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Popperian Falsificationism in IS: Major Confusions and Harmful Influences

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Abstract:

The current relationship between Popper's philosophy of science and Information Systems (IS) is complex and often confused. On the one hand, many influential members of the IS community claim that much IS research follows Popper's falsificationism. On the other hand, many assumptions underlying Popper's falsificationism, including the nature of theories as exceptionless laws rejected by a singular unsupportive observation are inappropriate and misleading. Moreover, Popper also rejected all inductive inferences and inductive methods as unscientific which, alas, has led some influential IS scholars to dismiss inductive inferences in major IS methodologies. Such Popperian advice is harmful as virtually all statistical or qualitative IS research relies on inductive inferences – and there is nothing wrong with that. Finally, we offer a solution for how to deal with the scientific significance of the problem of induction. This solution is inductive fallibilism. This means recognizing that theories, rather than always being held as true or false simply, often contain varying inductive supportive and unsupportive evidence.

Keywords: Popper, Falsification, Positivism, Natural Science Model, Induction, Scientific Basis for Rigor in IS.

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1 Introduction

Popper's philosophy is highly influential in Information Systems (IS). Several IS sources report that Popperian falsification "dominates much of our research today" (Tanriverdi et al., 2010, p. 830). Numerous influential articles in IS note that Popperian falsifiability is a requirement that "a theory must satisfy in order to be scientific" (Lee, 1989, p. 36). In IS, Popperian (1959, 1963) methodology is often identified with "the scientific method" that "has proved itself over the centuries" (McBride, 2018; see also Smith, 2020). Most IS studies are viewed as "positivist" (Orlikowski & Baroudi, 1991), and "positivism" in IS is often taken to follow Popper's scientific methodology (Gregor, 2018, p. 116). Furthermore, falsificationism, a view associated with Popper, is often deemed "positivist" (Evaristo & Karahanna, 1997; Lee, 1991; Siponen & Tsohou, 2018). Although no philosophy, including Popper's, is universally accepted in IS, many IS articles claim to follow, or allude to, Popper's tenets.

Importantly, Popper's indirect influence is much stronger in IS than direct citations to Popperian philosophy suggest. Many IS scholars cite or base their studies on a methodology grounded in Popperian concepts without citing either Popper or his key concepts. For instance, numerous IS papers claim to follow the hypothetico-deductive (H-D) method by citing Lee (1989, 1991) without citing Popper, a key source of the H-D method presented by Lee (1989, 1991).

Several researchers have critically scrutinized the intellectual foundations of IS. For example, as Salovaara et al. (2020, p. 65) note, the "defining characteristics of a healthy research discipline is [the] ability to correct its knowledge." To do this, we need "a stream of research that critically identifies, analyses, and contests mistakes, theoretically or empirically unfounded claims" (Salovaara et al., 2020, p. 65). The influence of Popperian philosophy in IS is thus in need of a critical review. This is because several influential IS authors suggest that Popperian methodology dominates much of IS research (Tanriverdi et al., 2010, p. 830). However, in the contemporary philosophy of science, core Popperian tenets – including those commonly cited in IS, such as falsificationism – are almost universally rejected. As Musgrave (2004) notes, "most philosophers of science think it [Popper's philosophy of science] is fatally flawed" (p. 19)[1]. Although some critiques of Popper have been voiced in the IS literature (Gregor, 2014; Lyytinen & King, 2004; Seddon & Scheepers, 2015; Siponen & Klaavuniemi, 2020), to date no systematic review of Popperian concepts in IS can be found.

In our critical discussion of Popper in IS, many fundamental assumptions of IS research are at stake. Specifically, this essay argues the following: First, Popper is often misunderstood in IS as many IS research practices presented as Popperian are not actually Popperian. The nature of confusion regarding Popper's philosophy in IS is complex and varies. For example, statistical research in IS claiming to follow Popperian (1959) falsificationism does not actually falsify per Popper, and it should not falsify per Popper. In such cases, the confusion is a misunderstanding of the basic philosophical concepts rather than direct harmful research implications. Although some Popperian confusions also have direct harmful consequences, it is also important to untangle conceptual misunderstandings and minimize their further spread in IS journals and doctoral seminars (Rivard, 2014; Iivari, 2020; Williams & Tsang, 2015). Furthermore, in many cases where Popper's philosophy is correctly understood or followed in IS, some Popperian concepts are unfortunately harmful to IS research. For example, Popperian falsification implies that negative observation contradicting the theory leads one to reject the theory itself. Some methodological guidelines, even those published in *MIS Quarterly*, follow this advice. These beliefs are harmful, as they can hinder scientific progress and the accumulation of knowledge and lead to improper judgments. Finally, we suggest replacing Popper's uncompromising rejection of induction with a more modest form of inductive fallibilism.

2 The Impact of Popperian Philosophy in IS: A Brief Overview

To gauge Popper's influence in IS, we searched for the name "Popper" in the Association for Information Systems (AIS) Basket of 6 journals (MISQ, ISR, JAIS, JMIS, EJIS, and ISJ). We selected these 6 journals due to their AIS status. Although AIS rankings by themselves do not guarantee the quality of a study, they indicate influence. In addition, we searched for the name "Popper" in *Information and Organization* and

[1] "Popper's doctrine gives a correct account of neither the nature of the scientific theory nor of the practice of the scientific community in this case" (Putnam, 1974, p. 92). Lakatos and Feyerabend (1999) remark that how "Popper's philosophy survived for so long is a sociological mystery" (p. 92).

Journal of Information Technology, as these two IS journals are also known for publishing philosophical papers. The search resulted in 46 papers mentioning or citing Popper. In addition, we included in the search widely known Popperian concepts like “falsification/falsificationism” and “corroboration”, which we discuss in this paper. This search yielded 32 papers mentioning falsification/falsificationism and 22 papers mentioning corroboration without citing Popper directly. In sum, we found 100 papers referring to Popperian concepts in IS journals. We refer to these articles as the “sample” (see Appendix A).

Importantly, Popper’s indirect influence is much stronger than these figures suggest. Many IS scholars do not cite Popper directly but cite or base their study on a methodology based on Popperian beliefs. For example, numerous IS papers do not cite Popper but claim to follow the H-D method by citing Lee (1989, 1991). A key source of the H-D method presented by Lee (1989, 1991) is Popper (see also Siponen & Klaavuniemi, 2020). In this paper, we mainly focus on Popper’s *Logic of Scientific Discovery* (LSD) and *Conjectures and Refutations,* as they are by far the most frequently cited Popper works in the sample (see Appendix A). In the interest of transparency and to minimize misinterpretation, we provide direct quotations throughout this paper. Popper’s (1963) work is more than 560 pages long. Citing it without page numbers would make it hard for readers to determine whether our interpretation is justified.

3 A Brief Overview of Popperian Falsificationism and Its Criticism

Popper’s falsificationism has several names. It is helpful to mention some synonyms, which are seldom explained in the IS literature. Many IS scholars refer to Popper’s H-D method (Gregor, 2018; Lee, 1991), which is basically the same as Popper’s falsificationism. Popper also calls falsificationism “conjectures and refutations”, “the method of trial and error”, or the “method of science” (Grünbaum, 1976; Laudan, 1981, p. 1). Popper (1959, p. 7) also calls his falsificationism “the theory of the deductive method of testing” or “deductivism”. In short, the key assumption is that Popperian science advances not by confirming theories, but by falsifying them, that is, showing that theories are false. Next, we briefly mention some key Popperian ideas (Table 1) and their known problems. We discuss IS-specific problems in Section 4.

Table 1. Key Ideas from Popper that are Mentioned in IS Sources
(See also Appendix A for IS Beliefs about Popper)

Popper’s falsificationism	Simple Illustrations of Applications in IS
Theories are developed by “guessing” and “creative imagination” which follow no logic or rules.	Popperian IS scholars would guess the theory and hypotheses without following any predefined logic or rules.
Popperian theory is a universal “all-statement” that contains an exceptionless law.	Any IS theory that ranks as scientific per Popper should be exceptionless “all-statement”. E.g., in the case of IT use, such a theory, if it existed, would be in the form “in *all* cases of IT use [all-statement], ease of use is predicted by IT use”.
Inductive methods (IM) and inductive inferences (IF) are deemed unscientific.	It would be unscientific for Popper to develop a hypothesis/theory from inductive observations. Adding further supportive evidence does not make the theory/hypothesis any truer, acceptable, or probable (IF), for Popper.
Scientists do not confirm or verify theories; supportive evidence at best only “corroborates” the theory.	Popperian IS scientists do not try to find supportive evidence. If they happen to find it, it only “corroborates” the theory, which means that the theory is not yet falsified.
Scientists try to show that theories/hypotheses are false.	Popperian IS scientists put severe tests to show that their theories/hypotheses are false. Most IS studies in IS journals would show that their theories are false or corroborated but not yet falsified.
A single disconfirming observation can falsify the theory/hypothesis.	For example, in the IT use and ease of use context, a singular observation, such as one person not using IT due to ease of use, could falsify the hypothesis/theory on ease of use (per Popper).
Note: This is not a complete treatment of Popper’s philosophy; it reflects Popper’s tenets that are discussed in IS.	

Although most of these Popperian ideas (Table 1) are challenged in the philosophy of science, Popper is correct that guessing, imagination, and speculation may have an important role in scientific discovery (Laudan, 1980; Siponen & Klaavuniemi, 2020). Moreover, Popper is correct that a set of generic rules or predefined logic for the discovery of scientific theories, which would repeatedly lead to scientific breakthroughs, hardly exists (Nickles, 1990; Darden, 1991; Siponen & Klaavuniemi, 2020). For example, as Darden (1991 p. 16) notes, “probably no infallible logic for producing new theories exists; certainly none has yet been found”.

More problematic is Popper’s (1959) wholesale denial of all inductive inferences and inductive methods (Salmon, 1991). However, this is wrong, as inductive generalization can be useful (e.g., some observations inspire theory; Siponen & Klaavuniemi, 2020). Later, after the theory or hypothesis is proposed, it can be inductively confirmed, as scholars try to find further evidence to support the theory (Salmon, 1981), as we note later in the paper. Although inductive generalizations and confirmation are cornerstones in science, Popper denied both as unscientific (Salmon, 1981).

What is a scientific theory for Popper? Popper’s account of theory is a universal “all-” statement, consisting of exceptionless laws, for instance: “Of all points in space and time (or in all regions of space and time) it is true that…” (Popper, 1959, p. 40). A standard criticism is that most scientific theories in most sciences are not exceptionless laws (Putnam, 1974; Craver, 2008).

For Popper (1959), a test of a theory is an attempt to show that the theory is false, and not an attempt to find confirming evidence for the theory. As mentioned, this is problematic because scientists often try to find supportive evidence (Lakatos, 1978). Moreover, Popper’s (1959) notion of falsification, in which a singular observation falsifies a theory, is widely rejected. Popper fails to distinguish falsification (rejection of a theory) from anomalies, as any anomaly would be a refuting instance for Popper. In the philosophy of science, negative tests or observations inconsistent with the theory are called “anomalies” (Laudan, 1977, pp. 26–27). With Popper, a theory, such as “all ravens are black”, is refuted by a singular observation showing one non-black raven. Although this may sound intuitive, scientists often do not reject the theory in the case of a single anomaly or negative test. For example, Laudan (1977) claims that “almost every theory in history has had some anomalities [sic] or refuting instances; indeed, no one has ever been able to point out a single major theory which did not exhibit some anomalies” (p. 27). Similarly, Lakatos (1970) reports that all theories live in an “ocean of anomalies” (p. 135). From Popper’s perspective, this implies that most theories in all scientific domains would have to be refuted or falsified. The main point is that singular observations do not necessarily falsify a theory, in IS or elsewhere, as theories are not collections of exceptionless laws. After noting these Popperian assumptions, we now discuss Popperian tenets in IS.

4 Popperian Beliefs in IS: Major Confusions and Harmful Influences

In this section, we discuss several Popperian beliefs in IS, summarized in Table 2. As noted, although IS scholars cite Popper, Popperian views in IS are not homogeneous, and confusion abounds. For example, many IS scholars in statistical studies claim to falsify by correctly quoting Popper (1959) when they may not falsify in Popper’s sense. This implies a misunderstanding of Popper (1959). Although this particular confusion may not be harmful, it is valuable to clarify such misunderstandings (cf. Rivard, 2014; Iivari, 2020) and try to prevent the spread of further confusion (Williams & Tsang, 2015)[2]. We also argue that in some case study guidelines in IS, and what is called the scientific basis for IS, Popperian falsification has resulted in harmful beliefs, such as dismissing inductive evidence and – wrongly – deeming a lack of anomaly as a hallmark of theory.

Table 2. Popperian Beliefs in IS

Popperian beliefs in IS	Clarification of what Popper actually said	Problems in IS
Popper was a positivist.	Popper was not a positivist, but a critical rationalist.	Confusion about a major concept in IS philosophy.
The development of hypotheses must meet “strict adherence to rigorous rules”.	Hypotheses/theories are typically guessed; this process follows no strict logical rules.	Conceptual confusion, with potentially harmful consequences.

[2] For Rivard (2014), definitional clarity is “indispensable.” Such “deficiency can be particularly harmful because readers will themselves ascribe meanings to constructs, with the risk of ending up with as many meanings as there are readers” (ibid., p. vii). Rivard (2014, p. vi): “I would argue that a manuscript that aims at providing construct clarity… would indeed make a theoretical contribution.”

Popperian theory as a universal (all-) statement.	True Popperian theories are candidates for exceptionless scientific law.	Popperian theories are fully inappropriate in IS, with possible harmful consequences.
Falsification	True Popperian theories are falsifiable.	Possible conceptual confusion and misfit. Falsification is inadequate in IS, with possible harmful consequences.
Popperian falsification is complementary to inductive methods.	Popperian falsification is not complementary to inductive methods, because Popper dismissed any inductive methods as unscientific.	Potential conceptual confusion.
Inductive generalization is not a valid scientific procedure.	True, as Popper claimed that all inductive inferences are unscientific.	This view is unjustified and leads to many harmful consequences within and beyond IS.

These beliefs are discussed next in greater detail.

4.1 Popper was not a Positivist, but a Critical Rationalist

Traditionally, IS research is philosophically divided into "-isms." Most IS studies are viewed as a form of "positivism" (Orlikowski & Baroudi, 1991) which, in IS, is often taken to refer to Popper's scientific method (Gregor, 2018, p. 116). Popper is often presented as a "positivist" in influential IS articles (e.g., Lee, 1991). Given the importance of positivism in IS (Orlikowski & Baroudi, 1991) and Popper being its alleged source, it is necessary to clarify that *Popper explicitly denied being positivist*. As Popper (1976) explains:

> *I was criticized as a "positivist". This is an old misunderstanding created and perpetuated by people who know of my work only at second-hand*. (pp. 289–290)
>
> *the fact is that throughout my life I have combated positivist epistemology, under the name "positivism". I do not deny, of course, the possibility of stretching the term "positivist" until it covers anybody who takes any interest in natural science, so that it can be applied even to opponents of positivism, such as myself. I only contend that such a procedure is neither honest nor apt to clarify matters*. (p. 299)

One core tenet of positivism was the principle of verification, or verificationism, according to which the meaning of any synthetic (empirical) statement is reducible to its verification conditions. Popper vehemently disagreed with this as, for him, scientific theories are never verified. Rather, Popperian methodology is aimed at falsifying hypotheses. Popper himself called his philosophy "critical rationalism" (Siponen & Tsohou, 2018; Treiblmaier, 2019). Although this classification of Popper as a positivist may not be directly harmful in IS, it is crucial to clarify this in order to avoid confusion about basic philosophical concepts used in IS and minimize the further spread of such misinformation.

4.2 Popper on Scientific Discovery and Justification

Popper divides scientific activity into two main phases: the context of discovery and the context of justification (Table 3). This division was common in the philosophy of science around 1920–1960; therefore, it is not unique to Popper (Laudan, 1980).

Table 3. Popper on the Discovery and Justification of Theories

	Discovery of a theory	Justification of a theory
Focus	Invention of the hypothesis; how a hypothesis or theory is invented	Severe testing of the hypothesis
Logic	Does not follow any logic	Follows deductive logic

Citing Popper, Lee (1991) suggests that "hypothetico-deductive logic is a particular way of applying the logic of the syllogism" (p. 345), and it includes "rules of formal logic" and "rules of mathematics" (p. 344).

Others suggest that "the logic of discovery (Popper, 1959) implies the development and testing of hypotheses [and it] requires strict adherence to rigorous rules in order to meet the requirements of research and science" (Hassan et al., 2019, p. 199). We commend these IS scholars for introducing Popper's view of discovery and justification. Having said that, such pronouncements require two clarifications.

First, alas, Popper's (1959) title, *The Logic of Scientific Discovery*, is misleading (Laudan, 1980, p. 173). This is because Popper rejects any logic of discovery whatsoever. Specifically, Popper (1959) does not hold that in the context of discovery, there is "a process that requires strict adherence to rigorous rules" (Hassan et al., 2019, p. 199). In fact, Popper explicitly denies it. According to Popper (1959), the discovery of hypotheses or theories is an "irrational" and "creative process", following no logic. For Popper, formal logic rules apply only to the *justification* of theories.

Second, for Popper (1959), the logic of discovery does not coincide with the logic of hypothesis testing. Testing a hypothesis belongs to the context of justification, and discovery pertains only to how a hypothesis or theory was conceived. Moreover, IS papers that discuss Popper's H-D method often label it "theory testing" (Siponen & Klaavuniemi, 2020). In the IS literature on Popper, theory testing typically means testing already proposed theories (Siponen & Klaavuniemi, 2020). Popper did not require hypotheses to be based on existing theories or literature (Siponen & Klaavuniemi, 2020). Popper's (1959) emphasis on theory testing means that only tests (and related critical discussions) matter in the acceptance of the theory. Put differently, for Popper, how the hypothesis was discovered counts for nothing in the acceptance of the hypothesis (Nickles, 1985). As the name of Popper's (1963) "H-D method" suggests ("bold conjectures and attempted refutations"), scientists discover theory through bold and daring guesses—not from observations or existing theories.

In summary, stating that "the logic of discovery (Popper, 1959) [...] requires strict adherence to rigorous rules" (Hassan et al., 2019, p. 199) is inaccurate. This misinterpretation of Popper can be harmful, as scientific hypotheses/theories can be invented in various ways,[3] as emphasized by Popper. Requiring "strict adherence to rigorous rules" could limit scientific discovery and even lead to following apparently rigorous rules, which may lack evidence of their success (cf. Siponen et al., 2021). Here Popper's view makes sense insofar as it acknowledges various ways of inventing hypotheses, including speculation and guessing.

4.3 Popperian Conception of Theories as Sets of Universal Statements

For Popper (1959), the scientific knowledge is captured by theories. In general, theories are viewed as important in IS as well: A "required element" for any excellent paper is that it "sufficiently uses or develops theory" (Straub, 2009, p. vi). What constitutes a theory? Many IS scholars rely on Popper to provide the basic characteristics of scientific theory (Gregor, 2006; Kuechler & Vaishnavi, 2012)[4]. This raises the questions of what a theory for Popper is, and whether Popper's idea of theory is useful in IS.

According to Gregor (2006, pp. 614–615), "Popper (1980) held that theorizing, in part, involves the specification of universal statements in a form that enables them to be tested against observations of what occurs in the real world." Gregor (2006) interprets Popper correctly. However, it is important to clarify the nature of Popper's "universal statements" (p. 37) to understand their applicability in IS theory. Popper (1959, p. 40) calls a scientific theory "an all-statement, that is a universal assertion about an unlimited number of" something. An example of an all-statement is: "Of all harmonic oscillators it is true that…" (Popper, 1959, p. 40)[5]. Popper's (1959) scientific theories consist of laws, which are universal all-statements.

Is Popperian scientific theory useful in IS? No, as generally IS theories and models in qualitative or quantitative research are not a "universal assertion about an unlimited number of" something. If we conduct a qualitative case study in a few organizations, the findings typically do not lend themselves to universal generalizations, such as "all men are mortal." A Popperian theory as an "all-statement", or an exceptionless law, fares no better as a standard for statistical research in IS. Theories in statistical IS

[3] "No explicit general logic of discovery underlies either historical or contemporary scientific work, nor has any methodologist succeeded in formulating such a method despite centuries of attempts to distill science is this fashion" (Nickles, 1990, p. 11).
[4] "It has taken more than 350 years, from Francis Bacon (1994/1620) to Karl Popper (1989), to define and refine the Western scientific notion of 'theory'" (Kuechler & Vaishnavi, 2012, p. 396).
[5] "By contrast, statements which relate only to certain finite regions of space and time I call 'specific' or 'singular' statements" (Popper, 1959, p. 41).

research contain hypotheses, which are ultimately probabilistic or frequency statements, or statements of tendencies. Consider ease of use, which explains IT use (Davis, 1989). It should not be read as “of all IT users, it is always true that ease of use explains IT use”. The outcome of statistical studies in IS is typically a statistical generalization. In turn, laws or theories, according to Popper, offer universal generalizations, such as “All As are B”.

In summary, it is misleading to refer to Popperian (universal) theories in IS. Popper’s conception of theory and law is simply inapplicable in IS, whether IS scholars use process (i) or variance theories (ii), statistical models and hypotheses (iii), qualitative research (iv), or design science research (v). Also, generally, IS scholars should not deem explanatory or predictive theories per Gregor (2006) exceptionless, although Gregor (2006 p. 614) refers to Popperian view of theory as “universal statements”. Popper assumes that theories are universal “all-statement” claims, while IS theories and models are not. Popper’s falsificationism is especially problematic when the scientific theories do not primarily consist of universal claims, as we discuss next.

4.4 Falsification

The most common Popperian concepts mentioned in IS articles are falsification, falsificationism, and falsifiability. Many IS authors trace these concepts back to Popper (e.g., Wernick & Hall, 2004); see Table 2. In addition, several other IS authors refer to falsification, falsificationism, falsifiability, or similar concepts without any explicit reference to Popper (Mcavoy & Butler, 2009). These terms are widely known as Popperian concepts. For example, dictionaries of philosophy link falsification to Popper (Mautner, 1996, p. 147; Psillos, 2007, p. 90). Still, it is possible, in theory, that someone could use “falsification” in a different sense than Popper. To address this matter, in this section, we discuss falsifications that either directly or indirectly cite Popper or present the idea as that of Popper (1959) (see Table 4).

Table 4. Some IS Examples that Manifest the Importance of Falsification in IS

Selected IS examples of the importance of falsification	Author(s)
“For a theory to be regarded as falsifiable, it must be possible to refute its constructs and propositions by experience” (Popper, 1959)” (p. 281).	Briggs et al. (2008)
“Motivated by Popper’s (1959) view on falsification, they argue a theory benefits if scholars pursue its failure because more faith can be placed in robust theories” (p. 1313).	Burton-Jones et al. (2017)
“As in all scientific research, hypotheses must be stated in a manner that is falsifiable (refutable) (Popper 1992)” (p. 58).	DeLuca et al. (2008)
“Popper (1968) argues that the primary criterion of the scientific status of a model is its falsifiability, or refutability, or testability” (p. 266).	Dhar et al. (2014)
“In the Popperian model of science (1968) on which the hypothetic-deductive paradigm is based, we should be looking to falsify or reject our theories using the best and strongest tests available” (p. 648).	Evermann and Tate (2011)

Apparently, many IS authors explicitly highlight the standard account of Popperian falsification; see Table 4. For example, “[t]he H-D logic emphasizes falsification in hypothesis testing such that a single instance of disconfirming evidence is logically sufficient to refute a hypothesis” (Zhang, 2017, p. 829). Similarly, according to Ngwenyama and Nørbjerg (2010), a single case study can falsify a theory. They base their view on Popper (1959) and Lee (1989)[6]. According to the scientific method for case studies, “the theory, while falsifiable, must survive the actual attempts made at its falsification” (Lee, 1989, p. 36). Lee (1989, p. 36) connects falsification with “observation that contradicts a prediction.” Weber (2012, p. 16) notes, in line with Popper, that we cannot test all instances of a theory. However, a theory can be falsified (Weber,

[6] “It has been convincingly argued that a single case study can falsify an existing theory (Popper, 1959; Campbell, 1975; Lee, 1989)” (Ngwenyama & Nørbjerg, 2010, p. 305).

2012, p. 16). A number of IS papers (e.g., Wheeler, 2002, p. 141) claim to satisfy the requirement of falsifiability outlined by Lee (1991). The account that one observation can disprove a theory is also advocated by Lee and Hubona (2009).

There is nothing wrong in requiring that scientific hypotheses and theories should be testable. What is the problem with Popper's falsification then? As noted above, Popper takes scientific theories to be universal "all-" statements for the form "all As are B" (Giere, 1988, p. 37). According to Popper's (1959) standard interpretation, theories can be falsified by singular observational evidence showing "This A is not B" (Giere, 1988). To illustrate, "all ravens are black" can be falsified by observing a single raven that is not black. Moreover, Popper's (1959) falsification assumes that any theory, if it is going to be ranked as a scientific theory, must be falsifiable. This is also Popper's criterion for demarcating science from pseudoscience. However, as mentioned, statistical claims in IS hardly ever are of the form "all As are B". As noted, the TAM's ease of use should not be read as "all As are B"; that is, "*all* cases of IT are predicted by ease of use". Therefore, it does not make sense to falsify statistical claims in IS by showing "this A is not B", for example, showing the case of one person where IT use is not predicted by IT use. For IS statistical studies, we can always expect to find at least a singular refuting instance in terms of Popper ("this A is not B"). Thus, virtually all statistical studies in IS would be falsified from the outset. The same applies to qualitative studies. Basically, all qualitative theories applied in IS (and all models in IS based on qualitative research) would be falsified by Popper's light, as one is expected to find a singular non-confirming observation (this A is not B) for virtually all theories.

Consider, for instance, what is known as the positivist case study method, which claims to satisfy "the standards of the natural science model of scientific research" (Lee, 1989, p. 33). It requires Popperian falsifiability as "one requirement that a theory must satisfy in order to be scientific" (Lee, 1989, p. 36). To be more precise:

> *an observation that contradicts a prediction would be sufficient to cast doubt on (perhaps to the point of falsifying) the theory from which the prediction follows. On the other hand, an observation that confirms a prediction is never regarded as conclusively establishing the theory's truth*. (Lee, 1989, p. 36)

This recommendation, despite being in line with Popper (1959), is questionable: "virtually every scientific theory ever devised, including those accepted by scientists today, has anomalous instances" (Laudan, 1977, p. 37). A single anomaly, a negative observation contradicting the theory, hardly leads one to reject the theory. The positivist case study method (Lee, 1989), like Popper, fails to distinguish anomalies from falsifications. We should not falsify a theory based on one observation that contradicts the observation. For example, 1) habit or 2) ease of use as predictors of IT use should not be falsified, simply because there is "an observation that contradicts" the prediction.

For the sake of the argument, what if "a single instance of disconfirming evidence" (Zhang, 2017, p. 829) does not mean a "singular observation", but the statistical test result at the sample level in one study? This would still result in the rejection of most, perhaps all, widely tested theories in the social sciences and IS. We are not aware of any widely tested theory in IS or other social sciences that has never received unsupportive test results in some context throughout its history. As Lakatos (1970, p. 5) notes, all theories, "at any stage of its development, has unsolved problems and undigested anomalies." For example, in IS security, deterrence theory and the protection motivation theory are perhaps the most frequently used theories in studying security behavior (Straub,1990; Johnston & Warkentin, 2010). In both cases, there are disconfirming findings (e.g., Haag et al., 2021; Siponen et al., 2022). Nevertheless, these theories should not be regarded as falsified.

In summary, Popper's (1959) falsification treats one anomaly (even a singular observation: this A is not B) as a refuting instance. This is overly demanding, "as virtually every theory ever devised" contains anomalies (Laudan, 1977, p. 37). Popper's falsification fails to distinguish between *anomalies* (disconfirming evidence) and *falsifications* (evidence leading to the definitive rejection of a theory). In science, some anomalies can be more important than others. Popper's philosophy fails to account for this (Laudan, 1977). Accordingly, IS research should reject Popper's (1959) falsificationism as too demanding. Popper's falsification can lead to harmful consequences in IS. Consider: "it has been convincingly argued that a single case study can falsify an existing theory (Popper, 1959; Campbell, 1975; Lee, 1989)" (Ngwenyama & Nørbjerg, 2010, p. 305). This is simply too demanding, and it can lead to inappropriate judgments. For example, if in one case ease of use does not predict IT use, it does not mean that one should falsify the idea of ease of use as a potential predictor of IT use.

4.5 Popper and Inductive Inferences

There are other reasons why Popperian philosophy is harmful in virtually all empirical research traditions in IS. Popper rejected inductive generalizations and inductive inferences, whereas practically all empirically tested IS theories—in any IS research tradition—rely on inductive inferences. These issues are discussed in this section.

4.5.1 Popper Rejected Inductive Methods and All Inductive Inferences

Popper explicitly rejected the principle of induction and all inductive methods:

> *According to a widely accepted view—to be opposed in this book — the empirical sciences can be characterized by the fact that they use "inductive methods", as they are called.* (Popper, 1959, p. 3)

Popper's rejection of inductive methods is mentioned in IS (Gregor, 2018; Mingers, 2004, p. 89; Silva, 2007, p. 256). At the same time, some IS papers present induction as an alternative or complementary method to Popper's falsification or H-D method (e.g., Salovaara et al., 2020, pp. 65, 66–67). However, induction and inductive methods are not compatible with the Popperian H-D method or Popper's falsificationism, as Popper himself eschewed any inductive inference as unscientific.

This may seem surprising for many IS readers, as numerous IS articles divide research approaches into deductive and inductive (e.g., Avison & Fitzgerald, 1996; Birks et al., 2013) or inductive, deductive, and abductive (e.g., Braganza et al., 2009). More than 100 studies on IS describe most (IS) research as deductive (e.g., Chatterjee et al., 2015). We learn, for example, that "science is often deductive" (e.g., Baskerville et al., 2015), deductive is "the dominant research designs" (Chen & Hirschheim, 2004), or "scientific method, in the form of the deductive testing of theories, is widely known" (Lee, 1989, p. 36). But there is a catch. What is hardly ever stated in IS is that virtually all approaches, whether they are called inductive, "deductive", or abductive, rely on inductive inferences. And Popper rejected all inductive inferences as unscientific. In such circumstances, it is necessary to characterize inductive methods, an inductive inference, and then some relevant connections to IS.

Let's begin with inductive methods. Traditionally, in IS, inductive methods are methods in which theory "is derived from data" (Gregor, 2006, p. 622). Along the same lines, Popper (1963) deems methods "inductive" when they "proceed from observation or experiment" (p. 44). We have no complaints about these characterizations. For example, in a study following inductive methods, a theory or set of hypotheses is derived from empirical observations (e.g., interviews) rather than derived from theory. Currently, not all approaches use inductive methods, such as those where the hypotheses are taken from other theory as opposed to empirical observations. However, virtually all IS approaches—even those called "deductive" and abductive—use and rely on inductive inferences or inductive logic. What, then, is an inductive inference?

An inductive inference is an "inference from a finite number of particular cases [I observed several black ravens] to a further case [the next raven is black] or a general conclusion [all ravens are black]" (Mautner, 1996, p. 207)[7]. How does this relate to IS research? IS scholars typically engage in generalizations in qualitative, statistical, or design science studies (Table 5).

Table 5. Examples of Inductive Inferences in Qualitative and Statistical Studies

Selected IS study types	Selected IS examples of inductive inferences	Inductive inference	Why these inductive inferences are necessary
Statistical study of IT use	Generalization from a sample (e.g., 200 IT users) to a population (e.g., IT users in	**Inductive inference:** From a sample to a population. The inference from a sample to a	If such inductive inference were removed, not used, or banned, then statistical studies in IS would be pointless.

[7] Logicians deem induction an invalid inference because the truth of the premise ("I observed black ravens") does not ever guarantee the truth of the conclusion dismissing inductive inferences and confirmation ("the next observed raven must be black"). It is possible in principle that the next raven observed is not black.

	general).	population of IT users is inductive.	
Case study of IT investment	Generalization of the findings from cases (e.g., three cases) to beyond these cases (e.g., other organizations).	**Inductive inference:** Generalization of the findings from the cases to beyond these cases.	If such inductive inference were removed, not used, or banned, then case studies would not generalize beyond their cases.
Interview study of IT investment in Swedish banks	Generalization of 20 interviews from two Swedish banks to other banks.	**Inductive inference**: generalizing 20 interviews from two banks to other banks (beyond these two) is inductive inference.	If such inductive inference were removed, not used, or banned, then we could not generalize anything beyond the 20 interviews.

Virtually all generalizations in IS are inductive, although some IS scholars suggest otherwise (e.g., Grant & Ngwenyama, 2003; Lee & Baskerville, 2003). Very rarely IS methodologists describe generalizations as inductive. Consider a case study of two Swedish banks. If we generalize the findings to other banks, in Sweden or elsewhere, beyond these two, we make an inductive inference. In turn, if we conduct a statistical study in IS with a specified sample size and generalize the findings beyond the sample, we make an inductive inference (Williams & Tsang, 2015). As Niiniluoto (1976, p. 358) reported, "probabilistic explanations of statistical generalizations concerning particular finite populations are inductive in their character." Similarly, Popper (1959, pp. 3–4) characterizes induction as follows:

> *It is usual to call an inference "inductive" if it passes from singular statements (sometimes also called "particular" statements), such as accounts of the results of observations or experiments, to universal statements, such as hypotheses or theories.*

Popper (1963) rejected all inductive inferences as unscientific:

> *Induction, that is inference based on many observations, is a myth. It is neither a psychological fact, nor a fact of ordinary life, nor one of scientific procedure.* (p. 53)

To summarize, Popper rejected both *inductive methods* and *inductive inferences*. With inductive methods, a theory or set of hypotheses "is derived from data" (Gregor, 2006, p. 622; see also Iivari, 2023). However, most IS researchers actually use inductive inferences even if they do not use "inductive methods" – see Table 5. Even those who claim to use the most common approach in IS, dubbed "deductive", most likely also rely on inductive inferences (see Table 5). Virtually any generalization in qualitative or statistical research is an inductive inference (Table 5), and Popper would have accepted none of them. Is Popperian philosophy sound here? What is Popper's concern about induction, and is this concern valid in IS? These questions are addressed in the next section.

4.5.2 Inductive Fallibilism and the Scientific Problem of Induction

Popper's concerns pertain to the so-called problem of induction, which has raised potential confusion in IS. For example, Lee and Baskerville (2003) devote several pages to the problem of induction and use it to challenge statistical inference. A complete, uncompromising rejection of induction, however, ends up throwing out the baby with the bathwater. This is because it would render any generalization beyond observation unscientific (Williams & Tsang, 2015; Tsang & Williams, 2012). Seddon and Scheepers (2015) consider the problem of induction to be insoluble. They view the whole discussion of the problem of induction as a "red herring".

We advance a proposal on the scientific relevance of the problem of induction, and the vast majority of philosophers of science would embrace the inductive fallibilism we propose here (see Laudan, 1983). The qualification "scientific relevance" is important as we separate scientific problems from philosophical/logical ones. The solution is a form of *inductive fallibilism*. Next, we explain Popper's concern with inductive inferences in detail and our proposal. For starters, some background information. According to Gregor (2018, pp. 116–117), Popper's concerns with induction are grounded in his observation that induction cannot provide "certain knowledge." Similarly, Silva (2007) notes that inductive generalizations are not invariably true. According to Silva (2007, p. 256), "Popper indicates that no matter how many white swans an observer reports, these observations would not confirm the theory as necessarily being true." Although induction cannot provide certain knowledge, Popper also maintained that the problem of induction cannot be solved.

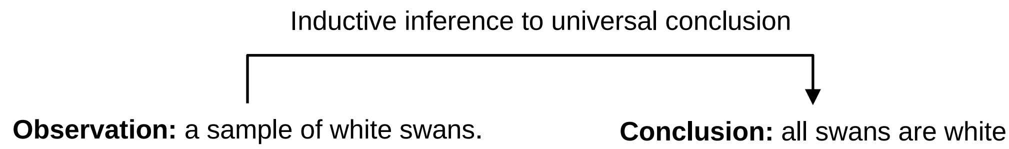

Figure 1. An Inductive Universal Generalization.

However, what does it mean to assert that inductive inferences cannot provide certain knowledge? We cannot know with 100 percent certainty that the next observed swan will be white (Figure 1). Silva's (2007) example is a universal generalization. However, generalizations from observations beyond the observations in IS (whether one uses statistical or qualitative research methods) are seldom universal. Nevertheless, this point still applies. Consider ease of use. If we have a number of observations where ease of use explains IT use, we cannot know for 100 percent certainty that the next observed case of IT use will be explained by ease of use. The issue then becomes the following: Inductive inference—generalization beyond observation (e.g., sample)—cannot yield 100 percent certainty. In other words, it cannot give such certainty that the generalization from the observations always matches (100 percent) with the observation. This can be dubbed the uncertainty of inductive knowledge. One natural conclusion from the uncertainty of inductive knowledge is inductive fallibilism. It is the thesis that scientific knowledge is always fallible. For example, if we conduct a case study on IT investment in Swedish banks, we cannot know with 100 percent certainty that the findings for one case apply beyond the observations. For example, we cannot be 100 percent certain that the same applies to other Swedish banks or other cases of IT investment.

Although Popper was a fallibilist (Klein, 2004, p. 139), his view of inductive inference is more radical than inductive fallibilism, that is, the uncertainty of inductive knowledge. The reason is simple. Popper rejected any inductive moves as unscientific (Popper, 1963, p. 53). Popper's view is questionable, as virtually all statistical studies, in IS as elsewhere, assume inductive inferences by generalizing the results beyond the sample (Table 5). Moreover, if qualitative IS studies generalize their findings beyond their observations, then this activity is inductive. Therefore, it is wrong to claim that scientists in IS or elsewhere do not use inductive inferences. Popperian IS scholars could reply that IS researchers who use inductive inferences are conducting questionable research practices. In fact, Baskerville and Lee (1999, p. 58) conclude, echoing Popper, that "inductive generalizing is not a valid scientific procedure". Still, according to Baskerville and Lee (1999), IS scholars apply inductive generalizability because they do not know it "to be incorrect" (p. 58). These claims are understandable if one's philosophical understanding is based on Popper (1959). Still, such claims are clearly false, and they offer misleading guidance to the IS community. All empirical sciences rely strongly on inductive inferences, making generalizations beyond observations (Salmon, 1981).

We offer the following suggestion for how the IS community should treat the scientific problem of induction. Inductive inferences are frequently used in science, and IS is no exception, although the IS community by and large may not have recognized that virtually all IS research practices (including those dubbed "deductive" and abductive) rely on inductive inferences. We should not flatly dismiss inductive inferences as unscientific. Inductive fallibilism is a much more reasonable position than Popper's wholesale rejection of induction. Inductive inferences play a prominent role in science, and any adequate scientific basis for IS must account for them. At the same time, with inductive fallibilism, we acknowledge that inductive inferences can be fallible.

5 Discussion

Our review of Popper's philosophy has several implications for IS research and practice. First, the IS community must understand that virtually all theories face anomalies (disconfirming observations), and one observation contradicting what the theory predicts or explains (an anomaly) seldom leads to a rejection of the theory. Numerous IS papers imply, following Popper, that a single negative observation should refute a theory. Popper's falsification correctly implies that one can falsify universal laws, such as "all men are mortal" (Lee, 1989), with a single observation. However, the situation is different with probabilistic (statistical) or qualitative studies in IS. As noted, we should not assign universal generalizability to qualitative or statistical studies in IS. In qualitative and quantitative studies, we should also account for inductive evidence of confirmation and disconfirmation (Siponen et al. 2023). As a result, any adequate scientific method must separate anomalies (disconfirming observations) from falsifications (a theory is definitively rejected). For example, case studies on IT investment may explain well in certain settings in certain types of organizations, be less explanatory in other settings, and be non-explanatory in yet another type of setting. Many IS methodologies, such as the scientific case study methods (Lee, 1989), the case study method for critical realism, and the scientific basis for rigor (Lee & Hubona, 2009), must be revised to account for the fact that theories in indeterministic settings are expected to get varying (inductive) support and counter-support.

Second, we propose inductive fallibilism in place of a wholesome rejection of all forms of induction *à la* Popper. The problem of induction, as presented by Popper, has raised criticisms and controversies in IS. Seddon and Scheepers (2015) view the problem of induction as insoluble. Others deem the Hume–Popper problem of induction solvable, but they do not know what the solution is (Tsang & Williams, 2012, p. 732). Seddon and Scheepers (2015) view the whole discussion of the problem of induction as a "red herring". Our view is as follows. Sometimes, philosophical or logically relevant problems do not go hand in hand with scientifically relevant problems. For example, the problem of induction in philosophy is whether we can justify induction in a non-circular way. However, this leads to thorny problems that are philosophically interesting, but their relevance to scientific practice is not clear[8]. One may note with Giere (1988, p. xv), "philosophical discussions of induction seemed so remote from scientific practice." What is the takeaway for scientific practice regarding induction? In a nutshell, let's assume some form of inductive fallibilism, IS generalizations may not necessarily hold beyond the observations and may be corrigible. If we accept inductive fallibilism, we should also accept the need to publish negative findings and replications. Based on our understanding, the extant discussion of the problem of induction (Baskerville & Lee, 1999; Gregor, 2018; Seddon & Scheepers (2015)) has not suggested that the scientific relevance of the problem of induction is inductive fallibilism. However, it could be that at least some of these scholars (Seddon & Scheepers, 2015) could accept our proposal. It is also possible that many IS authors who describe their approach as "Popperian falsification" or following Popper's "deductive method" do not actually follow Popper. Rather, they use inductive inference and follow inductive fallibilism.

Now, if we accept inductive fallibilism, where does this lead us, in addition to merely deeming inductive knowledge fallible? One approach is to obtain more observations, if the aim is generalizability beyond observations. Medical treatments, for example, move toward stronger tests and larger sample sizes. A similar approach is possible with statistical research or qualitative research in IS. If we have a single case study on IT investment in Swedish banks, we try to obtain more cases. This approach of having more observations, of course, does not mean that we can have 100 percent certainty for our generalizations. However, comparatively, we should prefer to say five cases over one case as a basis for generalizations, all other things being equal.

Third, critical research and negative results have been reportedly difficult to publish in IS, and falsification has been proposed as a solution for publishing criticism and negative results (Salovaara et al., 2020). This approach assumes that "approaches subscribing to falsificationism are knowledge-contesting", and falsification is useful in "identifying existing theories' boundary" (Salovaara et al., 2020, pp. 66–67). Others see it as harmful and incorrect when IS authors report that their studies are not generalizable to certain settings[9]. Is publishing critical and negative results useful, then? Yes, both are useful because they show the limits of our theories. Is Popper's falsification useful for attaining these goals? Unfortunately, Popper's falsificationism commits us to several other overly demanding tenets, for example, it ignores the inductive inferences important in science and does not distinguish anomalies from falsification. Moreover, recognizing inductive support or the use of inductive methods does not rule out knowledge-contesting or

[8] Hume's traditional problem of induction challenges us to justify induction itself, that is, to explain what ground we may have to believe in the principle of induction. But since the principle of induction cannot be justified deductively, it must be justified inductively. This generates a problem of circularity: in order to justify induction, we need to assume the very principle we are trying to explain.

[9] "It is incorrect and even harmful that many information systems researchers typically criticize their own intensive (qualitative, interpretive, critical, and case) research as lacking generalizability" (Baskerville & Lee, 1999, p. 49). They view this self-report on the lack of generalizability as "self-flagellation" (ibid., p. 50), which is "also harming the overall reputation of the academic discipline of IS" (p. 59).

disconfirming findings[10]. We must recognize inductive inferences and inductive evidence in a confirming and non-confirming manner. Yet we can subject them to further criticism without assuming Popper's falsification. In sum, criticism and fallibilism are important in scientific practice (Laudan, 1983). However, we can cultivate these goals without Popperian falsification.

Finally, what is actually Popperian falsification in IS? Much of IS research is reported to follow Popper's scientific method (Tanriverdi et al., 2010, p. 830). We contest this view, especially in the case of statistical studies, which rely on inductive inferences, and inductive confirmation, and thus hardly follow Popperian falsificationism (that is, deductivism). Pointing this out is important. Given that much of statistical IS research may not follow Popper, the philosophical underpinnings of "much of IS" research, therefore, remain an open question for future research. We do not think that Popper's falsificationism should be used in IS. However, those advocating Popperian falsification in IS must show how it can be revised as a viable approach.

6 Conclusions

The Popperian method is influential in IS. However, many IS authors, even those claiming to follow the Popperian method, especially in statistical research, do not really follow it. As an example, statistical research in IS claiming to follow Popperian (1959) falsificationism does not actually falsify per Popper and it should not falsify per Popper. In such cases, the confusion is a misunderstanding of basic philosophical concepts (falsification, inductive inference). It is necessary to clarify conceptual misunderstandings and minimize their further spread in IS journals and doctoral seminars (Rivard, 2014; Iivari, 2020; Williams & Tsang, 2015). Given that much IS research does not follow Popper, the task remains for IS philosophy to outline the philosophical underpinnings of the alleged IS methodology. This is an important task because many mainstream IS research activities are too far from Popper's philosophy of science to be explained in light of Popper. Moreover, in many cases, when Popper's philosophy is correctly understood or followed in IS, some Popperian concepts are unfortunately harmful to IS research. For instance, Popper's influence has led some IS scholars (e.g., case studies) to dismiss inductive inferences and inductive evidence. Virtually all statistical or qualitative IS research uses inductive inferences, and there is nothing wrong with that. This is because IS generalizations from a sample to a population, or generalizations from qualitative case studies beyond these cases are inductive inferences. Furthermore, Popper's philosophy may mislead some IS scholars to view anomalies as tantamount to falsifications. We have advocated inductive fallibilism over Popper's rejection of induction. Method accounts influenced by Popper (e.g., scientific case study, scientific basis for rigor) must distinguish anomalies from falsifications. Regarding Popperian theory, serious harmful misunderstanding results if a Popperian universal theory or law is imposed on statistical or qualitative theories in IS. Most likely no IS theory consists of Popperian exceptionless laws. Finally, Popperian philosophy also contains several key points for IS research, such as the role of speculation and serendipity in theory discovery, seeking disconfirming evidence, striving to disprove theories, correcting errors, and the importance of publishing critical and negative results. However, these can be pursued without commitment to Popper's falsificationism, which commits us to several other overly demanding tenets.

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[10] "Hume's problem has led to philosophers and scientists becoming increasingly convinced that knowledge expanding research requires a counterpart for seeking not just to generate claims or confirm them but also to test them critically. This is what approaches drawing from falsificationism provide. The approaches subscribing to falsificationism are knowledge-contesting" (Salovaara et al., 2020, p. 66).

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Appendix A: IS Beliefs about Popper

To grasp how Popper's philosophy is understood in IS, two people independently systematically analyzed all articles referring to Popper, falsificationism, and corroboration in the sample. The most frequently cited work of Popper in the sample (n = 28) was his first book, *Logik der Forschung*, published in 1934. The English translation *The Logic of Scientific Discovery* (LSD) appeared in 1959. The count includes reprints of LSD from 1968, 1980, 1992, and 2002. The famous concept of falsification was outlined in LSD. In 1945, Popper wrote on political theory, *The Open Society and Its Enemies*, cited only once in the sample. Popper's second influential philosophy of science book was *Conjectures and Refutations* (1963). In the sample, this was also the second most cited (n = 16) work by Popper.

Table A1. Our Sample of IS Papers Referring to Popperian Concepts

Criterion	number
mention falsification but not cite Popper's	32
mention corroboration but not cite Popper's	22
cite Popper's works	46
total	*100*

Table A2. Popper's Works Cited in Reviewed Journals

Work	count
The Logic of Scientific Discovery (1934, 1959, 1968, 1980, 1992, 2002)	28
Conjectures and Refutations (1963, 1965, 1968, 1972, 1989, 2003)	16
Popper's Three Worlds (1978)	3
Unended Quest an Intellectual Autobiography (1986, 2002)	2
Objective Knowledge (1972, 1979)	2
Normal Science and Its Dangers (1970)	2
The Poverty of Historicism (1957)	1
The Aim of Science (1957)	1
The Problem of Demarcation (1974)	1
The Open Society and Its Enemies (1945)	1
total citations:	*57*

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