Towards a Greater Appeal of Replication Research by Learning from the Field of Neuroscience

Completed Research

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Abstract

The replication of existing knowledge (e.g. previous study results) stands as an important research practice across all disciplines of science. Despite the importance of replication, the scarcity of replication studies is commonly criticized in business, management and Information System (IS) research. Therefore, to facilitate replication research in the IS community, efforts have already been made, such as establishing conference tracks and journals primarily focusing on publishing replication studies, and providing guidelines of how and why to conduct out replication research. Nonetheless, the perception of replication research remains unchanged, describing it as mundane. In this paper, we address this perception by asking how other research disciplines achieved and maintained a stronger culture of replication. To be specific, we analyzed replication studies from the field of neuroscience and elicited to potentially novel replication study types: transfer and method validation. We argue that both study types hold the potential to be more interesting to conduct and increase the appeal of replication research.

Keywords

Replication Research, Replication Study Types, Neuroscience.

Introduction

Replication research, e.g. the replication of research results, stands as an important research practice across all disciplines of science (Dennis and Valacich 2014; Gómez et al. 2010; King 1995). The replication of results converts tentative belief into accepted, tested, and trustworthy knowledge (Berthon et al. 2002), making it a powerful concept for scientific progress by reinforcing the foundations for new advancements and discoveries (Schmidt 2009).

Despite its importance, the rarity of replication research remains a major weak point and is commonly criticized in business, management and IS research (Berthon et al. 2002; Dennis and Valacich 2014; Hart and Gregor 2012). Other disciplines are also struggling with a lack of replication research. In this context, Baker (2016) investigated reproducibility in various disciplines (chemistry, biology, physics, engineering, medicine, and environmental studies) by questioning over 1,500 researchers. Around 90% of researchers perceive science to have at least a slight reproducibility crisis. The term "reproducibility crisis" describes the problem that the results of many empirical studies are impossible or at least difficult to reproduce by other researchers or the original study's authors. This calls into question how many studies are conducted (Fanelli 2009). Thus, an increase in replication research is desirable in many disciplines, including IS research, in order to strengthen existing knowledge and the theoretical base new studies base upon.

To facilitate replication research in the IS community, efforts have already been made, ranging from providing better guidelines of how and why to carry out replication research (Dennis and Valacich 2014) to establishing conference tracks and journals primarily focusing on publishing replication studies (AMCIS 2018; TRR 2018). Nonetheless, replication research remains a rarity in business, management and IS research (Dennis and Valacich 2014). We would argue that this is partly caused by the common perception of replication research to be "mundane", e.g. boring (Lindsay and Ehrenberg 1993). Replication research is perceived to be unable to provide interesting theoretical contributions, hindering

replication studies from being published in well regarded outlets, e.g. reviewers and editors are biased against publishing replication studies (Dennis and Valacich 2014).

This question has been addressed in several ways in several disciplines. Recommendations range from teaching the importance of replication and reducibility early (Frank and Saxe 2012) over pre-registration of studies (APS 2015) to sharing studies data online (Ioannidis 2016). However, these recommendations address primarily operational challenges by increasing the reproducibility and the eventual success in replicating a study. In the IS community, researchers are called to conduct replication studies by highlighting the value of replication research (e.g. Dennis and Valacich 2014; Niederman and March 2014). However, the quest to find a way to make replication research more appealing still seems unsolved, needing further investigation. Against this background, this study aims to contribute towards answering the great question of:

How can we make replication research more appealing to conduct and publish?

In order to provide contribution towards making replication research more appealing, we approach it by trying to learn from other disciplines, which have a more pronounced replication culture. To be specific, we analyzed the discipline of neuroscience. The replication culture of neuroscience distinguishes itself from others by the fact that neuroscience is the interface between psychology, biology and medicine (for a review on the emergence of neuroscience as a field of its own right, see Cowan et al. (2000)). Psychology is one of the fields strongest hit by the so-called replication crisis (Science 2015) and has the problem of hard-to-control experiment confounds and context of an experiment (Stroebe and Strack 2014). Neuroscience as a natural science, however, utilizes well defined experimental settings, which are much easier to be replicated. Neuroscience explores the biological basis of psychological hypothesis and theories. This exploration necessitates a replication of previously observed original behavioral findings to correlate them with neural recordings. Additionally, since neuroscience utilizes a plethora of different methods (imaging, electrical recordings, etc.), each with their own limitation, a phenomenon cannot be fully understood with just one experiment and has to be replicated by a different group with different methodological strengths to be fully investigated. Lastly, the neuroscience community, also a very active one (we found 53,521 publications with the tag neuroscience for 2016 when searching in ISI web of knowledge), acknowledges the need for replication (Kellmeyer 2017; Steckler 2015) and actively promotes publishing of replication studies (Bernard 2016). We believe that IS can learn from neuroscience, since it is also lending methods and theories from other disciplines, e.g. psychology.

We adopted the method of literature review (vom Brocke et al. 2009; Webster and Watson 2002) to find and analyze replication studies in the field of neuroscience, to subsequently compare them with replication research in IS research. In this process, we found that replication research in the field of neuroscience differs from common replication study types used in the AIS Transactions on Replication Research journal (Dennis and Valacich 2014; TRR 2018), e.g. exact, method and concept replication, by implicitly having a fourth type, which we termed “transfer” replication study, and a fifth study type, which we called “method validation” replication study.

We argue that especially the fourth replication type provides a potential ally to make replication research more appealing, as it promises more interesting outcomes, besides the binary “truth” (original study was successfully replicated) and “false” (original study could not be replicated). For instance, the transfer of existing theories into new context and applying them for new phenomena offers ground for identifying limitations of existing theories and formulating directions to overcome them.

Research Background - Replication Research

The aim of replication research is to enable scientific consensus on the proposed knowledge, by validating the results of previous studies (Berthon et al. 2002; Dennis and Valacich 2014; Schmidt 2009). Hence, the aim is to investigate the ability to generalize and strengthen existing knowledge. Thus, replication studies contribute to theory by substantiating the understanding of certain phenomena and research areas (Dennis and Valacich 2014; Niederman and March 2014).

Following Popper (1959, 1963), theories must be easy to falsify, however, the falsification of good theories remain unfruitful, e.g. replications remain successful. Thus, the scientific progress consists of (Salovaara and Merikivi 2015) (1) Proposing theory, (2) trying to refute theory, (3) improving or replacing theory to

better explain the investigated phenomena. In this context, replication research primarily addresses the second step of the scientific progress and tries to refute existing theories, which leads to strengthening theories that withstand refutation attempts (the process and the position of replication research within it is illustrated in Figure 1).

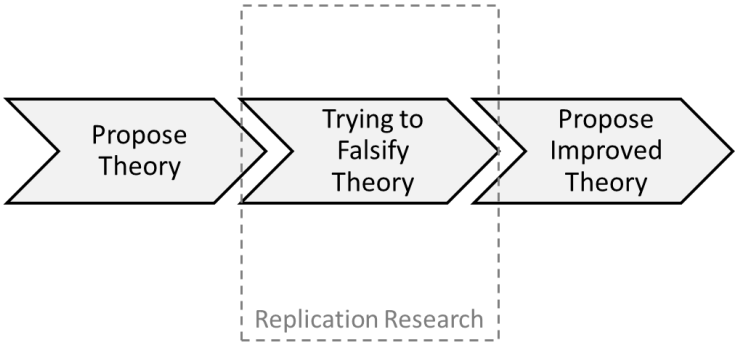


Figure 1: Process of Falsification

Against this background, replication studies can address different parts of a theory or study. To be specific, replication studies are carried out with at least one of five goals in mind (Schmidt 2009):

(1) Finding sample errors means to search for results that were obtained on the basis of improper data. The original study is replicated as closely as possible, with a new sample that has the same characteristics as the original study. The original method (commonly statistical test) is repeated, i.e., the p-value(s) of the original study by which hypotheses were supported or rejected initially. For example, in case the chance of a false positive result is $p=0.05$ in the original study, a positive replication study (e.g. also $p=0.05$) leads to a lower p-value overall ($p= 0.05x0.05 = 0.0025$), making a chance results (e.g. sample error) very unlikely (Schmidt 2009).

(2) Controlling for lack of internal validity is important to rule out external variables that interact with the study design and results (Schmidt 2009). Overall, it is concerned with "whether the researcher provides a plausible causal argument, logical reasoning that is powerful and compelling enough to defend the research conclusion" (Gibbert et al. 2008, p.1466).

(3) Uncovering fraud addresses the problem of human interference in the reported results. Although journals and conferences require authors to comply with their codes of research conduct, cases of fraud have been observed in the past (Wilmshurst 2002). To address this issue, the original study is replicated as exactly as possible to identify any deviations in results, which are caused by potential human interference (e.g. fraud) (Schmidt 2009).

(4) Expanding or generalizing results to cover a larger or different context addresses the generalization of original results across population and time. Against this background, a replication study is conducted to investigate whether the original results are specific to a certain population or context (Schmidt 2009). To give an example, a common discussion in the literature addresses if university students are a valid subject group for certain types of research (Compeau et al. 2012). Hence, replication studies can be conducted to verify the results of a study conducted amongst a student population by replicating it with non-student data. This increases the scope of the original study.

(5) Verifying original hypotheses means to provide hypothesis-conforming or hypothesis-disconfirming by repeating previous investigations (Snyder and White 1981). To verify a hypothesis in behavioral research means to reach beyond the function to confirm results by repeating the original experimental procedure. This means that a replication study follows different experimental setups, designed to replicate the hypothesis of the original study (Schmidt 2009).

Hence, the aim is not to develop genuine and novel results but rather to investigate the generalizability and strengthen results from previous studies. Thus, the theoretical contribution lies in the iterative improvement and elaboration of an existing theory, supporting them with empirical results or refuting them because of contrary replication results (Compeau et al. 2012).

Regarding the conduction of a replication study, different replication approaches were developed throughout the history of replication research (Berthon et al. 2002; Dennis and Valacich 2014; Gómez et al. 2014). The most prominent categorization in the IS research community is from Dennis and Valacich (2014):

(1) Exact replications share the same context and method with the original study. All treatments, methods, measures etc. are identical to the original research. Furthermore, the context remains the same, so if the original study used employees of a Chinese automotive company, the replication study will do so as well (Dennis and Valacich 2014).

(2) Method replications apply the same method as the original study but in a different context. For instance, this means that instead of employees of a Chinese automotive company, the replication study might use German undergraduate students (Dennis and Valacich 2014).

(3) Concept replications investigate the same context but apply different methods. Thus, they seek to answer the same research question testing the same hypotheses but with different measures, treatments, contexts and/or analytical methods. For example, in the replication study the wording of items used to measure key constructs might be altered (Dennis and Valacich 2014).

Research Approach

We base our research approach on the literature review approach, specifically on the seminal works of Webster and Watson (2002) and Vom Brocke et al. (2009). Following the taxonomy of literature reviews of Cooper (1988), we designed our research approach to conduct a literature review the following characteristics:

Focus – Practices and Applications: Our literature review focuses on the research practices and applications in context of replication research.

Goals – Integration: Our literature review aims at integrating replication research practices from the field of neuroscience within the IS research domain. Hence, the aim is not to critique. We want to look at how to make replication research more approachable and appealing – and there is nobody at fault for the lack of attractiveness.

Perspective – Neutral Representation: The literature review is supposed to provide a neutral analysis of which types of replication studies are conducted and what we can learn from them.

Coverage – Representative: The selected literature is supposed to be a presentative sample of replication research in neuroscience.

Organization – Conceptual: To identify types of replication studies, a conceptual perspective is required and therefore applied in our literature review.

Audience – General Scholars: The literature review is presumed to provide insights into replication research practices that are interesting for the entire IS community.

To enable the conduction of the previously described literature review, the research approach has three phases:

Phase 1 –Review: *How replication research is carried out in neuroscience?* In this phase, replication studies from the field of neuroscience were reviewed to identify replication study types and practices in neuroscience.

Phase 2 – Comparison: *How does replication research in the neuroscience differentiate from replication research in the IS community?* In the second phase, seminal works on replication research are reviewed and matched with the results of the first phase to achieve a coherent and complete picture of the status-quo.

Phase 3 – Interpretation: *What are the implications for the IS community?* In the last phase, the similarities and differences of replication studies are interpreted to elicit implications on how to make replication research more appealing for the IS community.

The steps and relations of the individual phases are illustrated in Figure 2 and are described in the following sub-sections.

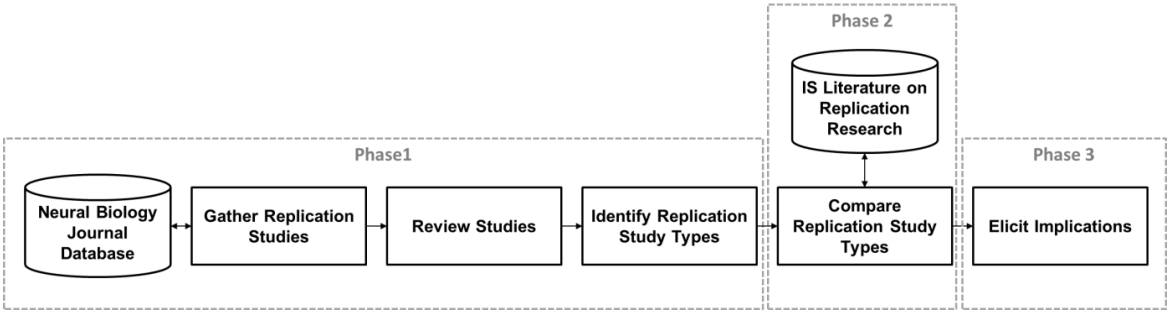


Figure 2: Research Process

Phase 1: Review of Replication Studies in Neuroscience

In the first phase, two points guided us to select the field of neuroscience as a reference point for finding aspects to make replication research more appealing. Firstly, as discussed in the introduction, neuroscience has a strong replication culture. Secondly, one of the authors is a researcher in the field of neuroscience. This is especially beneficial, as an understanding of the field, and methods used are essential to judge a paper's content.

Based on the experience of the author, we decided to select an open-access neuroscience journal for our literature search. This decision was made on the bases that replication studies often are considered to be not innovative enough for the traditional journals (showcasing that even the neurosciences are still suffering some shortcomings in relation to replication research). Thus, the neuroscience community is actively promoting open access to combat this publication bias (Koch and Jones 2016). According to the 2016 Journal Citation Reports (Journal Citation Reports 2016), the most cited neuroscience open access journals are: 1st "Frontiers in Human Neuroscience", 2nd "Frontiers in Cellular Neuroscience", and 3rd "Frontiers in Neuroscience". To ensure the review of a representative cross section over the whole field, we picked "Frontiers in Neuroscience". However, this had the unfortunate side effect, that it was impossible to use a keyword search to get replication studies.

The literature search was conducted in 2017 and we decided to include the entire publications of 2016 in our search (each year has a volume of around 722 publications), providing the manageable number of 631 publications for our filtering process. During the search, a two-step approach was applied. Firstly, the author with a background in neuroscience identified studies via title and abstract. The articles were filtered by two of the authors, one with a PhD in IS and one doctoral candidate in neuroscience. We reviewed the titles and abstracts of this selection for replication studies. Studies which presented novel results were excluded, as were review articles. We included articles which especially referred previous research and which stated to add to other studies. This reduced the sample to 59 articles. Those articles were then reviewed in depth over a full year and we excluded another 5. During that review process, we classified the studies into categories.

Phase 2: Comparison of Replication Study Types from Neuroscience and Information Systems Research

Base on the results of the first phase, we compared the elicited replication study types with the replication study types and their description common in the IS community. In this context, we decided to follow the replication study types used in the AIS Transactions on Replication Research journal (Dennis and Valacich 2014; TRR 2018). In this context, both authors revised the previously made categorizations and compared them to the categories found in the IS community.

Phase 3: Interpretation of Differences and Elicitation of Implications

In the last phase, we interpreted the differences in replication types by reflecting on what the differences can mean for future replication research. To be specific, we compared the process of falsification of Popper (1963) and which roles the new developed replication types can play within it.

Results - Replication Research in Neuroscience

While going through our literature set, we found six different types of replication studies (see Table 1), which we will describe in the following.

Studies in the first category retest the same hypothesis as the original study, using the same method, which can be termed **exact replication** (Dennis and Valacich 2014), as the original research is repeated as closely as possible. For example, the study of Morrison et al. (2016) investigates the reliability of fMRI brain mapping before implantation of direct brain stimulation devices (DCS). Here a number of studies already exist, but are often marred by small sample size as the number of available patients per brain surgery centers is limited. Hence, the study adds towards an existing body of work with the exact same methods to get a better evaluation of the previously reported effects. In total, we found three studies of this kind.

The third type, retests the same hypothesis as the original work, sometimes with an extension, but follows different method. Hence, studies in this type can be termed c**oncept replications**. The aim of such studies is to ensure that the previous results are not caused by a misuse or unsuitability of the original method. For example, Coutlee et al. (2016) are retesting the involvement of the intraparietal sulcus (ISP) in risk evaluation, which was shown by fMRI. The authors expose subjects to the same risky-choice task as the original study but after the IPS was disabled with transcranial magnetic stimulation. In total, we found ten studies of this type.

Name	Hypothesis	Method	Model	#	Example
Exact	Identical	Identical	Identical	3	Morrison et al. (2016)
Concept	Identical (sometimes extended)	Different	Identical	10	Coutlee et al. (2016)
Method	Identical	Identical	Different	11	Blizzard et al. (2016)
Transfer	Identical	Different	Different	5	Raffa et al. (2016)
Method Validation	Identical	Comparing different methods for the same outcome or against ground truth	Identical or simulated with known ground truth	25	Tudorascu et al. (2016)

Table 1: Elicited Replication Research Categories

In our fourth category, studies investigate a similar context compared to the original study and apply the same methodological approach. In this context, similar means that the replication study authors try to find the same results as the original study, but in a different context. Hence, this study type can be termed **method replication**. An example for this study type is Blizzard et al. (2016). In their study, they explored lower motor neuron degeneration after spinal cord injury, which was originally explored by using the same method on the subject of the model organisms “rat”. In the replication study, the subject was changed to be the model organisms “mice”. Overall, we found 11 studies of this type.

We termed the fifth type **transfer replication**. Transfer studies use the same method, but to test a different, yet similar hypothesis; with emphasis that the hypothesis is similar towards the original one. For example, Raffa et al. (2016) uses a well-established method to preoperative trace motor circuitry in brain cancer patients and attempts to use it to trace the language circuitry. This firstly, retests the used method and secondly, also the underlying assumption that both hypotheses are similar enough. In total, we found five studies of this type.

Lastly, there are studies, which have the aim of **method validation replication**. This is often done, by using a dataset which is either simulated or has a known ground truth and is then explored with the

method. Often, two methods are compared to see which of them is the more suited to a given task. Those studies are imperative for natural science research, since knowing the strengths and limitations of a method is vital in judging the results of original research. A good example is Tudorascu et al. (2016), in which the authors compare two popular programs used for fMRI analysis. We found 25 examples.

Discussion - Comparison of Replication Study Types

The aim of this study was to contribute towards making replication research more appealing. In this context, we elicited replication study types from the field of neuroscience and compared them with the common replication study types from the IS field. When comparing the five found replication study types with the common three study types (Dennis and Valacich 2014), it appeared that the study types transfer replication and method validation replication are not currently recognized (see Table 2). In context of making replication research more appealing, we see great potential in transfer replication studies.

When comparing the scope of each replication study type, the scopes of them spark the question: what constitutes a replication study and differentiates it from "regular" research? This question was especially triggered by the replication study type of transfer. Transferring theories from other disciplines or topics to explain phenomena is a common procedure and necessary to approach the to-be-investigated phenomena appropriately. One example in this context is the reapplication of the technology acceptance model, which has been proven to provide a foundation to approach technology acceptance in various contexts (Salovaara and Merikivi 2015).

Thus, there needs to be a differentiation between reapplying and replication of a theory. Based on our sample of neuroscience replication studies and our understanding of replication research, we argue that the differentiating factor is the research question and goal of the researchers conducting the study. When the goal is centered on the phenomena, e.g. explaining why certain things are the way they are, the study cannot be considered a replication study. In contrast, when the goal is to verify existing theory and analyze its capabilities as well as limitations, then the study can be clearly categorized as a replication study. Against this background, a transfer replication study has the clear focus on the theory and not on the phenomena. Nonetheless, a transfer study showing limits of existing theories is a great cause to ask why the theory was not capable of explaining the phenomena in a different context. By this, we see a transfer study as a link between pure replication research and "regular" research. Overall, it extends the replication goal of expanding or generalizing results to cover a larger or different context (Schmidt 2009) by actively seeking contexts that are not similar to the original one.

Normally, studies are tasked to transfer, adapt and apply existing theories to understand new phenomena, (see the previously described technology acceptance studies example). Conducting a transfer replication studies beforehand can take some pressure from these studies, by already transferring existing theories and also highlighting areas for adaption. In context of IS research, which is characterized by rapid changes caused by technology (Easley et al. 2000; Niederman and March 2014), it is important to iteratively reevaluate and adapt theories to stay relevant and accurate. This also includes evaluating if the scope of theories is decreasing or expanding. Hence, before developing entirely new theories, conducting transfer replication studies can reveal where existing theories remain relevant in IS research. Furthermore, this approach would greatly fit within the scientific process proposed by Popper (1963). Before proposing a new theory, replicating and possibly refuting existing theories can be a great means to sharpen the outlines of research gap and also the eventual contribution of a study. In sum, we see great potential in conducting transfer replication studies in the IS community.

Furthermore, we would like to address how the fifth replication study type, e.g. method validation replication, fits within our context. A method validation seeks to verify the method by either comparing it to other established methods, to a dataset with a known ground truth (simulation, phantom, etc) or both. This is different from the method replication proposed by Dennis and Valacich (2014), where the original study is replicated with the same method but in a different context. However, this does not question the ability of the method to get the correct results. Since differences in the outcome could be caused by the different context and if the method is itself flawed, it might lead to erronous replications. Hence, we see the method validation replication study type as an integral part of proper scientific work, which can help to rule out flawed methodology as a cause for failed replications.

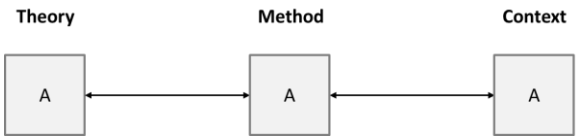
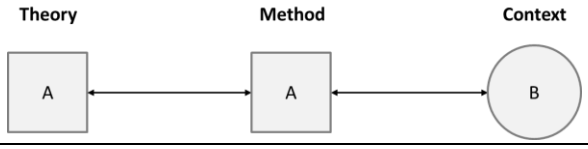
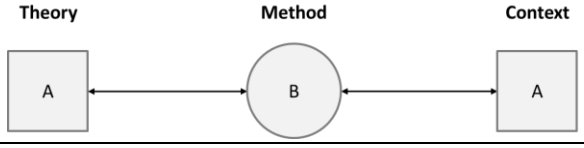
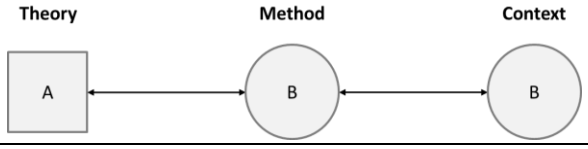
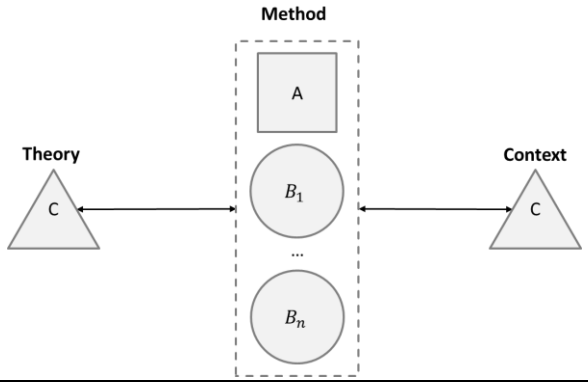
Name	Depiction	Description	IS References
Exact		Replicating the same theory or results (A) via the same method (A) in the same context (A) as the original study.	(Dennis and Valacich 2014)
Method		Replicating the same theory or results (A) via the same method (A) in a different context (B) as the original study.	(Dennis and Valacich 2014)
Concept		Replicating the same theory or results (A) via a different method (B) in the same context (A) as the original study.	(Dennis and Valacich 2014)
Transfer		Replicating the same theory or results (A) via a different method (B) in a different context (B) as the original study.	-
Method Validation		Replicating a known theory or results (C) via different methods (A and B) in a known context (C) to validate the original method (A).	-

Table 2: Replication Categories Comparison

Limitations and Future Research

One major limitation of our study is the sampling process. We only considered neuroscience studies from a single outlet and publication year. Hence, our sample cannot be termed exhaustive (Cooper 1988), limiting the generalizability of results. Nonetheless, the results of this study should provide ground for further discussion on replication research and the validity of our results.

Furthermore, we cannot be certain that we are the first to describe transfer replications studies. We could not find publications on this matter in IS literature and also not in seminal works from other disciplines, during our research process. However, we did not conduct a systematic and structure literature review of all possible replications study types in science and can therefore not be certain to have found a previously unknown type of replication studies. Future research should address this shortcoming by systematically searching and matching literature on replication research from other disciplines to complete our picture. Nonetheless, we would argue that our description of it provides merit to the IS community.

Lastly, we would like to point out that our paper lacks any prescriptive knowledge on how to conduct any of the analyzed replication study types. Hence, future research should address how transfer and method validation replication studies should methodologically be conducted and also how they should be documented and presented. Without this further conceptualizations, especially transfer replication research can fall in the pitfall of being interesting but inaccessible.

Conclusion

We are not the first (e.g. Dennis and Valacich 2014; Niederman and March 2014; Salovaara and Merikivi 2015) and hopefully not the last to call for more replication research in the IS research community, making the effort to change our perception regarding the value of replication research. In this paper, we addressed the limited perception of replication research to be binary in outcome (proof or refutation of previous theories and results) by conceptualizing a new replication study type: transfer. A transfer replication study transfers existing theories in a new context, investigating the capabilities and limitations of existing theories. Thereby, transfer replication studies can provide a foundation of subsequent studies, addressing how existing theories should be adapted to overcome limitations and eventually helping to understand new phenomena. Furthermore, we see value in also conduction method validation replications. Besides validating existing theories, we should also engage in replicating methodological approaches, to avoid problems such as discovering that an often used method is faulty because of improper implementation or errors in the underlying assumptions. The importance of such work has recently been painfully highlighted in neuroscience by the work of Eklund et al. (2016). In their publication, they compared established parameter sets in different MRI analysis programs. Although, those parameter sets where widely used, they led to inflated false positive rates, with significant differences between the programs. The results of their study casted doubt on the results of 40,000 fMRI studies. It is therefore imperative that published methods have to be checked by independent sources and no method should be considered infallible.

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