Author(s): Siponen, Mikko; Klaavuniemi, Tuula

Title: Why is the hypothetico-deductive (H-D) method in information systems not an H-D method?

Year: 2020

Version: Accepted version (Final draft)

Please cite the original version:

Siponen, M., & Klaavuniemi, T. (2020). Why is the hypothetico-deductive (H-D) method in information systems not an H-D method?. Information and Organization, 30(1), Article 100287. https://doi.org/10.1016/j.infoandorg.2020.100287

Forthcoming in *Information and Organization*

Why is the hypothetico-deductive (H-D) method in information systems not an H-D method?

Mikko Siponen and Tuula Klaavuniemi

Abstract

The hypothetico-deductive (H-D) method is reported to be common in information systems (IS). In IS, the H-D method is often presented as a Popperian, Hempelian, or natural science method. However, there are many fundamental differences between what Popper or Hempel actually say and what the alleged H-D method per Hempel or per Popper means in IS. To avoid possible misunderstanding and conceptual confusion about the basic philosophical concepts, we explain some of these differences, which are not mentioned in IS literature describing the H-D model. Due to these distinctive differences, the alleged H-D method per Hempel or per Popper in IS cannot be regarded as the H-D model per Hempel or per Popper. Further, the H-D model is sometimes confused with another model in IS, the deductive-nomological (D-N) model of explanations. Confusing the H-D and D-N methods can also produce stagnation in the fundamental methodological thinking in IS. As one example, the H-D model (per Hempel or per Popper) does not require hypotheses to be based on existing theories or literature. As a result, misunderstanding the H-D model in IS may seriously limit new hypothesis or theory development, as the H-D model in the philosophy of science allows guessing and imagination as the source for hypotheses and theories. We argue that although IS research (1) generally does not follow the H-D method (per Hempel or per Popper), and (2) should not follow the H-D method, (3) we can still learn from the H-D method and criticisms of it. To learn from the H-D method, we outline method of hypothesis (MoH) approaches for further discussion. These MoH approaches are not hypothetico-deductive, but *hypothetico-inductive-qualitative* or *hypothetico-inductive-statistical*. The former MoH

endeavors to be suitable for qualitative research, while the latter is aimed for statistical research in IS.

Keywords: Hypothetico-deductive; Hypothetical-deductive; Hypothesis; Theory testing; Guessing

1. Introduction

Many IS studies report that the hypothetico-deductive (H-D) approach is the most common research approach in IS. For example, Orlikowski and Baroudi (1991) found that most IS papers follow "hypothetico-deductive logic" (p. 9). About ten years later, Vessey et al. (2002) reported "hypothetico-deductive approaches" are the most common approach in IS. More recently, it is reported that H-D "remains the dominant approach within IS research not only in North America but also in Europe" (Hassan et al. 2019 p. 200) and "the hypothetico-deductive research…crowds the pages of our journals" (Hassan 2017 p. 319). Some IS authors also report that the H-D method is common in social science: "the Popper-Hempel 'hypothetico-deductive' model…still influence[s] social science research today" (Smith 2006 p. 193). IS scholars view the H-D method as the method of the natural sciences (Lee 1991; Mingers & Standing, 2017), or "has roots in natural sciences" (Orlikowski & Baroudi 1991), is positivistic (Orlikowski & Baroudi 1991; Lee 1991), or is Popperian or Hempelian (Gregor 2018 p. 116; Lee 1991; Smith 2006). All these authors can be credited for introducing the H-D philosophy to IS.

Many H-D claims in IS appear justified. For example, it is true that Hempel (1966) and Popper (1935/1959, 1963) are among the most well-known advocates of the H-D approach in the philosophy of science literature (Achinstein, 1970; Nickles 1985; Snyder 1997)[1]. It is also true that the H-D approach by Popper (1935/1959) or Hempel (1966) was also influenced by natural science

[1] The H-D method is also called "the method of hypothesis" in the philosophy of science (Laudan 1977a; 1981 p. 1). Hempel (1966) refers to "the method of hypothesis" (p. 17). Popper (1963) often uses the term "conjectures and refutations" (see also Laudan 1981 p. 1).

and medical research. Moreover, IS authors describe the H-D method as theory testing or theory-based (e.g., Barkema et al. 2015; Kumar et al. 1998; Loock et al. 2013; Walsh 2015), and (we argue that) it is not wrong to say that the H-D method (per Hempel or per Popper) emphasizes theory testing.

Closer scrutiny will show that what IS research often assigns to the H-D method—or the H-D method per Hempel or per Popper—is different from the H-D method (per Hempel or per Popper) in important ways. Such differences are not mentioned by the H-D method articles in IS. Due to these differences, it can be misleading to imply that IS studies follow H-D (logic) per Hempel or per Popper.

Our paper contributes to IS by untangling conceptual and philosophical confusions about basic philosophy of science concepts, such as the H-D method (per Hempel or per Popper), and its relation to the deductive-nomological (D-N) model and statistical hypotheses. For example, the H-D method (per Hempel or per Popper) recognizes guessing and imagination in proposing new theories and hypothesis. Mistaking these important implications of the H-D method in IS can fundamentally impede theory development by unnecessarily limiting hypotheses and theories to those already propounded in existing theory and the literature.

We also contribute to IS by sketching the naturalistic method of hypothesis (MoH) approaches, which are influenced by some of the strengths and weaknesses of the Popperian H-D method.
As a philosophical account that aims to understand science as scientists do it (see section 4.1), our MoH acknowledges that often guessing, speculation, and serendipitous findings have been major factors in developments within the natural sciences and medical research. However, our approach also eschews finding a global *a priori* logic or stepwise manual for scientific discoveries that

precludes other possible approaches. We postulate that imposing a global, stepwise manual for scientific discoveries may prevent such discoveries.

2. The hypothetico-deductive approach in IS and the philosophy of science

In this section, we discuss a number of reasons why the reported H-D method in IS cannot be regarded as the H-D method (per Hempel or per Popper). We also explain differences between the reported H-D method in IS and the H-D method in the philosophy of science. Some of the differences are summarized in Table 1. All IS papers cited have made numerous contributions to IS research, and any criticism we provide (even if correct) does not negate the many other merits of these IS papers.

Table 1. Some of the differences between the H-D method reported in IS and in the philosophy of science. This paper does not contain a complete description of the H-D per Popper or per Hempel.

H-D method in IS	**H-D method in the philosophy of science**
Stemming from natural science, advocated by Hempel and Popper	Hempel and Popper are perhaps the most well-known advocates of the H-D method in the philosophy of science, and their accounts somewhat reflect natural science.
Hypotheses are based on existing theories or literature.	Hypotheses can be guessed or imagined by scientists. They can contradict 1) *all* existing theories and 2) *all* existing literature. In fact, for Popper good hypotheses do this.
For some others, hypotheses are based on observations or developed inductively.	Typically, inductively generated hypotheses and hypotheses derived from observations are eschewed.
The source of the hypothesis has weight in the acceptance of the hypothesis.	The source of the hypothesis is irrelevant or adds nothing in the acceptance of the hypothesis.

The H-D method is associated with statistical studies, albeit some scholars report that the method can be used in qualitative studies or design science.	The H-D method seems to be inappropriate for statistical studies. It is also questionable for qualitative studies and design science in IS.

We argue in section 2.1 that the hypothesis in the H-D method (per Hempel or Popper) is typically guessed, while in IS H-D literature, hypotheses are often believed to be based on already established theory or literature. In section 2.2, we point out that with the H-D method per Hempel or per Popper, the source and context of the hypothesis are irrelevant for the acceptance of the hypotheses, because only the test results matter in the acceptance of the hypothesis. In section 2.3, we note how the H-D method deals with universal generalizations; thus, it seems to be an inappropriate method for qualitative studies and for testing statistical claims. Moreover, as the H-D method seems to be confused with the D-N model of explanations in the IS literature, in section 2.4. we clarify basic differences between the H-D and D-N models. Finally, in section 2.5, we clarify the important difference between the logic of the context of justification and the context of discovery, which is important in Popper's H-D approach, albeit the difference is unexplained in IS H-D literature referring to Popper and logic.

2.1. H-D hypotheses are typically characterized as resulting from guesswork

Many IS studies describe the H-D approach as theory-testing: "Much of the information systems literature assumes design science should be theory-based: a sort of hypothetico-deductive, theory-testing mode of design science. Outside of information systems, however, design science seems to be more theory-discovery: a pre-theoretical mode of design science" (Baskerville 2008 p. 442). This view seems to imply that the "theory-testing" in the H-D method is applying or testing already proposed theories, and it is less about theory discovery, and it is not "pre-theoretical." Many other IS studies seem to report similar views. For example, Kumar et al. describe "the hypothetico-deductive logic of inquiry" based on Lee (1991). (Lee [1991] cites Popper for H-D.) They explain that "the first step in this logic employs the technical-economic perspectives of transaction cost theory…, the theory of competitive advantage…, as starting points for identifying a set of propositions" (Kumar 1998 p. 201). To give another example, "we employ a…hypothetico-deductive, theory-testing mode of design science…, which is characterized by a design that is informed by kernel theories" (Looch et al. 2013). Moreover, Gregor (2018) sees that by positivism, an IS scholar "usually refers to an approach in which hypotheses are developed from theory" (p. 116). Gregor (2018) continues that "what is often termed positivism in IS is work that employs the hypothetico-deductive (H-D) approach, which largely follows Popper" (p. 116). To give a final example, Walsh (2015) reports that "in a hypothetical-deductive stance, the literature is usually first investigated for clues to lay down hypotheses" (p. 533).

It is correct to say that the H-D method (per Hempel or per Popper)[2] involves theory-testing or hypothesis testing. However, in the H-D method, as commonly presented in the philosophy of science literature (or as presented by Hempel or Popper), the hypothesis or theory is self-invented by the scholar.[3] For the H-D method (in the philosophy of science), self-invention is typically described as the hypothesis is *guessed* or *imagined* by the scholar. For example, Darden (1991) notes that "[t]he hypothetico-deductive method has dominated many characterizations of science: a hypothesis is guessed (somehow) and a consequence is deduced" (p. 9). To give another example, "the standard hypothetico-deductive view [is] that hypotheses are typically discovered by non-rational guessing" (Snyder 1997 p. 583). Similar accounts are given by Achinstein (1970), Laudan (1971). As the IS literature often reports the H-D method as a Hempelian or Popperian approach, it is important to check what Popper and Hempel say about this. Let us start with Popper (1935/1959): "theories are themselves guesswork. We do not know, we only guess." Popper (1935/1959)

[2] Or how the H-D approach is commonly presented in the philosophy of science literature (see e.g., Achinstein 1970; Darden 1991; Laudan 1971; Snyder 1997).

[3] As the H-D method is presented in the philosophy of science literature (footnote 2), the hypothesis may not have to be self-invented. However, the literature (see, e.g., Achinstein 1970; Darden 1991; Laudan 1971) commonly describe the H-D approach as such.

maintains: “we must not look upon science as a ‘body of knowledge’, but rather as a system of hypotheses; that is to say, as a system of guesses” (p. 318). Elsewhere, Popper (1935/1959) notes “‘scientific knowledge’, consists of guesses” (p. 381). Finally, Popper (1963) notes how theories are “free creation of our minds, the results of an almost poetic intuition” (p. 192) and “*every* discovery [of hypothesis or theory] contains…‘a creative intuition’” (Popper 1935/1959 p. 8). For Hempel (1966), scientific hypotheses and theories are “invented” by “happy guesses” and “creative imagination,” and they may “require great ingenuity” (p. 15). Furthermore, for Popper (1974), in particular, a good hypothesis (what Popper calls a bold conjecture) is the one that “clashed with all then accepted views” (p. 119). For Hempel (1966), the invented hypothesis can “involve a radical departure from current models of scientific thinking, as did, for example, the theory of relativity and quantum theory” (p. 15). In contrast, IS literature often describes the H-D method as generating hypotheses that are based on a previous theory (Baskerville 2008 p. 442; Gregor 2018 p. 116; Kumar 1998 p. 201; Looch et al. 2013; Walsh 2015).

To summarize the discussion thus far, the H-D method, or the H-D method per Popper or per Hempel, is importantly different in the philosophy of science than the IS literature suggests. For example, the H-D method per Hempel (1966) or per Popper (1935/1959, 1963) would accept guessing as a source for theories or hypotheses. Moreover, Hempel or Popper typically characterizes hypotheses development as guessing (or imagination). However, Hempel or Popper may not require that a hypothesis must be guessed. It is difficult to believe that the top IS journals would generally accept hypotheses reportedly based solely on guessing (per Popper) or “happy guesses” (per Hempel), which deliberately do not follow “any process of systematic inference” (Hempel 1966 p. 15). For example, it is reported by a former editor in chief (EIC) of *MIS Quarterly* that a “required element” for an excellent paper in top IS journals is that it “sufficiently uses or develops theory” (Straub 2009 p. vi). Hempelian (1966) H-D, however, suggests that the discovery of “important, fruitful theories…requires inventive ingenuity; it calls for imaginative, insightful guessing" (p. 17). Self-invented theories or hypotheses by imaginative guessing, which clashes "with *all* then accepted views" of previous theory and research (Popper 1974 p. 119), hardly satisfy the criterion of sufficiently using a theory in IS top journals.

There is another potential confusion between IS reports of the H-D method, and the H-D method in the philosophy of science literature. Some influential IS papers also report the H-D method is observation-driven. For example, Mingers (2004) discusses the "hypothetico-deductive method... [where] [s]cience was still seen to be based on empirical observations…From such observations, theories were generated" (p. 89). However, the H-D literature in the philosophy of science indicates that hypotheses or theories are *not* generated by empirical observations but are, for instance, guessed (e.g., Achinstein 1970; Darden 1991; Laudan 1971; Snyder 1997, 1999). For example, let us look at Achinstein's (1970) H-D description: "The scientist does not infer a law [=theory] from data. He invents it, guesses it, imagines it, and then derives consequences from it which he tests" (p. 87). As Hempel (1966) notes, "Scientific hypotheses and theories are not derived from observed facts, but invented...they constitute guesses" (p. 15).

To give another example, "The standard view…is the hypothetico-deductive model developed in the natural sciences... The world is assumed to be governed by universal, general laws, and science proceeds by uncovering these laws through repeated observations which lead, by way of induction, to a hypothetical law" (Mingers & Standing 2017 p. 172). It is true that many H-D philosophers (e.g., Popper 1935/1959) view theories as comprised of one or more universal law(s), which Hempel sometimes calls "general laws" (Hempel 1942; Hempel & Oppenheim, 1948). However, one could argue that in the H-D approach (Achinstein 1970; Darden 1991; Laudan 1980; Nickles 1985; Snyder 1997), the theories (or laws or hypotheses) are discovered *not* by induction (and not by repeated observations), but by guessing, for example. As Hempel (1966) reports:

> [s]cientific knowledge…is not arrived at by applying some inductive inference procedure…but rather by what is often called "the method of hypothesis" [H-D], i.e., by inventing hypothesis…and then subjecting these to empirical test. (p. 17)

2.2. Consequentialism in the H-D method

The H-D method (in the philosophy of science) is commonly regarded as "the consequential methods of justification" (Nickles 1985 p. 179) or what Laudan (1980) calls "consequentialism." The "consequential methods of justification" in the case of the H-D method mean that the source (and context) of the hypothesis or theory is irrelevant, and does not add value (or add zero value) in judging the acceptance of the hypothesis or theory.[4] What matters in the acceptance of the hypothesis are tests which accept or reject the hypothesis or theory.[5] For example, when it comes to the acceptance of the hypothesis, the Popperian H-D puts all weight on testing and zero weight on the source of the hypotheses (Nickles 1985).[6] To drive the point home, consider two cases. In the first case, the hypothesis or theory is based on a well-known reference theory. In the second case, the hypothesis or theory is not based on any theory, but it is simply guessed after drinking a bottle of wine. For Popper (1963), this information is irrelevant in the acceptance of the hypothesis. For Popper (1963), a hypothesis based on a well-known theory *adds nothing* to the acceptance of the hypothesis or theory.

Somewhat similarly, Hempel (1966) claims in his philosophy of natural sciences that the empirical consequences (or results) of the test (thus, the term consequentialist approach) matter, not the source of the hypothesis. Interestingly, (as far as we know) IS authors, even those who refer to Hempel or Popper as the source of the H-D approach, do not mention the consequentialism aspects

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[4] For Popper, hypothesis "[g]eneration methods [i.e., methods for discovering a theory or a hypothesis] carry a special epistemic weight, namely, zero. No information employed in discovering or constructing a claim can also justify it" (Nickles 1985 p. 183).

[5] The position of Hempel versus Popper is different here, and cannot be described in detail in this paper.

[6] Carefully speaking, hypotheses are not "accepted" for Popper. Positive results can tell only that the hypotheses are "corroborated" (Popper 1935/1959). See also footnote 18.

of the H-D method as described above. It is also questionable whether top IS journals commonly accept the consequentialist idea in the H-D method that the source of the hypothesis or theory is irrelevant when considering its acceptance. For example, at the first *International Conference on Information Systems*, Keen (1980) required the use of reference theories among other things in order that IS is scientific. As a result, Grover and Lyytinen (2015) state that this is the dominant approach to "adapt[s] or borrow[s]…grand(er) social theories originating within reference disciplines" (p. 272).[7]

It seems that the reference theory approach—in which hypotheses are developed from existing theory or literature—is often considered the H-D method in IS (Baskerville 2008 p. 442; Gregor 2018 p. 116; Kumar 1998 p. 201; Looch et al. 2013; Walsh 2015). The fundamental requirement of this theory-testing H-D approach in IS seems to be that a hypothesis must be based on a theory, or at least on the literature. If so, then the source of the hypothesis is relevant. If so, then this approach is not H-D per Popper or per Hempel, but something else.

2.3. The H-D method is developed for universal generalizations and not for statistical studies

In this section, we explain why the H-D approach (as commonly presented in the philosophy of science literature) may be inappropriate for IS. Scientific hypotheses can be of various types, such as universal statements, particular statements, and statistical hypotheses (Salmon 1975). Many authors (e.g., Gregor 2018; Lee 1991; Mingers & Standing 2017; Orlikowski & Baroudi 1991; Walsh, 2015; Wu 2012) associate the H-D method with statistical research or statistical hypothesis testing—or imply that the method can be used for this purpose. For example, Mingers and Standing (2017) describe "the hypothetico-deductive model" assuming "universal, general laws," which are "stochastic rather than deterministic and so statistical analysis of the data is necessary particularly, in management and econometrics, regression, structural equation modelling (SEM)" (p. 172). Lee

[7] Now, more than hundreds of different reference theories are used in IS (Larsen et al. 2015).

(1991) suggests that the “positivist approach,” namely, “inferential statistics, hypothesis testing, mathematical analysis, and experimental and quasi-experimental design” (p. 342), follows “the rules of hypothetico-deductive logic” (Lee 1991 p. 343). When Lee (1991) describes “the rules of hypothetico-deductive logic,” he refers to Popper. However, it has been claimed by Salmon and others that the H-D approach is not a method for statistical studies. If this is the case, then statistical studies in IS rarely (if ever) can follow “the rules of hypothetico-deductive logic”. Furthermore, discussing this issue leads us to suggest that “H-D logic” may be inapplicable to qualitative or design science research practices in IS.

In fact, the former EIC of the journal *Philosophy of Science* advises scientists that “the hypothetico-deductive method (H-D) is fundamentally inappropriate for testing statistical statements” (Salmon 1975 p. 459). Salmon (1975) further advises scientists: “[T]he H-D method is a method for confirming universal generalizations and particular statements. It is not a method for confirming laws. Even well confirmed universal generalizations may be ‘accidental’ generalizations rather than genuine laws” (p. 462). In the philosophy of science around 1930–1960, scientific hypotheses (and theories) were basically laws and some situational conditions (Craver 2008; Putnam 1974). The laws were universal, i.e., exceptionless, statements (Craver 2008; Teller 2004). For example, Hempel and Oppenheim (1948) ask, “What are the characteristics of lawlike sentences?” (p. 153). They reply, “[f]irst of all, lawlike sentences are statements of universal form, such as […] ‘All metals are conductors of electricity’” (p. 153). Popper (1934/1959) tells us that “[t]he theories of natural science, and especially what we call natural laws, have the logical form of strictly universal statements” (p. 48). However, not all universal generalizations, such as accidental generalizations, count as true laws, which Hempel and Popper were well aware of. For example, consider the statement all coins in my bucket are copper. This would be an "accidental generalization", which just “happens to be the case” (Hempel 1966 p. 55), and not a true universal law (per Hempel or Popper). Thus, the H-D method may (dis)confirm universal generalizations, but the method lacks the ability to determine whether a universal generalization is a genuine law.[8] To be more precise, the H-D method lacks resources to separate true laws from accidental universal generalizations.

However, some seminal IS studies seem to conflate universal laws and statistical techniques, for example, by suggesting that statistical techniques can lead to discovery of universal laws (Mingers & Standing 2017; Orlikowski & Baroudi 1991).[9] It is important to clarify several reasons why statistical techniques in IS hardly, if ever, lead to universal laws. The generalizations from the universal laws are by definition universal (i.e., exceptionless) generalizations (Teller 2004). In turn, commonly, generalizations resulting from statistical claims in science (e.g., statistical hypotheses) are not universal (i.e., exceptionless) generalizations in most cases. Perhaps in the IS context, generalizations from statistical claims can never be universal (exceptionless) generalizations (see the example below). What then are statistical hypotheses and generalizations? They could be seen as probabilistic statements—anyway, they are not universal (exceptionless) generalizations. An example is helpful to illustrate the difference between universal laws and statistical statements. In the case of universal laws, if there is a law that "All ravens are black," then if there is a raven, it must be black. Otherwise, either what we are seeing is not a raven, or the law is not a true universal law. "If all ravens are not black," then we cannot have the true universal law "All ravens are black." In turn, consider the following statements:

1. 70% of patients who have been diagnosed with DLBCL[10] (a type of cancer) and are treated with two specific treatments (rituximab and chemotherapy) will be alive after the two-year follow-up point.

[8] "The use of the H-D method does not guarantee the establishment of any laws" (Salmon 1975 p. 462).

[9] For example, "the hypothetico-deductive model" assumes "universal, general laws," which are "stochastic rather than deterministic and so statistical analysis of the data is necessary particularly, in management and econometrics, regression, structural equation modelling (SEM)" (Mingers & Standing 2017 p. 172). Or consider "[t]he standard, positivist view underlying statistical analysis is the Humean one of constant conjunctions of events leading to universal laws" (Mingers & Standing 2017 p. 171). However, statistical techniques in IS, including SEM, cannot (dis)confirm true universal (or deterministic) laws. This is because statistical hypotheses in IS are probabilistic, and not universal, statements, while universal laws are universal (exceptionless) statements.

[10] DLBCL is an acronym for diffuse large B-cell lymphoma.

2. Smoking increases the likelihood of getting lung cancer.
3. IT use is explained by habit.

Claims 1 and 2 are probabilistic claims; with the difference that in the second, the probability values are unspecified. These claims are not (presented as) universal (exceptionless) laws, because not *everyone* who smokes will definitely get lung cancer (1) and not *every* patient with DLBCL who receives a combination of rituximab and chemotherapy treatments will be alive after the two-year follow-up point (2). Claim 3 could be read as a universal (exceptionless) generalization. However, we should not deem it a universal (exceptionless) generalization. If claim 3 were a universal (exceptionless) generalization, it would mean that *every* IT use case (without exception) is explained by habitual use. However, we know that this is not the case.

Moreover, Salmon (1975) advises us that statistical studies do not follow the H-D method, "since no statement concerning the composition of any sample can be *deduced* from the statistical statement" (p. 459). Elsewhere, Salmon (1976) notes that "[t]he H-D method…requires that an observational prediction be *deductively implied* by the hypothesis, and it is impossible to *deduce*, on the basis of a statistical generalization, what any given sample will be like" (p. 380). There are several reasons why statistical studies in IS may not meet the "deductive" part of the H-D account. We describe two. Let us use the example of what Lee (1991) in IS refers to as "syllogistic reasoning" and "The Rules of Hypothetico-Deductive Logic," namely, "All men are mortal" (major premise), "Socrates is a man" (minor premise), and "Socrates is a Mortal" (conclusion) (pp. 344–345). Now, "All men are mortal" is a universal generalization; it could be also called a law. Provided that "All men are mortal" (major premise), and (we are certain that) "Socrates is a man" (minor premise), then it is a valid deductive inference to conclude that "Socrates is a Mortal". It follows from the minor premise with deductive certainty that "Socrates is Mortal."[11] There is no

[11] With deductive inference, "the truth of all the premises guarantees the truth of the conclusion" (Mautner 1996 p. 207).

uncertainty involved in the conclusion that Socrates is mortal (if Socrates is a man, and all men are mortal).

However, as we have mentioned, statistical claims are not universal (exceptionless) generalizations, such as “All men are mortal,” but probabilistic. Again, let us presume that “smoking increases the likelihood of getting lung cancer among men.” Then we know a man called Jack, and we know that he smokes. Based on this, we cannot conclude with deductive certainty that Jack will get lung cancer. Based on the information given, we could only say that by smoking he has increased his risk of getting lung cancer. But this is not a valid deductive inference. The conclusion is inductive and probabilistic. It is not certain in the sense that we cannot be certain that Jack will definitely get lung cancer. Second, in addition to statistical studies assuming probabilistic statements (e.g., hypotheses, generalizations), the statistical generalization from a sample to beyond the sample (typically, to a population in IS) is inductive.[12]

In IS literature, deductive commonly refers to the application of existing theories to a IS phenomenon (Gregor 2006).[13] To be clear, this is not a critique of Gregor (2006). There is nothing wrong with defining deductive in this way, provided that we know what it means. However, in hypothetico-*deductive* reasoning per Popper or per Hempel, *deductive* means a deductive inference or a valid inference (see Mautner 1996 p. 94). For example, Salmon (1976) describes the deductive part of the H-D method in the following: “From hypothesis (H), and a statement of initial conditions, an observation predication, called as implication statement (I), is deduced…deductive logic is used to determine whether a suggested “implication” actually has the required deductive relationships to the hypothesis” (p. 377). In a deductive inference, the conclusion is a necessary

[12] “[P]robabilistic explanations of statistical generalizations concerning particular finite populations are inductive in their character” (Niiniluoto 1976 p. 358).
[13] A “theory can be referred to as deductive, meaning that it has been deduced from an existing body of theory” (Gregor 2006 p. 622).

consequence of the premises (Mautner 1996 p. 94), as the Socrates example demonstrated.[14] From the perspective of logic, not all theory applications are deductive; some can be inductive. Deeming "hypotheses derived from an existing theory" in IS to be deductive could be influenced by the deductive-nomological (D-N) model of explanations, which sometimes in IS seems to be confused with the H-D method. Next, we discuss this model.

2.4. The H-D approach is not the same as the deductive-nomological model of explanations

Hempel and Oppenheim (1948) outline a well-known logic of explanation, later labeled by Hempel (1965 p. 380) the "the deductive nomological model" (D-N). It is called deductive-nomological "because it involves deduction from laws" (Hitchcock 1995 p. 305).[15] Because this model is sometimes confused with the H-D model, or simply misunderstood, it is important to briefly explain some key aspects of the D-N model. The model (Hempel & Oppenheim 1948) consists of Law(s) (L), Conditions (C), and an Explanandum (E):

- the event to be explained (*explanandum*): This raven is black.
- is deduced from a true general law (*explanans*): All ravens are black.
- with appropriate initial conditions (*explanans*): This is a raven.

The following is not a complete description of the D-N model. For the model, an explanation is a deductive argument (deductively valid argument, valid deductive inference). According to the D-N model, we explain, for example, a singular event (e.g., this is a raven) by subsuming it into a (covering) law (e.g., all ravens are black). Explanations in natural and social sciences hardly follow this model (Hedström & Ylikoski 2010), and it can allow absurd claims, as long as they can fit the explanatory pattern (Salmon 1971). The D-N model can be used only when we already have the law (and the initial conditions). This model does not say anything about how we get the law (and the

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[14] "An inference is deductive if and only if it is supposed to be valid; in other words, if its premises are true, then its conclusion must be true... Otherwise it is invalid" (Williams & Tsang 2015 p. 26).

[15] In the philosophy of science, nomological commonly means laws: "Sciences that seek to discover general laws for indefinitely repeatable events and process are nomothetic" (Mautner 1996 p. 295).

initial conditions) and what counts in accepting the law. In a nutshell, the D-N model is about *the logic of scientific explanation*. The H-D method is not about the logic of scientific explanation. In contrast, the H-D method says (1) how we get the candidate for the law (or hypothesis or theory) and (2) what counts in accepting it.

It is suggested that the D-N model of explanation is common in IS (Evaristo & Karahanna 1997). However, it is questionable for a number of reasons (of which we discuss two) whether any IS research truly follows the D-N model. Let us recall that "[i]n the D-N model the phenomenon to be explained must follow deductively from the explanatory statements, and the laws occurring in the explanatory statements must be universal laws" (Salmon 1975 p. 462). First, IS models or theories hardly contain universal, i.e., exceptionless, laws, such as "all men are mortal." The theories applied in IS may consist of, for example, probabilistic statements. However, "Probabilistic [statements]…are of a statistical character… [the hypothesis are] probability hypotheses…[and they] can hardly be said to be a general law" (Hempel 1942 p. 41).[16] Second, as mentioned, in IS statistical research, the phenomenon to be explained does not follow deductively but inductively.[17] Such models have statistical evidence, which offer inductive-probabilistic support for the models. Again, consider a statistical study where IT use is explained by habit. We should not deem the results a universal (exceptionless) law. Instead, the result could be seen as a statistical generalization. The results offer inductive-probabilistic support for the hypothesis (they do not follow deductively).

Moreover, although "the fundamental aims of these two schemas [H-D versus D-N] are quite distinct" (Salmon 1990 p. 7), sometimes, in IS the D-N model seems to be confused with the H-D

[16] "if they are statistical then they are not logically similar to the laws used in the D-N model" (Salmon 1975 p. 463).

[17] "once we allow for statistical explanation, we have already given up on a purely deductive model of explanation" (Leibowitz 2011 p. 487). Recall also: "[P]robabilistic explanations of statistical generalizations concerning particular finite populations are inductive in their character" (Niiniluoto 1976 p. 358).

method. For example, it is reported how "[t]he standard view of the logic of *explanation* is the hypothetico-deductive model developed in the natural science" (Mingers & Standing 2017 p. 172). To give another example, Smith (2006) discusses "the Popper-Hempel 'hypothetico-deductive' model of *explanation*" (pp. 193-194), while Orlikowski and Baroudi (1991) refer to "the hypothetic-deductive account of scientific *explanation*" (p. 10). However, in the philosophy of science, the H-D method is not regarded as a logic of *explanation*. For example, Wesley Salmon calls it a "schema for scientific confirmation" (Salmon 1990 p. 7). In turn, the D-N model is regarded as a logic of explanation (Hempel 1965; Salmon 1990 p. 7), as explained in the beginning of this section. To give another example where IS readers may confuse H-D and D-N, it is noted that "the traditional hypothetico-deductive model [...] sees explanation as the deduction of consequences from general laws (covering law model)" (Mingers & Standing 2017 p. 172). Here readers of (Mingers & Standing 2017 p. 172) may have inferred that the H-D model is also the covering law model. In 1957, Dray called the D-N model the covering law model, and since then, the term the covering law model has been used as a synonym for the D-N model. However, Hempel and Oppenheim's (1948) covering law model (the D-N model) is not the same as the H-D method by Hempel or Popper, as we explained above. Moreover, acceptance of the H-D method does not "commit one to the acceptance of the deductive-nomological model of explanation" (Salmon 1975 p. 462).

2.5. The logic of discovery versus the logic of justification in the H-D method

The logic of discovery versus the logic of justification is important for many H-D philosophers. Lee (1991) suggests that "[h]ypothetico-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). For H-D logic, Lee refers to Popper's book *Logic of Scientific Discovery*. However, in this book, Popper (1935/1959) denies a *logic* for the discovery of hypotheses or theories: "the initial stage, the act of conceiving or inventing a theory, seems to me neither to call for logical analysis nor to be susceptible to it" (p. 31). Popper also notes "that *every* discovery contains 'an irrational element'"

(p. 8). To be clear, this is not a critique of Lee (1991). However, these differences are not explained (by Lee 1991), and they can create confusion among IS readers. Explaining this issue is also necessary to understand some of the fundamental concerns about the H-D method in section 3.

To explain why Popper said so, hypothetico-deductivists, including Popper, tend to advocate a separation between discovery and justification. What does this mean? We have noted, thus far, that with the (Popperian) H-D method, a hypothesis can be guessed. What we have not yet said explicitly, thus far, is the following. For Popper, because scientific discovery (discovery of a hypothesis or a theory) is an "irrational" and "creative process," there cannot be a *logic* or method for discovering theories. We propose the interpretation that Hempel's (1966) view is similar. There are no mechanical rules for deriving hypotheses: "the ways in which fruitful scientific guesses are arrived at are very different from any process of systematic inference" (Hempel 1966 p. 15).

Finally, *justification* means how ideas or hypotheses (or theories) are justified, or how they are "accepted", after the ideas or hypotheses have been outlined[18]. For example, although Popper (1935/1959) denies any logic for discovery of theories and hypotheses, he acknowledges that there is a logic of justification. Popper (1935/1959) sees this logic to be deductive. Popper's H-D did not allow induction, only deduction. Hempel (1966) notes that "scientific inquiry…may be said to be inductive…inasmuch it involves the acceptance of the hypotheses on the basis of the data that afford no deductively conclusive evidence for it, but lend it only more or less strong inductive support, or confirmation" (p. 18). In other words, the positive tests for the hypothesis (in the context of discovery) allow "inductive support" for the hypothesis, because the tests in the justification do not provide deductive conclusive evidence for the hypothesis (p. 18).[19] As mentioned, it is highly

[18] "Accepted" do not mean that the accepted hypotheses/theories cannot be revised later. Typically H-D philosophers assumed fallibilism, namely that ("accepted" or "rejected") scientific hypothesis/theories are provisional and revisable.

[19] "Acceptance of a hypothesis on the basis of positive H-D testing involves accepting a conclusion which contains more information than the premises, and thus lacks the certainty associated with correct deductive arguments, whose conclusions must be true if their premises are true. There are no correct deductive arguments whose conclusions contain more information than their premises" (Salmon 1976 p. 376).

questionable that IS studies (e.g., statistical) apply a deductive logic of justification (see footnote 17).

3. The method of hypothesis

Thus far, we have explained some key reasons why the alleged H-D method (per Hempel or per Popper) in IS cannot be regarded as H-D (per Hempel or per Popper). In this section, we discuss some, albeit not all, of the basic critiques of the H-D method, summarized in Table 2. Recognizing these issues is important for starting the discussion about which aspect of the H-D model we should keep, omit, or modify in IS. We briefly describe the first version of an alternative method, called the method of hypothesis (Table 2).

Table 2. Some, albeit not all, basic H-D ideas, and how they differ from the MoH.

Some H-D ideas in the philosophy of science	The MoH we propose
H-D hypothesis discovery is (typically) characterized as guessing and imagination	Section 3.1. H-D hypothesis discovery is more than guessing: The context, scholars' background, and methods can influence and restrict guessing and imagination
Only tests in the "justification" phase matter for the acceptance of the hypothesis in the H-D method	Section 3.2. Evidence in the discovery phase can also give some justification for scholars proposing the hypothesis
Strict separation between the discovery and justification	Section 3.3. No strict separation between discovery and justification: cyclical and interactive relationships between discovery and justification

The H-D method starts with guessing the hypothesis	Section 3.4. While research often involves guessing, it does not have to start with a guessing hypothesis
Emphasizing the *logic* in justification and discovery	Section 3.4. Emphasize naturalism, according to which justification or discovery does not have to follow one certain generic logic that is defined *a priori*

3.1. Guessing only in a vacuum or theory-laden guessing in a research context?

A sympathetic reader of Hempel or Popper can find countless cases where the ideas for hypotheses and theories have been obtained by guessing and imagination. For example, in 1811, in the *First Introduction to General Physics*, Ørsted notes, “When it is not clear under which law of nature an effect or class of effect belongs, we try to fill this gap by means of a guess. Such guesses have been given the name conjectures or hypotheses” (p. 297). To give another example, Einstein viewed theory development as an intuitive eureka experience, and not a rule-following activity (Einstein in Popper 1935/1959 p. 8): “theory cannot be fabricated out of the results of observation, but that it can only be invented” (Einstein’s letter to Popper in 1935). Einstein’s (1929) method is *Gedankenexperiment*, roughly speaking, imagination through thought experiments. In addition, the approach of Nobel Laureate in Physics Feynman (1965) resembles H-D: “In general we look for a new law by the following process. First we guess it” (p. 156). For Feynman (1965), the test matters, because the hypothesis can contain “as much junk in the guessing as you like” (Feynman 1965 p. 164). Furthermore, economic models are “imagined by economists. They are not observed or discovered, they are constructed by economists using their imagination” (Mäki 2009 p. 78).

Moreover, serendipity findings are well-known in natural sciences and medical research. A serendipity finding is "an accidental discovery, in other words 'an observation by chance in a beneficial way while looking for something else'" (Prasad et al. 2016). For example, more than 35.2% of all cancer drugs in clinical use around 2012 were discovered with the aid of serendipity (Hargrave-Thomas et al. 2012). More recently, Prasad et al. (2016) claim that "rational drug discovery and targeted therapies have minimal roles in drug discovery, and that serendipity and coincidence have played and continue to play major roles." A typical case is a drug that is developed for one condition and is then revealed to be beneficial for another, going beyond the originally hypothesized assumptions. For example, thalidomide is used as a drug for cancer treatment today. It was originally hypothesized as a drug for use to prevent morning sickness in pregnant women (Wang et al. 2016). Well-known examples of accidental inventions include sildenafil (better known as Viagra; Campbell 2000) and penicillin (Fleming 1929/1980). A classic natural science example is Jeffreys et al.'s (1985) invention of DNA fingerprinting, published in *Nature*: "It all started with a glorious accident. What we were interested in was trying to get a human genetic variation. It was nothing to do whatsoever with forensics. It was basically aimed at human genetics and medical genetics. Completely by accident we came up with what proved to be the world's first DNA fingerprint. We realised we had solved a problem we had never set out to solve" (Daily Mail 2009).

Given the importance of guessing and accidental discoveries, are Hempel and Popper, therefore, correct in characterizing the discovery of hypotheses or theories as guessing? It is one thing to say that a scientific discovery is characterized as guessing, or it is "irrational" guessing (with Popper 1935/1959) or "happy guesses" (Hempel 1966). It is another thing to say that a scientific discovery can involve guessing and imagination. And it could be that Popper and Hempel would have agreed with this idea. Nevertheless, we argue that the latter view better describes what actually happens in natural science (to which Hempel and Popper referred). For example, Achinstein (1970) suggests that the “personality, training and dreams” (p. 91) of the scientists matter in scientific inferences. Achinstein (1970) also suggests the role of background information, albeit he does not discuss this in detail.

However, there are more influences on guessing. We suggest that guesses are theory-laden. The theory-ladenness of guess refers to the background beliefs and assumptions that scholars have obtained through their scientific upbringing. It also includes scientific training. Theory-ladenness of guess is not precisely the same as the Hansonian (1958) theory-ladenness of observation, because the latter refers to observations. A similar point is that scientific discoveries in many cases may require certain knowledge of the specific phenomenon. This point is briefly mentioned by Gutting (1980). If we study the role of the *culture* of non-work-related use of Sina Weibo in Chinese organizations, how can persons who have never been to China and never met a Chinese person make good guesses about such culture? The theory-ladenness of guess highlights the role of the proper context and background knowledge that inspires hypothesis formulation. It is not the same as a theory-based hypothesis in the IS “H-D” method, because the hypotheses are not necessarily formed in compliance with a specific theory. Merrilee Salmon and Marco Nathan have suggested to us that Hempel's H-D and Popper’s H-D would most likely agree with what we call the theory-ladenness of guess.

Another important point is the influence of research settings and methods on the discovery. For example, a physicist may use a particle accelerator. In such cases, the ideas must fit the particle accelerator settings. In IS, scholars may use, for example, certain statistical techniques and qualitative research settings. These settings may already set certain limits on what can be guessed and speculated. As a simple example, if a scholar uses a one-time survey to study IT use, then speculating about the dynamics, change, and development of the phenomenon (or what explains it) is beyond the scope, because a one-time survey cannot examine such things.

Moreover, the Popperian H-D method (guess and then test) misses the difficulty of creating testing situations. For instance, it is hardly a good option to go to the closest pub and ask customers to guess how the entire universe was created. The reasons are many. For one thing, some guesses may be difficult to test. If one guesses that the universe was created by totally invisible aliens from other dimensions, how we are going to test it? Popperians (1963) would accept it and any guess as a tentative hypothesis until it has been tested.

3.2. Discovery evidence can also give some justification for scholars proposing the hypothesis

There is another important aspect that the H-D model misses. Even if scholars make guesses, they may try to find all kinds of evidence for the hypotheses, before they make the stronger test(s), or Popperian "severe tests." Guesses or research ideas can be also rejected, or put on hold, before they proceed to major test(s). For example, scholars have ideas, and they find evidence for the ideas. But the evidence is not compelling enough to make larger tests. The Popperian H-D approach and how the H-D approach is commonly described in the philosophy of science (e.g., Achinstein 1970; Darden 1991) lack resources to explain such cases.[20] A related critique is the difficulty of separating discovery from justification, required by hypothetico-deductivists, including Popper (Achinstein 1970). If the idea or guess for the hypothesis has been evaluated before the strong tests, then how is this evaluation not "justification"? The MoH should avoid these issues. Our approach, the MoH, views that discovery evidence can also give some justification for scholars proposing the hypothesis. However, recognizing this concern leads us to an additional problem of the H-D method.

3.3. Various theory-laden guessing and "testing" cycles before test-ready hypothesis formulation and testing

[20] As mentioned, per the Popperian H-D approach, or how the standard H-D is commonly described in the philosophy of science, hypotheses are first guessed, and then they are tested (e.g., Achinstein 1970; Darden 1991). The test counts only in the acceptance of the hypotheses.

Scholars can have ideas, and then seriously consider the ideas, and perhaps find some evidence for the ideas, before proposing the actual hypothesis (the test-ready hypothesis) and test(s). To allow this, philosophers introduced something between discovery and justification, the “preliminary evaluation” of the hypothesis after its “generation” (Schaffner 1980, p 178). In turn, Laudan (1977b) proposes the “context of pursuit” between discovery and justification. Our approach is different. Our MoH approaches consider discoveries and justification as cyclical and interactive, especially up to the formulation of a test-ready hypothesis. A natural science research study (Giere 1988) and our approaches can contain numerous educated, theory-laden guesses and testing cycles before the larger tests. This is different from the (Popperian) H-D method. The results of these testing cycles inform the speculation and hypothesis development (cyclical and interactive relationships between discovery and justification). However, with the MoH, there are finally test-ready hypotheses, propositions (or research ideas), which are then tested. The hypothesis before the test-ready hypothesis can be described as the working hypothesis. Often, the details of all considerations regarding the working hypothesis and the tests are not discussed in the paper, and they do not necessarily follow any formal syllogism (Giere 1988). This is precisely why we say such research follows the method of hypothesis: It is not important to report all that was speculated and tested. Therefore, for our MoH, typically, only the important test or tests are reported. This is common among natural science practitioners. The serendipity of findings, which we discuss next, demonstrates this.

3.4. Does it have to start with guessing, and how does the H-D method account for serendipity findings?

Hanson (1958) claims that the H-D method “has not anything to do with real discovery in natural science” (p. 1073). Hanson (1958) maintains that hypothetico-deductivists ignore the role of data or the phenomenon in inspiring hypotheses or theories. For Hanson (1958), physicists start with data, not with a hypothesis. (Actually whether physicists start with the data or hypothesis may vary between "theoretical" and "experimental" physics, for example.) The H-D method (as it is often presented in the philosophy of science), and the Popperian H-D approach in particular, starts with guessing the hypothesis.[21] Similarly, Achinstein (1970) criticizes the H-D method as "a scientist may have made an inference to a hypothesis on the basis of certain data and the hypothesis may still be conjecture" (p. 91). These points are important, because scholars may be faced with certain data, which inspire the guessing. Then the research does not start with guessing, and guessing does not occur in a vacuum, but it is inspired by some data or observation. The (Popperian) H-D approach cannot explain these cases (Achinstein 1970). Our MoH approaches do not have to start with guessing. For example, the MoH can start with serendipitous findings, which inspire theory-laden guessing. Thagard (2009) suggests that a discovery in medical research results from two psychological processes: questioning and search (Figure 1). Discovery also includes serendipity (Thagard 2009). His example is Marshall and Warren's discovery of *Helicobacter pylori*, which won the Nobel Prize. In this case, the start of that discovery "was entirely serendipitous, happening accidentally in the course of his [Warren] everyday work as a pathologist" (Thagard 2009 p. 12).

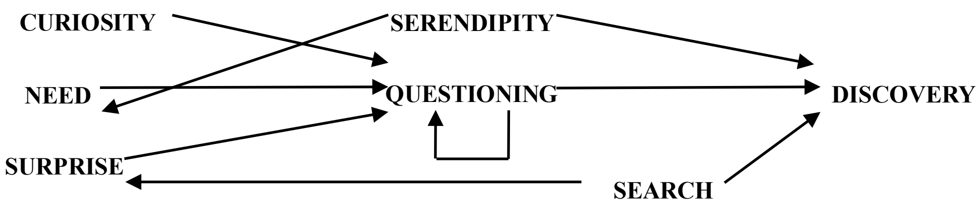

Fig. 1. Thagard's (2009) theory of psychological discovery.

Warren's observation was a surprise for him, because it contradicted generally held beliefs (Thagard 2009). This surprise and his curiosity led to questioning (Thagard 2009). It was also driven by medical need. Warren asked Marshall to help him (Thagard 2009). They searched the existing literature, and they concluded that their findings were a new type of bacteria, not

[21] For example, Popper may not require that hypothesis *must* be guessed. But with Popper, or how H-D is described in the philosophy of science (Achinstein 1970; Darden 1991; Laudan 1981; Nickles 1985), all what we learn from happening in the discovery is a guess or imagination.

previously found. Our MoH can contain such cases, but the starting point does not have to be a *serendipitous* finding. For example, the serendipitous finding can come during the research process of another issue, similar to the Jeffreys et al. (1985) case. The Popperian H-D method, or the H-D method often presented in the philosophy of science, has difficulty accounting for such cases. The MoH could address this point. We do not even try to say where the discovery starts, and we do not try to outline generic *a priori* logic of it. The reasons why a discovery starts are too numerous and changing to be listed *a priori* (Nickles 1990). They can come from a colleague, from a practitioner, from feedback from a seminar, from reviewers of journals, from funding agencies, and so on.

4. Discussion

Figs. 2, 3, and 3 summarize key differences between the H-D model in IS, the H-D model in the philosophy of science, and the MoH. The figures do not contain all details. The exact details also partly depend on the precise source for the H-D model in the philosophy of science. For example, what is called the Hempelian H-D model is somewhat different from the Popperian H-D model (and many differences cannot be described here). Some differences regarding the H-D model can also be found in IS literature, which future research may reveal.

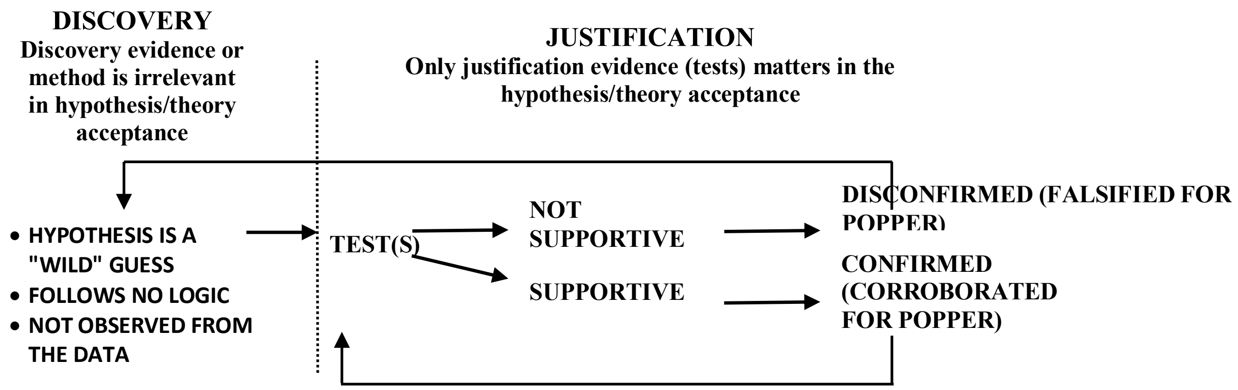

Figure 2. A simplified and abstracted version of the H-D in the philosophy of science.

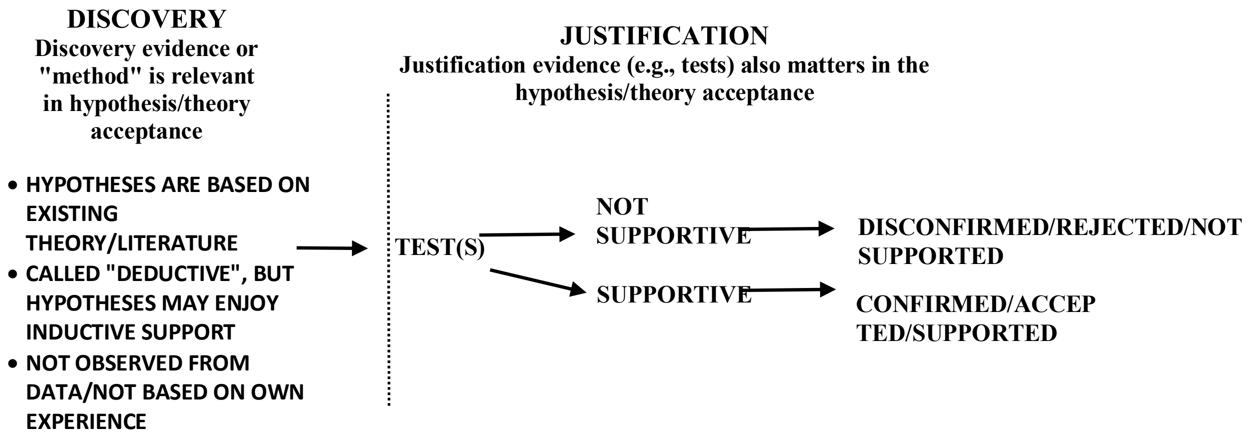

Figure 3. A simplified and abstracted version of H-D in Information Systems.

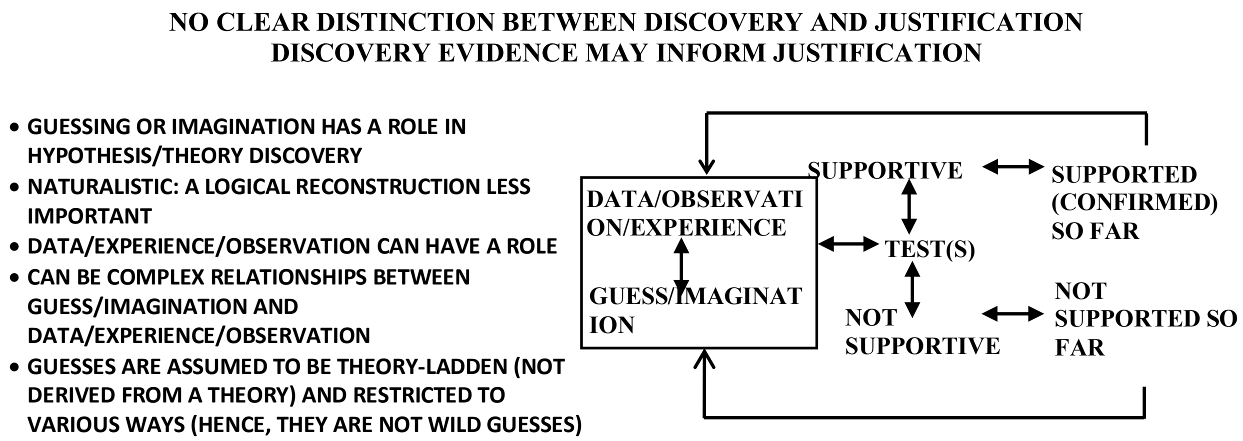

Figure 4. A simplified and abstracted version of MoH.

4.1. From logic to naturalism

In this section, we explain how the underlying philosophical assumptions in our MoH are naturalistic, and not based on *a priori* philosophizing common to H-D philosophers. It is important to understand that much of the philosophy around 1920–1960 focused on outlining the *logic* of something (van Benthem 2006 p. 65). For instance, Popper's (1935/1959) most famous book is titled the *logic* of scientific discovery; in turn, Hempel outlines *the logic* of explanation, called D-N. Logic means mathematical logic (Giere 1988 p. xv). For example, our interpretation is that Popper's yardstick for rationality is formal logic, or what Giere (1988) refers to as mathematical logic. Our approach is more naturalistic (Giere 1985, 1988 p. xv). Similar to Giere (1988), we do not assume that scientific rationality is only formal or mathematical logic. Like Giere (1988), we see such philosophizing as extra-scientific. What then is this naturalism? In the philosophy of science, naturalism is sometimes associated with Giere's (1985) "Philosophy of Science Naturalized." However, in the philosophy of science naturalism is not a homogenous movement (Thagard, 2009). Nevertheless, perhaps one important point shared by many naturalists is a rejection of the idea of *a priori* philosophizing, common to Popper or logical empiricists such as Hempel. What does this mean here? It means examining and learning from successful scientific activities as such without forcing them to meet certain *a priori* logic and leaving those things out, or deeming them irrational (cf., Popper's claim that scientific discovery is irrational), which do not meet the logic. We do not try to outline one specific universal logic of discovery and justification with our MoH. For example, naturalism views "scientific reasoning not so much as a process of inference [in terms of certain logic or syllogism] but as one of decision making" (Giere 1988 p. xvi). In fact, it can be problematic if scholars have to follow a certain universal *a priori* defined logic or stepwise hypothesis development method. Numerous philosophers from Achinstein (1980) and Feyerabend (1975) to Hempel (1966) and Wittgenstein (1953) have tried to explain the difficulties. One key difficulty is the following: "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). Similarly, "[p]robably no infallible logic for producing new theories exists; certainly none has yet been found" (Darden 1991 p. 16).

As a result, our MoH purposefully avoids suggesting a generic stepwise manual for theory or hypothesis development. Why our MoH approaches avoid such global manuals for theory development is also naturalistic. If a global logic of discovery is important for scientists, then why can theory building methods not be found in (say) *Science*, *Cell*, *Nature*, or *New England Journal of Medicine?* Could it be that forcing a stepwise, generic *a priori* process for theory discovery can seriously restrict new idea development, which does not fit the process? This Popper, logical empiricists (e.g., Hempel) and many of their famous critics (e.g., Feyerabend, Laudan, and Kuhn) knew very well. This is precisely why our MoH approaches do not contain such steps. There is also the risk that they prevent the development of such theory development activities that do not meet the method's steps.

Finally, although our aim is not to outline a specific logic, it is necessary to inform readers that our MoH is not ultimately a deductive method. The results hardly follow with deductive certainty (section 2.3). With the MoH, one accepts "a conclusion which contains more information than the premises, and thus lacks the certainty associated with correct deductive arguments, whose conclusions must be true if their premises are true" (Salmon 1976 p. 376).[22]

4.2. MoH: Sources of discovery, and some implications for qualitative and quantitative research

Our MoH can use qualitative methods and statistical methods. In both cases, the hypothesis or hypotheses are imagined or guessed, often based on some source. Possible sources include (but are not limited to) observations, data, and experience.

[22] "There are no correct deductive arguments whose conclusions contain more information than their premises" (Salmon 1976 p. 376).

For example, the observation-driven MoH approach uses observations (e.g., case studies or interviews) for theorizing or developing hypotheses. This approach can use imagination or educated guessing, but it is influenced by the observations. There can be interplay between imagination, guessing, and observations (e.g., reading case materials after interviews), but such interplay does not have to follow any *a priori* defined steps. It does not matter how these observations are done, but whether evidence supports these findings in future studies. This approach especially fits cases where scholars who have observable access in terms of case studies and interviews.

The data-driven MoH approach uses educated guesses and imagination to form hypotheses or theories from data, where the scholar does not have observational access in person to the phenomenon (e.g., a data set that the scholar has obtained). There are interplays between imagination, guessing, and the data, but such interplays do not have to follow any *a priori* defined steps or rules of logic.

The experience-based MoH approach uses a scholar's own personal experiences as the basis for theorizing or developing hypotheses. There can be an interplay between imagination or guessing and recalling one's own experiences, but such interplay does not have to follow any *a priori* defined steps or rules of logic. It does not matter how these observations are done, but whether evidence supports these findings. This method is suitable for cases where the scholar has his or her own (practical) experience in the IS phenomenon of interest.

Actual scientific research can combine various approaches (and does not to be limited to these). For example, the data-driven approach could be mixed with the experience-based approach, when big data findings are imagined against one's own experiences. Again, as is typical in natural science research, such interplays do not have to follow any *a priori* steps (or rules of logic). Moreover, similar to what is common in natural sciences, the focus of the study can change in all of these

MoH approaches. That is to say, scholars can start with studying one thing but find something else, and they end up reporting this something else (cf., Jeffreys et al. (1985) case in section 3.1).

For all of these MoH approaches, at some point one or more tests or evidence are presented to confirm or disconfirm the hypothesis. By confirm, we mean that the hypothesis can be seen to be supported by the evidence presented so far, while disconfirm means that the hypothesis cannot be seen to enjoy supportive evidence in the cases presented so far. In the positive case, the hypothesis most likely gets inductive support from the tests. MoH assumes fallibilism of scientific knowledge (see footnote 18): "all knowledge claims are provisional and in principle revisable." (Mautner 1996 p. 147)

If the test mainly contains qualitative evidence (e.g., interviews), the MoH could be called *hypothetico-inductive-qualitative*. If the test primary contains statistical evidence, the method could be called *hypothetico-inductive-statistical*[23]. Consider a qualitative scholar's study of IT use. The hypothesis could be influenced by potential sources of discovery, such as 1) his or her own experiences (the experience-based MoH approach), 2) data the scholar has obtained (the data-driven MoH approach), and 3) others' observations (the observation-driven MoH). Then the scholar can imagine or guess what, for example, may explain the IT use. This can be a complex interplay between the sources of discovery and imagination (guessing). This results in a preliminary working hypothesis, in this case what explains IT use. The scholar can also obtain some qualitative data (preliminary tests), say, a few interviews, to test his idea further. The data analysis (analysis of the interviews in this case) does not have to follow a specific data analysis method to the letter. Based on the findings and further imagination, one may revise the working hypothesis or reject it. Again, this can be a complex interplay cycle between the data and imagination. It is not needed to report with which formal logic these various moves comply. In addition, or alternatively, one can conduct

[23] Term "hypothetico-inductive" is borrowed from Niiniluoto and Tuomela (1973). They propose "a theory of what we call hypothetico-inductive" (p. IX).

more “tests,” in this case, qualitative interviews. The cycle can be repeated more than once. Finally, there are larger or serious "test(s)", for example, interviews. Depending on the findings and scholars’ interest, this can lead to reporting the findings or alternatively, conducting more test(s) or imagination. In the case of the MoH, the hypotheses are not originally taken from theory. However, later it can be realized that findings or working hypothesis are close to some theory, construct, or model. If such cases happen, the scholar can decide whether he or she is trying to confirm this theory or construct, modify it, disconfirm it (or criticize some theory), or develop an alternative theory or explanation. The result of the MoH does not have to be a theory. The results are compared with existing (related) studies.

5. Conclusions

Many IS authors have contributed to the introduction of the H-D schema to IS. However, the H-D method, or the H-D model per Popper or per Hempel, is more importantly different in the philosophy of science than the IS literature suggests. At the same time, such differences are not explained by the H-D method articles in IS. One may reply that some IS authors have developed their own version of the H-D method, where guessing is replaced, for example, by “find an already established theory,” and the source of the hypothesis or theory is very relevant when considering the acceptance of the hypothesis or theory. There might also be reasons to downplay guessing and imagination and reply to it with theory-testing or theory-based hypotheses in IS. However, these reasons, if they exist, are not explained by the H-D literature in IS. If such reasons exist, they should be justified rather than the IS practice labeled as Popperian or Hempelian or natural scientific. Deeming the H-D method in IS as Popperian or Hempelian or natural scientific creates conceptual and philosophical confusion, and it may mislead IS scholars. Further obscurity may be created when the H-D method is further confused with the D-N model of explanations and statistical research in IS. Finally, because the H-D model is designed for universal generalizations and particular statements, it is confusing to regard it as a method for testing statistical hypotheses in

IS. The model's usefulness for qualitative research is also questionable. After all, we should not believe that qualitative or statistical research in IS confirms or falsifies exceptionless *universal generalizations* such as "all men are mortal."

Revisiting the H-D model, as it is presented in the philosophy of science, can provide new insights to IS. For example, a shortage of proposals for IS-specific theories cannot result due to compliance with the H-D method. This is because with this method, new theories would be guessed very often, as "a scientist can start with a rough guess" (Hempel 1966 p. 21) or hypotheses "may be merely wild guesses" (Salmon 1976 p. 461). The H-D model in the philosophy of science highlights the important role of guessing and imagination in the generation of hypotheses and theories. We argue that IS can learn some of this from this method. To this extent, we proposed the MoH. Our MoH is not H-D in terms of Hempel or Popper, and it is not a deductive method. Our MoH approaches, purposefully, put less importance on how the hypothesis was generated when it comes to reporting the research. With our MoH, like H-D, the hypotheses do not have to be based on existing theory or literature. Accepting only hypotheses based on existing theory or literature can limit scientific discovery by proposing what is already known. With the MoH, evidence can support (or question) the hypotheses, and post-hoc reasons for the hypotheses may be provided. Later research can further examine the hypotheses. Accepting the MoH, or even the guessing involved in the H-D method, would not only render guessing and imagination acceptable in IS but would also make them major factors in hypothesis and theory discovery. Countless scientific discoveries in natural science and medical research have involved guessing, imagination, and the use of accidental discoveries. We should not ignore them as sources for hypotheses. Given that the "theory-testing research" (H-D) in IS is not H-D (per Hempel or per Popper), a task remains for future research to outline a philosophical account of this form of H-D (or theory-testing research) in IS. Finally, our first proposal for the MoH should also enjoy a critical review, which hopefully results in application examples and further improvements.

Acknowledgements

We thank the editors and reviewers of *Information & Organization,* as well as Dr. Merrilee Salmon, Dr. Marco Nathan, Dr. Mikko Rönkkö, and Professor William Bechtel for their comments on the early versions of this paper. We also thank Professor Ilkka Niiniluoto for commenting on Hempel's and Popper's H-D methods.

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