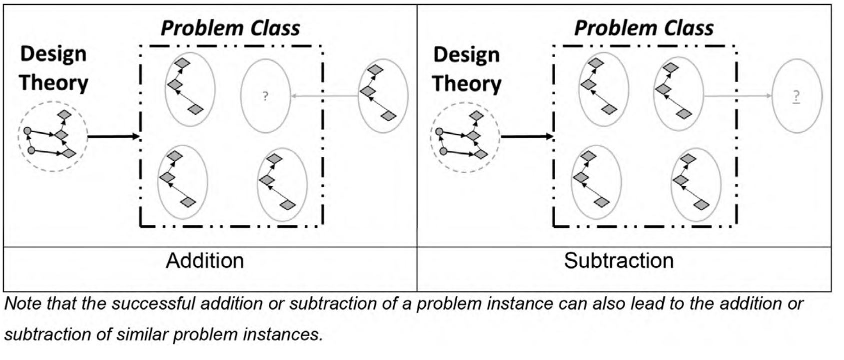

FIGURE 10 Functions of replication in design science research. Note that the successful addition or subtraction of a problem instance can also lead to the addition or subtraction of similar problem instances

(1) successful addition of the problem instance; (2) unsuccessful addition of the problem instance; (3) successful subtraction of the problem instance; and (4) unsuccessful subtraction of the problem instance, with each outcome leading to an extension or reduction in the problem class of the replicated design theory.

4.2 | Impact of replication in design science research

When looking at the outcome of adding or subtracting problem instances from the problem class of a design theory, we can identify the potential changes in projectability and confidence (see Table 1) associated with a design theory.

1. *Successful addition of a problem instance*: The successful addition of a problem instance leads to a decrease in confidence because it questions the boundaries of the present problem class, necessitating further testing of which problem instances are actually a part of it. Projectability increases because the problem class is extended, indicating that the design theory covers more problem instances than was originally described.
2. *Unsuccessful addition of a problem instance*: If the addition is unsuccessful, confidence in the design theory increases because the present boundaries of the problem class have been (partly) confirmed. In contrast, the projectability of design theory remains unchanged because its original assessment has been confirmed.
3. *Successful subtraction of a problem instance*: If an attempt to subtract a problem instance from the present problem class of a design theory is successful, confidence in the design theory decreases because the boundaries of the present problem class have been (partly) refuted. Hence, the projectability also decreased.
4. *Unsuccessful subtraction of a problem instance*: An unsuccessful attempt to subtract a problem instance from the problem class of design theory leads to an increase in confidence because of the confirmed boundaries of the present problem class. The projectability does not change because design theory addresses the same problem class as before.

Replication can also indirectly lead to movements in the fitness dimension, depending on the utility in solving the added or subtracted problem instances. For example, when problem instances are successfully added to the problem class of a design theory, which are solved with comparatively high utility, the overall utility increases. Hence, replication can lead to increases or decreases in the overall fitness associated with a design theory, when adding or subtracting leads to significant changes in the overall utility. However, we would call this effect 'indirect' (see Table 1) because it is not the main outcome of the replication and very difficult to assess clearly.

Within the context of knowledge accumulation in DSR, replication adds new movements in a three-dimensional space consisting of projectability, fitness, and confidence. The movements identified by vom Brocke et al. (2020) are conceptualised on the basis of DSR projects that actively adapt existing design knowledge to solve problems. In this regard, their movements were within the plane of projectability and fitness, whereas confidence depended on the quality of the evaluation. In comparison, replication does not change the design theory itself, and instead can help to better understand existing design theories, which can lead to implications for how to develop improved ones. Therefore, replication moves design theory on the plane of projectability and confidence (see Figure 11).

TABLE 1 Relation between replication outcome and impact on a design theory

		Impact		
No.	Replication outcome	Confidence	Projectability	Fitness
1	Successful addition	Decrease	Increase	Indirectly
2	Unsuccessful addition	Increase	Unchanged	Indirectly
3	Successful subtraction	Decrease	Decrease	Indirectly
4	Unsuccessful subtraction	Increase	Unchanged	Indirectly

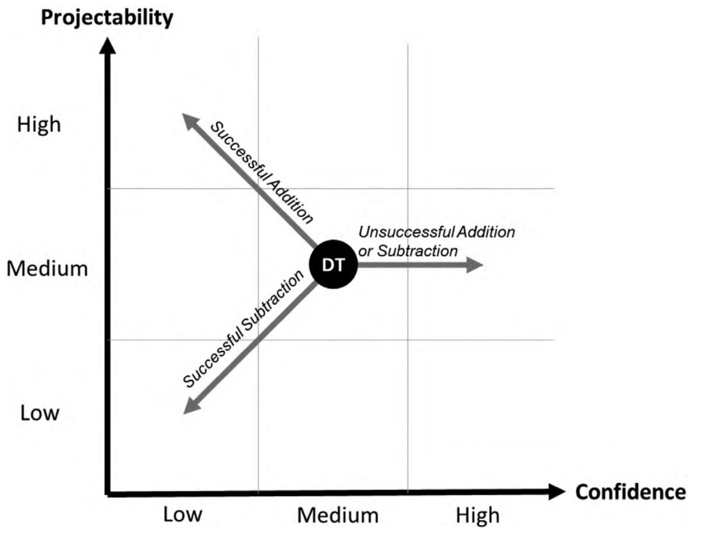

FIGURE 11 Outcomes and impacts of replication on design theories

5 | DISCUSSION

This paper set out to understand whether replication of design theories is possible and what potential benefits it might bring. To do this, we first systematically analysed what replication does in the context of truth theory, and recognised that replication has a function, outcome, and overall impact on the theory. Through replication, the explanation space of the truth theory is tested by trying to either subtract or add phenomena. These considerations were translated into the context of design theories by comparing the similarities and dissimilarities in scientific progress between truth and utility research. In both progressions, replication is performed to assess the position of current theories relative to the goal of progress (truth or utility), and when a theory is refuted (i.e., lacks confidence), the replication results hold implications for the development of a new and improved theory. The difference lies in the fact that truth is binary (true or false), whereas utility is on a scale (more or less). Nonetheless, replication can be applied in both progressions and can serve as a means of assessing the level of utility of design theory.

Second, during the transfer of replication logic (function, outcome, and impact) from the context of truth to utility, we identified that the impact of replication on design theory is a change not only in the associated level of confidence, but also in its projectability. Successful replication of a design theory can lead to associated high levels of projectability and confidence, which would render it a highly mature design theory that is rare in DSR (Gregor & Hevner, 2013).

The following section outlines the implications of the answers to these two research questions. We first establish further considerations that put the developed concept of the replication of design theories into context with current discourses within the DSR community. We also aim to provide avenues for future investigation. Thereafter, we formulate a call for action that addresses how replication should become a part of the DSR community.

5.1 | Further considerations

An ongoing discussion exists within the DSR community regarding the issues of design theory reuse (in practice and research) (Kruse & Seidel, 2017; vom Brocke et al., 2017) and knowledge accumulation (vom Brocke et al., 2020). Specifically, vom Brocke et al. (2020) describe the challenge of studies standing on their own, not building upon existing knowledge, and limiting the scope, extent, contribution, and impact of DSR studies. From our perspective, design knowledge is rarely reused because other researchers are not sure whether the knowledge is reliable (i.e., they lack confidence in design theory). Similarly, uncertainty regarding projectability can deter researchers from reusing an existing design theory; instead, they often opt to develop something new. Hence, replication is seen as a means to increase confidence and projectability, which would result in more reuse of design knowledge and subsequently help to break the current pattern of developing stand-alone knowledge (vom Brocke et al., 2020).[10] In this context, there is potential for investigating the interaction between replication and reuse.

Returning to the topic of a replication crisis discussed in the introduction, our conceptualization of design theory replication leads us to believe that a 'traditional' replication crisis is unlikely to happen in DSR. For a replication crisis to occur, an existing theory must be refuted, leading to the ripple effect that calls studies that build upon this refuted theory into question. However, design theory cannot be refuted because it will always provide utility in the context of a single problem instance of the original study (not considering fraud), and subsequent studies demonstrate utility on their own. Nonetheless, replication can provide an important function to the DSR community. Replication leads to the weeding out of 'bad' design theories and strengthens the academic community's confidence in 'good' design theories, so researchers can identify and build on well-supported design theories. Therefore, a 'design' replication crisis would mean that many existing design theories are unfit for knowledge accumulation; that is, attempts to build upon them fail more often than they succeed. Without a proper weeding out of 'bad' design theories, effort is likely to be lost when working with existing design knowledge, constituting a design replication crisis. Researchers may then run into a situation comparable to that of engineers who wanted to adapt IBM Watson for the healthcare context, but found that the provided decision support did not meet their expectations and the success in Jeopardy did not translate to healthcare (Lohr, 2021).

Furthermore, DSR has been described as struggling to develop real-world solutions (and therefore contribute to practice) while simultaneously attempting to contribute to the theory. Recent editorials in *the MISQ* (Rai et al., 2017) and the *Journal of the Association for Information Systems* (Baskerville et al., 2018) also comment on the challenge of balancing the desire to make scientific and practical contributions in DSR, proposing that both contributions are valuable and need not be present simultaneously in a single study. Replication can balance this tension. For instance, a study that has developed a design theory with high projectability claiming to address a large problem class should be replicated in various instances of this problem class, providing evidence or counterevidence for the claims made. This (counter)evidence could be used to determine the right position regarding the dimensions of confidence and projectability. Overall, a culture of regular replication leads to the development of robust and mature design theories.

The term 'replication' is relatively new in the context of DSR, and questions have arisen regarding its similarities and overlap with other terms. For instance, evaluation is a core activity of DSR (Hevner et al., 2004; Niederman & March, 2012) and it could be argued that the presented concept of design theory replication is, in essence, a re-evaluation (similar to the b-testing of van Aken (2004)) of a design theory. In this context, we refer to re-evaluation as a replication subgroup. Re-evaluation provides evidence for or against any claims made by design theory, by applying it to the problem instances within its problem class. Hence, re-evaluation covers the subtraction function. Replication of design theory also includes addition, which extends beyond re-evaluation. Similarly, we are aware that some concepts used by the DSR community (and those possibly related to replication research) are not represented in this paper because their relation to 'replication' is unclear. For instance, there is ongoing discourse on the clarity, transparency, and generalizability of DSR (Baskerville et al., 2018; Böhmann et al., 2019) that centres on how to demonstrate the limitations of design theories and artefacts, as well as how to allow for generalizability by re-examining the artefacts and design theories associated with different problems. The consideration of the design principle reuse implicitly points to a re-evaluation of artefacts in different application areas (Kruse & Seidel, 2017; Vom Brocke et al., 2017). Furthermore, the sampling approach is based on a systematic, randomised combination and reuse of artefact components to achieve higher instantiation validity (Lukyanenko et al., 2015, 2016). In future research, these concepts should be positioned relative to the presented concept of replicating design theories, providing the opportunity to unify and eventually identify areas with a strong knowledge base, as well as areas with existing knowledge gaps and voids (Müller-Bloch & Kranz, 2015).

It should also be noted that the DSR community is not the only research community that has noted the idea of the science of the artificial (Simon, 1969); other disciplines include computer science and mechanical engineering. These disciplines are also developing design theories (although they may not be termed design theories) in the form of new technologies (e.g., blockchain technology) and a set of boundaries where this new technology might be used to solve problems (e.g., decentralised cryptocurrencies). Exploring and defining these boundaries can be categorised as replication. Hence, we see the potential for exploring the similarities between other sciences of artificial and IS community specific DSR. Work by Gómez et al. (2010, 2014) could provide a starting point because they examined experiment-based research and computer science replication.

Furthermore, the DSR community may be driven by new technologies developed by computer scientists, leaving DSR to search for areas where this new technology might solve business-related problems (e.g., smart contracts), often adding the 'socio-' to the 'technological'. In this regard, DSR applies new technology as intended or tests its boundaries by identifying new areas for application. Against this background, the question of whether DSR is 'simply' the replication of claims made by new technologies arises. We argue that some research might fall into the previously described pattern (for instance, one could say that a current trend exists to search for problems that can be solved via blockchain technology), whereas other research is firmly based on the search for increasingly better solutions to prevailing problems (e.g., the green IS community). Nonetheless, this question could be fertile ground for discourse in the DSR community regarding whether DSR is problem-driven or technology-driven, and how replication relates to this tension.

Finally, questions regarding the replication of design theories for deterministic systems versus non-deterministic systems is another area that can be considered further. Specifically, design theories for self-learning systems produce instances that can function completely differently from each other and provide different levels of utility as a result. Finally, replication studies of such design theories are difficult to evaluate because many contextual factors can influence their outcomes. Thus, determining whether an addition or subtraction is successful or unsuccessful is nearly impossible. In addition, extracting clear implications on how to change design theory to produce better instances is intricate and difficult. Further consideration of how to replicate such design theories and extract clear implications is needed.

5.2 | Call to action

In the context of DSR theorising, replication studies can lead to several desirable outcomes (e.g., increasing the confidence and projectability of a design theory). Hence, replication studies in DSR have opened a valid (and previously underrepresented) pathway to stimulate the development of mature design theories (Gregor & Hevner, 2013). Such research can further bring IT artefacts to the core of theory building, and contribute to more 'home-grown' theories in IS research as a result. Based on this research opinion, we ask the IS research community to pay attention to the importance of replication in DSR and its recognition by reviewers and editors. Specifically, we observe two main areas of action.

First, the presented considerations and conceptualizations of replication research in DSR provide a framework for general thinking, but do not provide any prescription on how to conduct the design theory replication study. For instance, DSR can be characterised by its iterative and multi-method research approach (Gregory & Muntermann, 2014; Hevner, 2007; Hevner et al., 2004), with various methods combined for requirement elicitation, knowledge gathering, artefact development, solution evaluation, and design theory formulation. This leads to the question of how replication studies should approach this complex research structure. The first articles engaging such matters (e.g., Brendel, Lembcke, et al., 2021) are published; however, there is room for further discussion on this, such as conceptualising how addition and subtraction replication studies should be conducted. Similarly, there is a question of how important transparency is for design theory replication (Bernstein, 2017; Burton-Jones et al., 2021). For instance, if replications are to be precise, source code and original data sets might be required, and the question is whether publishing such supplementary material should be requested. Members of the DSR community should begin conducting replication studies and reflect on what studies they conducted, how they conducted them, and why they were conducted the way they were.

Second, publishing any replication study can be difficult because of the general mundanity and boredom associated with replication research (Lindsay & Ehrenberg, 1993), with negative results rarely being published (Dennis & Valacich, 2014). Hence, it is important to consider the contribution of design theory replication studies and how they relate to being publishable in leading and established IS journals (e.g., AIS Senior Scholars' Basket of Journals). We see movements in the space of design theory projectability, confidence, and (sometimes) fitness as the main contribution of replication studies. In the end, as a community, we should strive to develop design theories that are highly projectable, provide a high level of fitness, and are associated with high confidence. Thus, studies that provide significant movements in these dimensions should be published in leading journals. Our community must consider how to integrate design theory replication into the existing publication infrastructure, and review design theory replication studies for publication. As a result, we would like to call on editors and reviewers to have a more open mindset and allow for experimentation. There is a genuine opportunity to establish replication research in DSR; however, this opportunity is fragile, and, if not handled with care, is likely to lose its current potential.

6 | CONCLUSION

This paper examined the meaning and potential contribution of replication studies for DSR, targeting design theories in particular. Using a conceptualization of theory by Weber (2012) and replication research based on an extension of Popper's (1959, 1963) scientific progress by the notion of confidence, we were able to systematically derive the function, outcome, and impact of a replication study on replicated theory. By transferring this concept to design theories, we were able to deduce that the replication of design theories interacts with their associated levels of projectability and confidence. Eventually, replication of design theories leads to a body of knowledge that invites reuse and subsequent knowledge accumulation, departing from the current (undesirable) practice of stand-alone efforts.

As with any opinion paper and contribution of this type, the developed concept of replicating design theories is by no means definitive. Instead, its purpose is to illustrate the role that replication can play in DSR by providing an initial idea for future considerations and arguments for or against it. Researchers should therefore see the provided elaborations as ‘food for thought’, that could (hopefully) start an interesting and lively discussion. As a result, we call on scholars to adopt our replication framework as well as how it applies to design theories by elaborating on it to develop strong concepts and approaches for replication in DSR, as well as to foster its application and subsequent changes to the research domain. Similarly, we invite response and reaction papers following this paper, particularly those that comment on the different facets of this paper that could lead to frictions with epistemological positionings in DSR and how to resolve them.

DATA AVAILABILITY STATEMENT

No data to be disclosed.

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ENDNOTES

[1] Please refer to the original article for details.

[2] Note that Venable (2006) used the term ‘utility theory’ to describe an understanding of a theory that is produced by DSR, which is different from the understanding of design and action theories (Gregor, 2006) and design theories (Jones & Gregor, 2007). We follow the understanding of a design theory based on Jones and Gregor (2007), and, therefore, do not subscribe to the Venable's notion of a utility theory. Nonetheless, the idea of having a problem and a solution space (which is explored during a DSR project to find an effective solution component for a problem element) is seen as being

independent of the concept of a utility theory. Therefore, we will combine the concept of problem and solution spaces with the concept of a design theory. This view is similar to the use of the terms in Gregor and Hevner (2013) and vom Brocke et al. (2020).

[3] We use the term 'boundary' to describe the phenomena that a theory is intended to cover. Boundaries provide rules and definitions to identify and filter phenomena that are covered by a theory. However, as Weber (2012) and Niederman (2021) noted, precisely defining the boundary of a theory (i.e., describing the phenomena described, explained, and/or predicted by a theory) is challenging and many theories lack clear boundaries, which leads to studies exploring them.

[4] Scientific realism assumes that theories make claims that are either true or false and describes entities that objectively exist, and, therefore, an objectively observable world exists (Leplin, 1997, 2007).

[5] Note that the term 'confidence' is used here as an attribute of theoretical statements or propositions. In this view, it is assumed that a theory will progress from being proposed with little or no supporting evidence through many tests to a greater maturity, perhaps with more precise wording. The theory may or may not change over time; however, the level of confidence will increase with each supporting test and decrease with contradicting results (based on the report ot the National Academies of Sciences, Engineering, & Medicine, 2019).

[6] Note that we use the term 'phenomena' to describe an occurrence that has been or can be observed in reality.

[7] Note that, ideally, a theory is considered true until a counterevidence (e.g., via replication) leads to the development of an improved theory that is considered to be true.

[8] Note that we follow the notion that utility is subjective. When we talk about 'high' utility, we mean that a majority of the relevant stakeholders would agree that an artefact is highly useful. In contrast, when we speak about no utility, we mean that a majority of the relevant stakeholders would agree that an artefact has little to no utility.

[9] In this context, it can be assumed that it is highly unlikely that two design theories, both addressing the same problem class, provide the same level of utility.

[10] We are aware that there are exceptions to this general observation. For instance, Jay Nunamaker has an extensive record of studies that build upon each other in the field of group support systems and deception detection. Similarly, Roman Beck accumulates design knowledge in context of blockchain technology. However, at least from our perspective, cross researchers and research group knowledge accumulation can be considered rare.

REFERENCES

Al Turki, A., Bandara, W., & Gable, G. G. (2012). Design science research and the Core of information systems. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 309–327.

AMCIS. (2018). Replication Track at American Conference on Information Systems 2018. https://amcis2018.aisconferences.org/submissions/track-descriptions/

Baker, M. (2015). Over half of psychology studies fail reproducibility test. *Nature*, *520*, 253–255.

Baker, M. (2016). 1,500 scientists lift the lid on reproducibility. *Nature*, *533*(7604), 452–454.

Baskerville, R., Baiyere, A., Gregor, S., Hevner, A., & Rossi, M. (2018). Design science research contributions: Finding a balance between artifact and theory. *Journal of the Association for Information Systems*, *19*(5), 358–376.

Baskerville, R., Kaul, M., & Storey, V. C. (2017). Establishing reliability in design science research. Proceedings of the International Conference on Information Systems, 1–18.

Bernstein, E. S. (2017). Making transparency transparent: The evolution of observation in management theory. *Academy of Management Annals*, *11*(1), 217–266. https://doi.org/10.5465/annals.2014.0076

Berthon, P., Pitt, L., Ewing, M., & Carr, C. L. (2002). Potential research space in MIS: A framework for envisioning and evaluating research replication, extension, and generation. *Information Systems Research*, *13*(4), 416–427.

Böhmann, T., Schwabe, G., Briggs, R. O., & Tuunanen, T. (2019). Advancing design science research with solution-based probing. Proceedings of the Hawaii International Conference on System Sciences.

Braun, R., Benedict, M., Wendler, H., & Esswein, W. (2015). Proposal for requirements driven design science research proposal for requirements driven design science research. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 1–18.

Brendel, A. B., Diederich, S., & Niederman, F. (2021). An immodest proposal–going "all in" on replication research in information systems. *European Journal of Information Systems*, 1–10. https://doi.org/10.1080/0960085X.2021.1944822

Brendel, A. B., Greulich, R. S., Niederman, F., & Trang, S. (2020). Towards a greater diversity of replication studies. *AIS Transactions on Replication Research*, *6*(1), 20.

Brendel, A. B., Lembcke, T. B., Muntermann, J., & Kolbe, L. M. (2021). Toward replication study types for design science research. *Journal of Information Technology*, *36*(3), 198–215. https://doi.org/10.1177/02683962211006429

Burton-Jones, A., Boh, W. F., Oborn, E., & Padmanabhan, B. (2021). Advancing research transparency at MIS quarterly: A pluralistic Approach. *MIS Quarterly*, *45*(2), iii–xviii.

Dennis, A. R., Brown, S. A., & Wells, T. M. (2020). Replication crisis or replication reassurance: Results of the IS replication project. *MIS Quarterly*, *44*(3), iii–x.

Dennis, A. R., & Valacich, J. S. (2014). A replication manifesto. *AIS Transactions on Replication Research*, *1*(1), 1–4.

Goldkuhl, G. (2012). Design research in search for a paradigm: Pragmatism is the answer. In M. Helfert & B. Donnellan (Eds.), *Practical aspects of design science. EDSS 2011. Communications in Computer and Information Science* (pp. 84–95). Springer.

Gómez, O. S., Juristo, N., & Vegas, S. (2010). Replications types in experimental disciplines. Proceedings of the 2010 ACM-IEEE International Symposium on Empirical Software Engineering and Measurement.

Gómez, O. S., Juristo, N., & Vegas, S. (2014). Understanding replication of experiments in software engineering: A classification. *Information and Software Technology*, *56*(8), 1033–1048.

Gregor, S. (2006). The nature of theory in information systems. *MIS Quarterly*, *30*(3), 611–642.

Gregor, S., & Hevner, A. R. (2013). Positioning and presenting design science research for maximum impact. *MIS Quarterly*, *37*(2), 337–355.

Gregory, R. W., & Muntermann, J. (2014). Heuristic theorizing: Proactively generating design theories. *Information Systems Research*, *25*(3), 639–653.

Greulich, R. S., & Brendel, A. B. (2019). Towards a greater appeal of replication research by learning from the field of neuroscience. Proceedings of the Americas Conference on Information Systems, 1–10.

Hevner, A. R. (2007). A three cycle view of design science research. *Scandinavian Journal of Information Systems*, *19*(2), 87–92.

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75–105.

Hilpinen, R. (1992). On artifacts and works of art. *Theoria*, *58*(1), 58–82.

Iivari, J. (2015). Distinguishing and contrasting two strategies for design science research. *European Journal of Information Systems*, *24*(1), 107–115.

Ioannidis, J. P. A., Stanley, T. D., & Doucouliagos, H. (2017). The power of bias in economics research. *The Journal of the Royal Economic Society. The Economic Journal*, *127*(605), F236–F265.

Jones, D., & Gregor, S. (2007). The anatomy of a design theory. *Journal of the Association for Information Systems*, *8*(5), 312–335.

Kellert, S. H., Longino, H., & Waters, C. K. (2006). Introduction: The pluralist stance. *Minnesota Studies In The Philosophy of Science Series*, *19*, vii–xxix.

Kruse, L. C., & Seidel, S. (2017). Tensions in design principle formulation and reuse. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 1–10.

Kuhn, T. S. (1962). *The structure of scientific revolutions*. University of Chicago Press.

Lee, A. S., & Hubona, G. S. (2009). A scientific basis for rigor in information systems research. *MIS Quarterly*, *33*(2), 237–262.

Lee, J. S., Pries-Heje, J., & Baskerville, R. (2011). Theorizing in design science research. Lecture notes in computer science. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 1–16.

Leplin, J. (1997). *A novel defense of scientific realism*. Oxford University Press.

Leplin, J. (2007). Enlisting Popper in the case for scientific realism. *Philosophia Scientiæ*, *11*(1), 71–97.

Lindsay, R. M., & Ehrenberg, A. S. C. (1993). The Design of Replicated Studies. *American Statistician*, *47*(3), 217–228.

Lohr, S. (2021). What ever happened to IBM's Watson? New York Times. https://www.nytimes.com/2021/07/16/technology/what-happened-ibm-watson.html

Lukyanenko, R., Evermann, J., & Parsons, J. (2015). Guidelines for establishing instantiation validity in IT artifacts: A survey of IS research. Lecture notes in computer science. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 430–438.

Lukyanenko, R., Samuel, B. M., & Parsons, J. (2016). Toward artifact sampling in IS design research. Workshop on Information Technologies and Systems, 1–10.

Müller-Bloch, C., & Kranz, J. (2015). A framework for rigorously identifying research gaps in qualitative literature reviews. Proceedings of the International Conference on Information Systems, 1–19.

National Academies of Sciences - Engineering - Medicine. (2019). *Reproducibility and replicability in science*. The National Academies Press.

Niederman, F. (2021). A minimalist view of theory: Why this promises advancement for the IS discipline. The Data Base for Advances in Information Systems, forthcoming, The Philosopher's corner.

Niederman, F., & March, S. (2015). Reflections on replications. *AIS Transactions on Replication Research*, *1*(1), 1–16.

Niederman, F., & March, S. T. (2012). Design science and the accumulation of knowledge in the information systems discipline. *ACM Transactions on Management Information Systems*, *3*(1), 1–15.

Olbrich, S., Frank, U., Gregor, S., Niederman, F., & Rowe, F. (2017). On the merits and limits of replication and negation for IS research. *AIS Transactions on Replication Research*, *3*(1), 1–19.

Popper, K. R. (1959). *The logic of scientific discovery*. Hutchinson & Co.
Popper, K. R. (1963). *Conjectures and refutations: The growth of scientific knowledge*. Routledge and Kegan Paul.
Rai, A., Burton-Jones, A., Chen, H., Gupta, A., Hevner, A. R., Ketter, W., Parsons, J., Rao, H. R., Sarkar, S., & Yoo, Y. (2017). Diversity of design science research. *MIS Quarterly*, *41*(1), iii–xviii.
Salovaara, A., & Merikivi, J. (2015). IS research Progress would benefit from increased falsification of existing theories. Proceedings of the European Conference on Information Systems, 1–16.
Schmidt, S. (2009). Shall we really do it again? The powerful concept of replication is neglected in the social sciences. *Review of General Psychology*, *13*(2), 90–100.
Schooler, J. W. (2014). Metascience could rescue the 'replication crisis'. *Nature*, *515*(7525), 9.
Simon, H. A. (1969). *The sciences of the artificial (third)*. MIT Press.
Stroebe, W., & Strack, F. (2014). The alleged crisis and the illusion of exact replication. *Perspectives on Psychological Science*, *9*(1), 59–71.
Van Aken, J. E. (2004). Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. *Journal of Management Studies*, *41*(2), 219–246.
Venable, J. (2006). The role of theory and Theorising in design science research. Proceedings of the International Conference on Design Science Research in Information Systems and Technology, 24–35.
Venkatesh, V., Morris, M. G., Davis, G. B., & Fred, D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425.
vom Brocke, J., Hevner, A., Maedche, A., & Winter, R. (2017). Call for papers special issue JAIS: Accumulation and evolution of knowledge in design science research. *Journal of the Association for Information Systems*, 1-3.
vom Brocke, J., Winter, R., Hevner, A., & Maedche, A. (2020). Accumulation and evolution of design knowledge in design science research – A journey through time and space. *Journal of the Association for Information Systems*, *21*(3), 520–544.
Weber, R. (2012). Evaluating and developing theories in the information systems discipline. *Journal of the Association for Information Systems*, *13*(1), 1–30.
Wynn, D., & Williams, C. K. (2012). Principles for conducting critical realist case study research in information systems. *MIS Quarterly*, *36*(3), 787–810.

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