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Exploratory Factor Analysis, Theory Generation, and Scientific Method

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This article examines the methodological foundations of exploratory factor analysis (EFA) and suggests that it is properly construed as a method for generating explanatory theories. In the first half of the article it is argued that EFA should be understood as an abductive method of theory generation that exploits an important precept of scientific inference known as *the principle of the common cause.* This characterization of the inferential nature of EFA coheres well with its interpretation as a latent variable method. The second half of the article outlines a broad theory of scientific method in which abductive reasoning figures prominently. It then discusses a number of methodological features of EFA in the light of that method. Specifically, it is argued that EFA helps researchers generate theories with genuine explanatory merit; that factor indeterminacy is a methodological challenge for both EFA and confirmatory factor analysis, but that the challenge can be satisfactorily met in each case; and, that EFA, as a useful method of theory generation, can be profitably employed in tandem with confirmatory factor analysis and other methods of theory evaluation.

The first 60 years of the 100-year history of factor analysis was largely devoted to the development of exploratory factor analytic (EFA) methods. However, despite the advanced statistical state and frequent use of EFA within the behavioral sciences, debate about its basic nature and worth continues. Most factor analytic methodologists take EFA to be a method for postulating latent variables which are thought to underlie patterns of correlations. Some, however, understand it as a method of data reduction which provides an economical description of correlational data. Further, with the advent of confirmatory factor analysis and full structural equation modeling, the prominence of EFA in multivariate re-

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search has declined. Today, methodologists and researchers often recommend and employ confirmatory factor analysis as the method of choice in factor analytic studies.

In this article I examine the methodological foundations of EFA and argue for the view that it is properly construed as a method for generating rudimentary explanatory theories. In the first half of the article I contend that EFA is an *abductive* method of theory generation that exploits an important precept of scientific inference known as *the principle of the common cause.* It is surprising that this characterization of the inferential nature of EFA does not figure explicitly in the factor analytic literature, because it coheres well with the generally accepted view of EFA as a latent variable method. Since abduction and the principle of the common cause are seldom mentioned in the factor analytic literature, I provide a characterization of each before showing how they are employed in EFA. In the second half of the article I outline a broad theory of scientific method in which abductive reasoning figures prominently. I then discuss a number of methodological features of EFA in the light of that method. In particular, I argue that, despite a widespread belief to the contrary, factorial theories do have genuine explanatory merit; that the methodological challenge of factor indeterminacy can be satisfactorily met by both EFA and confirmatory factor analysis; and that EFA as a useful method of theory generation can be profitably employed in tandem with confirmatory factor analysis and other methods of theory evaluation.

THE INFERENTIAL NATURE OF EFA

Abductive Inference

It is commonly thought that inductive and deductive reasoning are the only major types of inference employed in scientific research. It is well known that conclusions of valid deductive arguments preserve the information or knowledge contained in their premises, but they do not add new information or knowledge. By contrast, inductive arguments are ampliative in that they add new information or knowledge to existing information and knowledge. However, inductive arguments, though ampliative, are *descriptive* in character because they reach conclusions about the same type of manifest attributes mentioned in their premises. Importantly though, science also adds to its store of knowledge by reasoning from factual premises to *explanatory* conclusions. This type of inference, which is widely ignored in scientific methodology, is known as *abduction.*

The basic idea of abductive inference can be traced back to Aristotle, but its modern formulation is due to the pioneering work of the American philosopher and scientist, Charles Sanders Peirce (1931–1958). Peirce's writings on abduction are underdeveloped and open to interpretation, but they are richly suggestive. They were largely ignored in the first half of the twentieth century, but recent developments in the fields of philosophy of science, artificial intelligence, and cognitive science more generally (e.g., Josephson & Josephson, 1994; Magnani, 2001; Thagard, 1988, 1992) have built on Peirce's ideas to significantly advance our understanding of abductive reasoning.

Abduction is a form of reasoning involved in the generation and evaluation of explanatory hypotheses and theories. For Peirce, "abduction consists in studying the facts and devising a theory to explain them" (1931–1958, Vol. 5, p. 90). It is "the first starting of an hypothesis and the entertaining of it, whether as a simple interrogation or with any degree of confidence" (1931–1958, Vol. 6, p. 525).

Peirce maintained that abduction had a definite logical form that he came to represent in the following general schema (Peirce, 1931–1958, Vol. 5, p. 117):

> The surprising fact, C, is observed.
> But if A were true, C would be a matter of course.
> Hence, there is reason to suspect that A is true.

Although Peirce's schematic depiction of abductive inference is suggestive, it needs to be amplified and modified in various ways to qualify as an instructive account of explanatory inference in science. First, the facts to be explained in science are not normally particular events but empirical generalizations or phenomena and, strictly speaking, they are not typically observed (Woodward, 1989). Rather, it is the data themselves that are observed and that serve as evidence for the phenomena. In turn, it is phenomena, not data, that serve as evidence for the abduced theories.

Second, confirmation theory in the philosophy of science makes it clear that the facts or phenomena follow as a matter of course, not just from the proposed theory, but from that theory in conjunction with accepted auxiliary claims from background knowledge.

Third, the antecedent of the conditional assertion in Peirce's schema should not be taken to imply that abductive inferences produce truths as a matter of course. Although science aims to give us true, or approximately true, theories of the world, the supposition that the proposed theory be true is not a requirement for the derivation of the relevant facts. All that is required is that the theory be plausible enough to be provisionally accepted. It is important to distinguish between *truth*, understood as a guiding ideal for science (a goal that we strive for but never fully reach), and the *acceptance* of theories which is based on evaluative criteria such as predictive success, simplicity, and explanatory breadth. As proxies for truth, justificatory criteria such as these are indicative of truth, but they are not constitutive of truth.

Fourth, it should be noted that the conclusion of Peirce's argument schema does not assert that the hypothesis itself is true, only that there are grounds for thinking that the proposed hypothesis might be true. This is a weaker claim that allows one to think of a sound abductive argument as delivering a judgment that the hypothesis is initially plausible and worthy of further pursuit. As we shall see, assessments of initial plausibility constitute a form of generative justification which involves reasoning from warranted premises to an acceptance of the knowledge claims in question.

Fifth, Peirce's schematic depiction of abductive inference focuses on its logical form only. As such, it is of limited value in understanding the theory construction process unless it is conjoined with a set of regulative constraints that enable us to view abduction as an inference, not just to any explanation, but to plausible explanations. Constraints that regulate the abductive generation of scientific theories will comprise a host of heuristics, rules, and principles that govern what counts as good explanations. We will see later that the principle of the common cause is a key principle (better, heuristic) that regulates abductive reasoning within EFA.

Peirce's understanding of abduction was somewhat protean in nature, although for him it tended to take its place at the inception of scientific hypotheses, and often involved making an inference from puzzling facts to hypotheses that might well explain them. However, recent work on abduction reveals that there are a number of different ways in which explanatory hypotheses can be abductively obtained. In focusing on the generation of hypotheses, Thagard (1988) helpfully distinguishes between different types of abduction. One of these, existential abduction, hypothesizes the existence of previously unknown objects or properties. Another, analogical abduction, employs successful past cases of hypothesis generation to form new hypotheses similar to relevant existing ones. In the next section, I will suggest that existential abduction is the type of abduction involved in the factor analytic production of explanatory hypotheses, although analogical abduction too is sometimes employed in this regard.

It should be clear from this series of remarks about abduction that Peirce's schematic depiction of the logical form of abduction needs to be changed to something like the following:

> The surprising empirical phenomenon, P, is detected.
> But if hypothesis H were approximately true, and the relevant auxiliary knowledge, A, was invoked, then P would follow as a matter of course.
> Hence, there are grounds for judging H to be initially plausible and worthy of further pursuit.

This recasting of Peirce's characterization of an abductive argument accommodates the fact that it is typically empirical phenomena that hypotheses are produced to explain, it acknowledges the role of background knowledge in the derivation of hypotheses, it assigns a regulative role to truth in science, and it signals the importance of initial plausibility assessments in the generation and development of new knowledge.

EFA and Abduction

I turn now to consider my initial claim that EFA is fundamentally an abductive method of theory generation. I begin by briefly acknowledging two earlier efforts to characterize EFA as an abductive method, and then elaborate on the claim that EFA largely trades in existential abductions. In part, this exercise will involve indicating that the modified Peircean schema for abductive inference applies to EFA.

Fifty years ago, Hartley (1954) drew a distinction between *descriptive* and *inferential* factor analysis and defended the then unpopular view that inferential factor analysis could justifiably be used to hypothesize unobserved causal factors. Hartley argued his case by analogy to the logic involved in the study of unobserved physiological entities, but he realized that a compelling case for the inferentialist reading of factor analysis could only be made by appeal to an appropriate theory of inference. Hartley expressed surprise at the time that factor analysis stood without appeal to any theory of inference. It is remarkable, then, that expositions of EFA fifty years later, still do not make explicit reference to a theory of inference in order to characterize the reasoning involved in moving from descriptions of manifest variables to statements about latent variables.

Although the mainstream psychometric literature makes no attempt to characterize EFA as an abductive method, both William Stephenson and William Rozeboom began to address this matter over forty years ago. Stephenson's (1961) insightful scientific creed contains a brief attempt to explicitly characterize EFA as an abductive method, while Rozeboom's work (1961, 1972) provides more detailed evidence in support of the view that EFA is an abductive method. Rozeboom spoke of *ontological inductions* which extend our referential reach beyond covariational information to hypotheses about latent factors which are new ontological postulations. He also described EFA as an *explanatory inductive* method because it helps generate conceptions of latent factors that explain why the covariational regularities of interest obtain. Here, Rozeboom clearly used the term *induction* in a broad sense where it has the same general meaning as *abduction.*

As noted earlier, existential abduction often hypothesizes the existence of entities previously unknown to us. The innumerable examples of existential abduction in science include the initial postulation of entities such as atoms, phlogiston, genes, viruses, tectonic plates, planets, Spearman's *g*, habit strength, and extraversion. We now know that some of these entities exist, that some of them do not exist, and we are unsure about the existence of others. In cases like these, the initial abductive inferences are made to claims primarily about the *existence* of theoretical entities in order to explain empirical facts or phenomena. Thus, in the first instance, the hypotheses given to us through the use of EFA do little more than postulate the existence of the latent variables in question. They say little about their nature and function and it remains for further research to elaborate on the first rudimentary conception of these variables.

The factor analytic use of existential abduction to infer the existence of the theoretical entity *g* can be coarsely reconstructed in accord with the above modified Peircean schema for abductive inference along the following lines:

> The surprising empirical phenomenon known as the *positive manifold* is identified.
> If *g* exists, and it is validly and reliably measured by a Weschler intelligence scale (and/or some other objective test), then the positive manifold would follow as a matter of course.
> Hence, there are grounds for judging the hypothesis of *g* to be initially plausible and worthy of further pursuit.

I remarked above that our conceptions of the latent factors of EFA come to us through existential abductions. In fact, the factor analytic generation of hypotheses is sometimes a mixture of existential and analogical abduction where we simultaneously posit the existence of a latent variable and offer the beginnings of a characterization of that entity by brief analogy to something that we understand quite well. Recall, analogical abduction appeals to known instances of successful abductive hypothesis formation to generate new hypotheses like them. To accommodate the presence of analogical abduction, the abductive argument schema just given would need an additional premise that indicates there is reason to believe that an hypothesis of the appropriate kind would explain the positive manifold. When Spearman first posited general intelligence to explain correlated performance indicators, he thought of it as mental energy, likening it to physical energy—a process well understood by the physics of the time. His initial inference to claims about *g*, then, was a blend of existential and analogical abduction.

This example serves to illustrate the point that methodologists should take the method of EFA proper to include the factor analyst's substantive interpretation of the statistical factors. In this regard, it is important to realize that the exploratory factor analyst has to resort to his or her own abductive powers when reasoning from correlational data patterns to underlying common causes. This point can be brought out by noting that the modified Peircean schema for abduction, and its application to the generation of Spearman's hypothesis of *g*, are concerned with the form of the arguments involved, and not with the actual generation of the explanatory hypotheses. In each case, the explanatory hypothesis is *given* in the second premise of the argument. An account of the genesis of the explanatory hypothesis must, therefore, be furnished by some other means. I think it is plausible to suggest that reasoning to explanatory hypotheses trades on our evolved cognitive ability to abductively generate such hypotheses. Peirce himself maintained that the human ability to engage readily in abductive reasoning was founded on a guessing instinct that has its origins in evolution. More suggestively, Carruthers (2002) maintains that our ability to engage in explanatory inference is almost certainly largely innate, and he speculates that it may be an adaptation selected for because of its crucial role in the fitness-enhancing activities of our ancestors such as hunting and tracking. Whatever its origin, an informative methodological characterization of the abductive nature of factor analytic inference must appeal to the scientist's own psychological resources as well as those of logic. In other words, it must be a methodological characterization that includes "the knowing subject."

Before leaving consideration of the general abductive nature of EFA, it should be briefly noted that there are a number of special features of EFA that play an important role in facilitating the abductive generation of hypotheses. For instance, simplicity, or parsimony, is an important desideratum in fashioning scientific explanations, and Thurstone's (1947) criteria for simple structure combine in an explicit formulation of parsimony in EFA. Thurstone's insight was to appreciate that rotation to the oblique simple structure solution provided an objective basis for acceptable terminal factor solutions that included reference to latent as well as manifest variables.

The Principle of the Common Cause

Having suggested that abduction, specifically existential abduction, largely characterizes the type of inference employed in the factor analytic generation of theories about latent variables, I now want to draw attention to a methodological principle that drives and shapes the nature of the existential abductive inference involved in EFA. It is well known that EFA is a common factor analytic model in which the latent factors it postulates are referred to as *common* factors. Not surprisingly, these factors are often understood, and sometimes referred to, as common *causes.* Yet, seldom have factor analytic methodologists attempted to formulate a principle, or maxim, of inference that guides the reasoning to common causes. There is, however, an important principle of scientific inference, known in philosophy of science as *the principle of the common cause*, that can be applied to good effect here. In what follows, I will discuss the principle of the common cause before spelling out its central role in EFA.

In *The Direction of Time*, Hans Reichenbach (1956) drew attention to the fact that, in both scientific and everyday reasoning we often explain a coincidence by postulating a common cause. In recognition of this fact, he explicitly formulated a maxim which he called *the principle of the common cause*. Reichenbach stated the principle cryptically, and informally, thus: "If an improbable coincidence has occurred, there must exist a common cause" (p. 157). For Reichenbach, this principle enjoins us to postulate a single common cause whenever there are events, or classes of events, which are statistically significantly correlated. To take one of

Reichenbach's original examples, if two lights in a room go out suddenly, the principle of the common cause says we should look for an interruption in their common power supply, such as a blown fuse.

Although Reichenbach's (1956) formulation of the principle will not do as it stands, the principle can be formulated as an important precept of human reasoning that governs a good deal of inference in science. The principle of the common cause has received some consideration in the philosophical literature, and sometimes appears to be tacitly employed in behavioral research, but it has been widely ignored in general scientific methodology.

In explicitly introducing the principle of the common cause, Reichenbach (1956) was concerned to capture the idea that if two events, A and B, are correlated, then one might be the cause of the other. Alternatively, they might have a common cause, C, where this cause always occurs before the correlated events. Reichenbach was the first to make this idea precise, and he did so by formulating it as a statistical problem. He suggested that when for simultaneous events A and B, $Pr(A \& B) > Pr(A) \times Pr(B)$, there exists an earlier common cause, C, of A and B, such that $Pr(A/C) > Pr(A/{\sim}C)$, $Pr(B/C) > Pr(B/{\sim}C)$, $Pr(A \& B/C) = Pr(A/C) \times Pr(B/C)$ and $Pr(A \& B/{\sim}C) = Pr(A/{\sim}C) \times Pr(B/{\sim}C)$ (Reichenbach, 1956, pp. 158–159). The common cause C is said to "screen off" the correlation between A and B, when A and B are uncorrelated conditional upon C. A common cause screens off each effect from the other by rendering its correlated effects (conditionally) probabilistically independent of each other. For example, given the occurrence of a flash of lightning in the sky, a correlation between two people apparently observing that flash is not just a coincidence, but is due to the flash of lightning being a common cause. Further, the probability of one person seeing the flash of lightning, given that it does occur, is not affected by whether or not the other person observes the lightning flash. Reichenbach's principle of the common cause can thus be formulated succinctly as follows: "Simultaneous correlated events have a prior common cause that screens off the correlation."

Despite the fact that Reichenbach's (1956) initial characterization of the principle of the common cause has some intuitive appeal and precision, more recent philosophical work (Arntzenius, 1993; Salmon, 1984; Sober, 1988) suggests that it needs to be amended in a number of ways. First, not every improbable coincidence, or significant correlation, has to be explained through a common cause. For this reason, the principle is sometimes taken to say, "If an improbable co-incidence has occurred, and there is no direct causal connection between the coincident variables, then one should infer a common cause." However, this amendment does not go far enough, for there are a number of other possible alternative causal interpretations of correlations. For example, two correlated variables might be mediated by an intervening cause in a developmental sequence, or they might be the result of separate direct causes, and so on. Responsible inference to a common cause must rule out alternative causal interpretations like these. We may, therefore, further amend Reichenbach's formulation of the principle to the following: "Whenever two events are improbably, or significantly, correlated we should infer a common cause, unless we have good reason not to." Clearly, the principle should not be taken as a hard and fast rule, for, in many cases, proper inferences about correlated events will not be of the common causal kind. The qualifier, "unless we have a good reason not to", should be understood as an injunction to consider causal interpretations of the correlated events other than the common causal kind. Also, there will be occasions when it is incorrect to infer any sort of causal inference. Some correlations are accidental correlations that are not brought about by causes.

Attempts to improve on Reichenbach's (1956) initial formulation of the principle of the common cause leads to the idea that there might be more than one acceptable version of the principle. We might expect this to be the case, not just because Reichenbach's formulation of the principle needs improving, but also because of the important point that different subject matters in different domains might well require different formulations of the principle. For example, Reichenbach, a philosopher of physics, took the principle to apply to correlated events that are spatially separated. However, behavioral and social scientists regularly infer common causes for events that are not spatially separated. This is clearly the case in psychology where the correlated variables can be performance measures on tests of intelligence and personality. Further, Sober (1988) has argued that in evolutionary theory phylogenetic inference to common ancestry involves postulating a common cause, but that this will be legitimate only if certain assumptions about the process of evolution are true. Thus, in formulating a principle of the common cause in a way that can be used effectively in a given domain, relevant contingent knowledge about that domain will shape the formulation of the principle, and moderate its use. As noted in the characterization of abduction provided earlier, the production of scientific knowledge is a three-termed relation between evidence, theory, and background knowledge. Routine use of a fixed, general formulation of the principle of the common cause that reasons from correlational data alone is unlikely to lead consistently to appropriate conclusions.

Two related features of the principle of the common cause should also be acknowledged: as Salmon (1984) has observed, the principle is sometimes used as a principle of explanation (we appeal to common causes to *explain* their correlated effects), and it is sometimes used as a principle of inference (we use the principle to *reason* to common causes from their correlated effects). The principle of the common cause is a form of abductive inference where one reasons from correlated events to common causes thought to explain those correlations. Thus, we can go further than Salmon and claim that the principle of the common cause simultaneously combines these explanatory and inferential features to yield explanatory inferences.

The suggestion that there might be different versions of the principle of the common cause prompts mention of a closely related principle that Spirtes, Glymour, and Scheines (2000) call *the Markov condition.* This principle has recently been employed in Bayesian network modeling of causal relations. Roughly stated, the Markov condition says that, conditional on its direct causes, a variable is probabilistically independent of everything except its effects. The Markov condition is in effect a generalized screening-off condition from which one can derive a version of the principle of the common cause as a special case. As a generalized screening-off condition, the Markov condition applies both to common and intervening causes. By contrast, the principle of the common cause only screens off common causes from their correlated effects. Because of this, it can be taken as the appropriate screening-off requirement for EFA.

I turn now to the application of the principle of the common cause to EFA.

EFA and the Principle of the Common Cause

The need for the principle of the common cause. It is sometimes said that the central idea in factor analysis is that the relations between a large number of observed variables are the direct result of a smaller number of latent variables. McArdle (1996) maintains that this is a theoretical principle employed in empirical research to identify a set of underlying factors. However, while true of EFA, this principle does not constrain factor analysts to infer the *common* latent factors that are the appropriate outcome of using common factor analysis. For this to happen, the principle has to be linked to the principle of the common cause, or recast in more specific methodological terms in accordance with that principle. Not only does the principle of the common cause enjoin us to infer common causes, it also assumes that that those inferences will be to relatively few common causes. Reichenbach's (1956) original formulation of the principle which allows inference to just one common cause is obviously too restrictive for use in multiple factor analysis. However, amending the principle to allow for more than one common cause, combined with the restraint imposed by following Ockham's razor (do not multiply entities beyond necessity), will enable one to infer multiple common causes without excess.

Although EFA is used to infer common causes, expositions of common factor analysis that explicitly acknowledge the importance of the principle of the common cause are difficult to find. Kim and Mueller's (1978) basic exposition of factor analysis is a noteworthy exception. In discussing the conceptual foundations of factor analysis, these authors evince the need to rely on what they call *the postulate of factorial causation*. The postulate of factorial causation is characterized by them as "the assumption that the observed variables are linear combinations of underlying factors, and that the covariation between observed variables is solely due to their common sharing of one or more of the common factors" (p. 78). The authors make clear that the common factors mentioned in the assumption are to be regarded as underlying causal variables. Taken as a methodological injunction, this postulate functions as a variant of the principle of the common cause. Without appeal to this principle, factor analysts could not identify the underlying factor pattern from the observed covariance structure.

Two features of the principle of the common cause that make it suitable for EFA are that it can be applied both in situations where we do not know how *likely* it is that the correlated effects are due to a common cause (this feature is consistent with the views of Reichenbach (1956), Salmon (1984), and Sober (1988) on common causal reasoning), and also in situations where we are essentially ignorant of the *nature* of the common cause. The abductive inference to common causes is a basic explanatory move which is non probabilistic, and qualitative, in nature. It is judgments about the soundness of the abductive inferences, not the assignment of probabilities, that confers initial plausibility on the factorial hypotheses spawned by EFA.

It is important to appreciate that the principle of the common cause does not function in isolation from other methodological constraints. Embedded in EFA, the principle helps one limit existential abductive inference to those situations where we reason back from *correlated* effects to one or more *common* causes. Although covariation is an important basic datum in science, not all effects are expressed as correlations, and as noted earlier, not all causes are of the common causal variety. It follows from this that one should not always look for common causal interpretations of multivariate data, for there are numerous alternative latent variable models. The simplex model of latent variables is a clear case in point (cf. Mulaik & Millsap, 2000). Further, it should be pointed out that the frequency of proper use of EFA should be much less than the frequency of proper use of the principle of the common cause, because the principle can be employed by non-factor analytic means, as will be indicated later.

In this first half of the article, I have argued that an appeal to abductive inference, linked to the principle of the common cause, leads naturally to the view that EFA is an abductive method of theory generation that enables researchers to theorize the existence of latent variables. Although this method uses the statistical ideas of multiple regression and partial correlation, it does so to facilitate inferences to the latent variables. On the view presented here, EFA is glossed as *a set of multivariate procedures which help us reason in an existentially abductive manner from robust correlational data patterns to plausible explanatory prototheories via the principle of the common cause.*

COMMON FACTOR ANALYSIS AND SCIENTIFIC METHOD

In the second half of the article, I propose to speak about the place of common factor analysis in scientific inquiry broadly understood. To this end, I briefly discuss the restrictions of two well-known theories of scientific method, before outlining and adopting a broader theory of scientific method. This broader theory will serve to provide a methodological framework within which one can locate, further explicate, and evaluate the nature and role of EFA in scientific research. In this regard, my principal concern will be to argue that EFA helps researchers generate theories with genuine explanatory merit; that factor indeterminacy is a methodological challenge for both EFA and confirmatory factor analysis (CFA), but that it is a challenge that can nevertheless be satisfactorily met; and, that as a valuable method of theory generation, EFA can be employed profitably in tandem with its confirmatory namesake and other theory evaluation methods.

EFA and Scientific Method

Much of the history of the development of general theories of scientific method has discussed the relative merits of inductive and hypothetico-deductive theories (Laudan, 1981). Mulaik (1987) locates EFA historically within 18th- and 19th-century empiricist philosophy of science and its restrictive inductivist conception of scientific inquiry. The inductive view of scientific method was said to obtain knowledge from experience by establishing generalizations based on theory-free observations. According to the scientific ideal of that time, inductive method was held to be an organon for the discovery of secure knowledge that is devoid of explanatory hypotheses. Of course, today it is a methodological truism to claim that there cannot be such a method, and Mulaik is clearly right to point out that EFA cannot be expected to deliver such knowledge. However, it should be stressed that even a modern view of inductive method, understood as a fallible generator of empirical generalizations, cannot properly accommodate EFA as a latent variable method. As noted at the beginning of the article, generalizing inductive inference is descriptive inference in the sense that it licenses inferences to more of the manifest attributes that are sampled; it does not have the conceptual resources to reach latent source variables that are understood as causal mechanisms. For this to be possible, an explanatory form of ampliative inference is needed, as my earlier remarks on abduction and its relevance to EFA have sought to make clear.

The hypothetico-deductive account of scientific method has assumed hegemonic status in twentieth century psychology (Rorer, 1991; Rozeboom, 1972). As such, it continues to sustain the popular view that scientific research is essentially a matter of testing hypotheses and theories, and with it, the corollary that there are no scientific methods for formulating hypotheses and theories (Hempel, 1966). While CFA finds a natural home within the confines of hypothetico-deductive method (more of which later), EFA stands outside that method, offering an abductive logic of theory generation which the hypothetico-deductive method denies is possible.

The present author (Haig, 2005) has proposed a broad theory of scientific method that provides a ramified framework within which one can locate EFA and other research methods. Because abductive reasoning figures prominently in the method, it is called an *abductive theory* of scientific method. This abductive theory assembles a complex of investigative tasks that ranges across a broad spectrum of research endeavors. According to the theory, science often, but by no means always, proceeds as follows: Guided by evolving research problems that comprise packages of empirical, conceptual, and methodological constraints (Haig, 1987; Nickles, 1981), sets of data are analyzed with a view to detecting robust empirical regularities, or phenomena (Woodward, 1989). Once detected, these phenomena are explained by abductively inferring the existence of underlying theoretical entities. Here, abductive inference involves reasoning from claims about phenomena, understood as presumed effects, to their theoretical explanation in terms of those latent entities (Peirce, 1931–1958; Rozeboom, 1972; Thagard, 1988). Upon positive judgments of the initial plausibility of these explanatory theories (cf. Whitt, 1992), attempts are made to elaborate on the nature of the causal mechanisms. This is done by constructing plausible models of those mechanisms by analogy with relevant ideas in domains that are well understood (Harré, 1976). When the theories are sufficiently well developed, they are assessed against their rivals on a number of evaluative dimensions. However, because science simultaneously pursues multiple goals (Hooker, 1987), and theories are often underdetermined by the relevant evidence (McMullin, 1995), theory appraisal will frequently have to be undertaken on dimensions other than predictive accuracy (McMullin, 1983). Theories are assessed against their rivals in terms of their explanatory goodness, with judgments of the best explanation being undertaken by comparing theories in respect of their explanatory coherence (Thagard, 1992).

This abductive theory of method attempts to bring together an array of ideas on important aspects of the research process, many of which fall outside the province of the standard inductive and hypothetico-deductive accounts of scientific method. Of particular relevance for this article is that fact that theory generation is depicted as an abductive process, a fact that enables the abductive theory of method to incorporate EFA within its fold. When this happens, EFA functions as a submethod of the general abductive theory and serves to provide a detailed methodological account of how theories about common causes can be abductively generated from correlational evidence. The general abductive theory of method is also able to subsume the inductive account of method. With its emphasis on generalization, the inductive method can be seen at work in the process of phenomena detection.

Before turning to EFA again, three brief points about the relation between EFA and the general abductive theory of method should be noted. First, the justification for adopting a general abductive theory of scientific method is confined to the fact that it facilitates the examination of EFA in a suitably broad methodological perspective. A full examination of the merits of this abductive theory as a wide-ranging, coherent account of scientific method awaits another occasion. Second, the justification for the abductive depiction of EFA, given in the first half of the article, has been developed independently of the acceptance of the broad abductive theory of method, and as such can be used outside its ambit.

Third, the abductive employment of EFA within the theory generation phase of the broad abductive account of scientific method begs no important question about the abductive nature of that phase. Rather, it lends credibility to the broad theory's account of theory generation by being consistent with its general account of that process.

EFA, Phenomena Detection, and Explanatory Theories

EFA and phenomena detection. As just noted, the abductive theory of method contends that scientific research often involves the initial detection of empirical phenomena, followed by the construction of explanatory theories in order to understand those phenomena. Here, I want to draw attention to an important feature of EFA by suggesting that, strictly speaking, it contributes to phenomena detection as well as theory construction. As such, it is a mixed method having both data analytic and theory generation roles.

Quite different accounts of scientific inquiry tend to share the view that scientific theories explain and predict facts about observed data. However, as noted earlier in the discussion of Peirce's (1931–1958) original characterization of abductive inference, this widely held view fails both to distinguish between data and phenomena and, in consequence, to appreciate the fact that typically, it is phenomena, not data, that our theories are constructed to explain and predict. It will be recalled that phenomena, unlike data, are relatively stable, recurrent features of the world that we seek to explain, and that it is their generality and stability that make them, not data, the appropriate objects of explanation. In extracting phenomena from the data, we often use statistical methods. EFA is a case in point. Its name not withstanding, EFA is not a particularly exploratory method, but it is nevertheless used to seek replicable data patterns, which are a standard requirement for making claims about phenomena. This can be seen in the methodological requirement, stated initially by Thurstone (1947), and reinforced by Cattell (1978), that the obtained factor pattern should be repetitive, or invariant, across different data sets in distinct populations. Both of these pioneers of factor analysis realized that an interpretation of extracted and rotated factor patterns made little scientific sense if they were specific to a particular covariance matrix and did not, or were unlikely to, generalize to other covariance matrices.

EFA and explanatory theories. One challenge to the interpretation of EFA as an abductive method of theory generation is the claim that the theories it produces are of little explanatory worth. In countering this criticism, I will suggest that factorial theories spawned by EFA are essentially dispositional in nature, and that dispositional theories do have genuine, though limited, explanatory import (cf. Rozeboom, 1984; Sober, 1982). Existential abduction, it will be recalled, postulates the existence of new entities without being able to characterize their nature.

Thus, in exploiting this form of abduction, EFA provides us with an essentially dispositional characterization of the latent entities it postulates.

Dispositional theories provide us with oblique characterizations of the properties we attribute to things by way of their presumed effects under specified conditions (cf. Mumford, 1998; Tuomela, 1978). For example, the brittleness of glass is a dispositional property causally responsible for the breaking of glass objects when they are struck with sufficient force. Our indirect characterization of this latent property, brittleness, is in terms of the relevant striking and breaking events. Similarly, Spearman's original theory of *g* was essentially dispositional in nature, for *g* was characterized obliquely in terms of children's school performance under the appropriate test conditions.

As noted immediately above, dispositional theories have often been regarded as explanatorily suspect. Perhaps the best known, and most frequently cited, example of this is Molière's scoff at explaining the soporific effects of opium by appeal to its dormitive power. However, as Rozeboom (1973) maintains,

> the *virtus dormitiva* of opium *is* why people who partake of this particular substance become drowsy. Of course, that by itself leaves a great deal unknown about this power's nature, but learning of its existence and how to diagnose its presence/absence in particular cases is a necessary preliminary to pursuit of that knowledge. (p. 67)

Similarly, with EFA, the existential abductions to latent factors postulate the existence of these factors without being able to say much, if anything, about their actual nature. It is the job of EFA to help us bring our factorial prototheories into existence, not to develop them and specify their nature. As the general abductive account of scientific method makes clear, the latter task is undertaken through the use of analogical modeling strategies. To expect EFA to develop theories, as well as generate them, is to fail to understand its proper role as a generator of dispositional theories.

An answer to the question of whether dispositional theories are of genuine explanatory worth requires us to focus on whether such theories have explanatory power. Two aspects of explanatory power that are relevant here are explanatory depth and explanatory breadth. Explanatory depth is naturally understood as existential depth. Existential depth is accorded those explanatory theories in science that are deep-structural in nature. Theories of this sort postulate theoretical entities that are different in kind, and hidden from, the empirical regularities they are invoked to explain. In postulating theoretical entities, deep-structural theories extend our referential reach to new entities, and thereby increase the potential scope of our knowledge. The factorial theories afforded us by EFA have existential depth because the typical products of factor analytic abductions are new claims about hidden causal entities that are thought to exist distinct from their manifest effects.

Existential depth deserves to be considered as an explanatory virtue of EFA's postulational theories.

The other feature of explanatory power, explanatory breadth, is a long-standing criterion of a theory's worth. Sometimes, explanatory breadth is understood as *consilience*, which is often portrayed as the idea that a theory explains more of the evidence (a greater number of facts) than its competitors. The prototheories of EFA do not have consilience in this sense, for they typically do not explain a range of facts. Nor are they immediately placed in competition with rival theories. However, factorial theories of this kind are consilient in the sense that they explain the *concurrences* embodied in the relevant patterns of correlations. By appealing to common causal mechanisms, these factorial theories unify their concurrences and thereby provide us with the beginnings of an understanding of why they concur.

The two criteria that comprise explanatory power are not the only dimensions of theory appraisal that should be considered when submitting a factorial prototheory to preliminary evaluation. The fertility of a theory is also an important evaluative consideration. In general terms, this dimension focuses on the extent to which a theory stimulates further positive research. It should be noted here, that while our initial dispositional descriptions of latent factors are low in informational content, they do not, or need not, act as a heuristic block to further inquiry as some commentators on factor analysis suggest. Lykken (1971), for example, judges latent variable explanations from factor analysis to be "still born," whereas Skinner (1953) declares that they give us false assurances about the state of our knowledge. However, given that EFA trades in existential abductions, the dispositional ascription of latent factors should serve a positive heuristic function. Considered as a preliminary to what it is hoped will eventually be full-blooded explanations, dispositional ascriptions serve to define the scope of, and mark a point of departure for, appropriate research programs. Viewed in this developmental light, dispositional explanations are inquiry-promoting, not inquiry-blocking.

EFA and the Spectre of Underdetermination

The methodological literature on factor analysis has given considerable attention to the indeterminacy of factors in the common factor model. Factor indeterminacy arises from the fact that the common factors are not uniquely determined by their related manifest variables. As a consequence, a number of different common factors can be produced to fit the same pattern of correlations in the manifest variables.

Although typically ignored by factor analytic researchers, factor indeterminacy is an epistemic fact of life that continues to challenge factor analytic methodologists. Some methodologists regard factor indeterminacy as a serious problem for common factor analysis and recommend the use of alternative methods such as component analysis methods because they are considered to be determinate methods. Others have countered variously that component analysis models are not causal models (and, therefore, are not proper alternatives to common factor models), that they do not typically remain invariant under the addition of new variables, and that the indeterminacy of factor scores is seldom a problem in interpreting common factor analytic results because factor scores do not have to be computed.

One constructive perspective on the issue of factor indeterminacy has been suggested by Mulaik and McDonald (McDonald & Mulaik, 1979; Mulaik, 1987; Mulaik & McDonald, 1978). Their position is that the indeterminacy involved in interpreting the common factors in EFA is just a special case of the general indeterminacy of theory by empirical evidence widely encountered in science, and it should not, therefore, be seen as a debilitating feature that forces us to give up on common factor analysis. Essentially, I agree with this outlook on the factor indeterminacy issue and will discuss it in this light. I will argue that EFA helps us produce theories that are underdetermined by the relevant evidence, and that the methodological challenge that this presents can in fact be met in an acceptable way. I conduct my discussion against the backdrop of the broad abductive theory of scientific method outlined earlier.

Indeterminacy is pervasive in science. It occurs in semantic, metaphysical, and epistemological forms (McMullin, 1995). Factor indeterminacy is essentially epistemological in nature. The basic idea of epistemological or, more precisely, methodological, indeterminacy is that the truth or falsity (better, acceptance or rejection) of a hypothesis or theory is not determined by the relevant evidence (Duhem, 1954). In effect, methodological indeterminacy arises from our inability to justify accepting one theory amongst alternatives on the basis of empirical evidence alone. This problem is sometimes referred to as the underdetermination of theory by *data*, and sometimes as the underdetermination of theory by *evidence.* However, because theories are often underdetermined by evidential statements about phenomena, rather than data, and because evidence in theory appraisal will often be superempirical as well as empirical in nature, I will refer to the indeterminacy here as the underdermination of theory by *empirical evidence* (UTEE).

Construing factor indeterminacy as a variant of UTEE is to regard it as a serious problem, for UTEE is a strong form of undertermination that needs to be reckoned with in science. Indeed, as an unavoidable fact of scientific life, UTEE presents a major challenge for scientific methodology.

Concerning scientific method, there are a number of places where UTEE occurs. The two that are relevant to common factor analysis are: (a) The broad abductive method's context of theory generation, where EFA can be employed as an abductive generator of rudimentary explanatory theories; and, (b) the context of theory evaluation, where CFA can be used to test factorial theories in an essentially hypothetico-deductive manner. Here, I will discuss factor indeterminacy as UTEE for EFA. I will briefly address the issue of factor indeterminacy as it affects CFA in the penultimate section of the article.

Mulaik (1987) sees UTEE in EFA as involving inductive generalizations that go beyond the data. I believe the *inductive* UTEE should be seen as applying specifically to the task of establishing factorial invariance where one seeks constructive or external replication of factor patterns. However, for EFA there is also need to acknowledge and deal with the *abductive* UTEE involved in the generation of explanatory factorial theories. The sound abductive generation of hypotheses is essentially educated guess work. Thus, drawing from background knowledge, and constrained by correlational empirical evidence, the use of EFA can at best only be expected to yield a plurality of factorial hypotheses or theories that are thought to be in competition. This contrasts strongly with the unrealistic expectation held by many earlier users of EFA that the method would deliver them strongly justified claims about the one best factorial hypothesis or theory.

How then, can EFA deal with the spectre of UTEE in the context of theory generation? The answer, I think, is that EFA narrows down the space of a potential infinity of candidate theories to a manageable subset by facilitating judgments of initial plausibility. It seems clear enough that scientists often make judgments about the initial plausibility of the explanatory hypotheses and theories that they generate. It is less clear just what this evaluative criterion amounts to (cf. Whitt, 1992). With the abductive theory of scientific method, judgments of the initial plausibility of theories are judgments about the soundness of the abductive arguments employed in generating those theories. I suspect that those who employ EFA as an abductive method of theory generation often make compressed judgments of initial plausibility. Consistent with the view of research problems adopted by the general abductive theory of scientific method, initial plausibility may be viewed as a constraint satisfaction problem. Multiple constraints from background knowledge (e.g., the coherence of the proposed theory with relevant and reliable background knowledge), methodology (centrally, the employment of EFA on appropriate methodological grounds; cf. Fabrigar, Wegener, MacCallum, & Strahan, 1999), and explanatory demands (e.g., the ability of factorial theories to explain the relevant facts in an appropriate manner) combine to provide a composite judgment of the theory's initial plausibility.

By conferring judgments of initial plausibility on the theories it spawns, EFA deems them worthy of further pursuit, whereupon it remains for the factorial theories to be further developed and evaluated, perhaps through the use of CFA. It should be emphasized that using EFA to facilitate judgments about the initial plausibility of hypotheses will still leave the domains being investigated in a state of considerable theoretical underdetermination. It should also be stressed that the resulting plurality of competing theories is entirely to be expected, and should not be thought of as an undesirable consequence of employing EFA. To the contrary, it is essential for the growth of scientific knowledge that we promote theoretical pluralism. The reason for this rests with our makeup as cognizers: We begin in ignorance, so-to-speak, and have at our disposal limited sensory equipment; however, we are able to develop a rich imagination and considerable powers of criticism. These four features operate such that the only means available to us for advancing knowledge is to construct and evaluate theories through their constant critical interplay. In this way, the strategy of theoretical pluralism is forced upon us (cf. Hooker, 1987). Thus, it is through the simultaneous pursuit of multiple theories with the intent of eventually adjudicating between a reduced subset of these that one arrives at judgments of best theory.

I have suggested that factor indeterminacy is a special case of the pervasive problem of UTEE. I have also argued that, if we adopt realistic expectations about what EFA can deliver as a method of theory generation, and also grant that the method contributes to the needed strategy of theoretical pluralism, then we mayreasonably conclude that EFA satisfactorily meets this particular challenge of indeterminacy.

EFA and CFA

Having argued that EFA is a method that facilitates the abductive generation of rudimentary explanatory theories, it remains to consider what implications this view of EFA has for the conduct of EFA research, including its relation to the current use of CFA.

The abductive view of EFA does highlight, and stress the importance of, some features of its best use, and I will mention four of these. First, it should now be clear that an abductive interpretation of EFA reinforces the view that it is best regarded as a latent variable method, thus distancing it from the data reduction method of principal components analysis. From this, it obviously follows that EFA should always be used in preference to principal components analysis when the underlying common causal structure of a domain is being investigated.

Second, strictly speaking, the abductive interpretation of EFA also acknowledges the twin roles of the method of searching for inductive generalizations, and seeking their explanations. As the broad abductive theory of scientific method makes clear, these research goals are different, but they are both important: To repeat, it is because the detection of phenomena requires reasoning inductively to empirical regularities that the abductive use of EFA insists on initially securing the invariance of factors across different populations. And, it is because the inductive regularities require explanation that one then abductively postulates factorial hypotheses about common causes.

Third, as noted earlier, the abductive view of EFA places a heavy emphasis on the importance of background knowledge in EFA research. In this regard, the initial variable selection process, so rightly emphasized by Thurstone (1947) and Cattell (1978), is of sufficient importance that it should be considered as part of the first step in carrying out an EFA study. For instance, in determining the variables that would be selected in his factor analytic studies of personality, Cattell was at pains formulate and follow principles of representative sampling from a broad formulation of the domain in question. Further, the importance of background knowledge in making abductive inferences to underlying factors should not be overlooked. In this regard, the modified Peircean depiction of abductive inference presented earlier explicitly acknowledged some of the manifold ways in which such inference depends on background knowledge. It is an important truism that the factorial hypotheses generated through abductive inference are not created *ex nihilo*, but come from the extant theoretical framework and knowledge of the factor analytic researcher. For most of our EFA theorizing, this source is a mix of our common sense and scientific psychological knowledge.

Finally, and relatedly, it should be made clear that acknowledging the importance of background knowledge in abductive EFA does not provide good grounds for adopting a general strategy where one discards EFA, formulates theories a priori, and uses factor analysis only in its confirmatory mode. This holds, even though with EFA one anticipates possible common factors in order to select sufficient indicator variables to allow one to overdetermine those factors. EFA has a legitimate place in factor analytic research because it helpfully contributes to theory generation in at least three ways: it contributes to detection of the empirical phenomena that motivate the need for generating factorial hypotheses; it serves to winnow out a lot of theoretically possible hypotheses at the hypothesis generation stage of inquiry; and, it helps to present factorial hypotheses in a form suitable for subsequent testing by CFA.

This last remark, which supports the idea that there is a useful role for abductive EFA in factor analytic research, raises the question of how EFA relates to CFA. In contrast to popular versions of the classical inductivist view of science that inductive method can generate secure knowledge claims, the use of EFA as an abductive method of theory generation can only furnish researchers with a weak logic of discovery that gives them educated guesses about underlying causal factors. It is for this reason that those who use EFA to generate theories need to supplement their generative assessments of the initial plausibility of those theories with additional consequentialist justification in the form of CFA testing, or some alternative approach to theory appraisal.

In stressing the need for the additional evaluation of theories that are obtained through EFA, it should not be implied that researchers should always, or even standardly, employ classical EFA and follow this with CFA. CFA is just one of a number of options with which researchers might provide a justification of factorial hypotheses. As an alternative, one might, for example, adopt Rozeboom's non-classical form of EFA as a method to generate a number of models that are equivalent with respect to their simple structure by using his versatile Hyball program (1991a, 1991b) before going on to adjudicate between these models by employing CFA. Another legitimate strategy might involve formulating a causal model using EFA and following it with a procedure like that defended by Mulaik and Millsap (2000) in which a nested sequence of steps designed to test various aspects of a structural equation model is undertaken.

A further possibility, that I do not think has been explored in the factor analytic literature, would be to follow up on the preliminary acceptance of rudimentary theories spawned by EFA by developing a number of factorial theories through whatever modeling procedures seem appropriate, and then submitting those theories to a non-factor analytic form of theory appraisal. For example, it would be quite possible for competing research programs to develop theories given to them through EFA and then submit those theories to comparative appraisal in respect of their explanatory coherence. Thagard's (1992) theory of explanatory coherence is an integrated multi-criterial method of theory appraisal that accepts as better explanatory theories those that have greater explanatory breadth, are simpler than their rivals, and which are analogous to theories that have themselves been successful. This strategy of using EFA to abductively generate explanatory theories, and employing the theory of explanatory coherence in subsequent appraisals of these explanatory theories, is abductive both fore and aft. As such, it fits nicely within the framework of the broad abductive theory of scientific method outlined earlier.

Finally, it should be said that there are a number of different methods for abductively generating hypotheses and theories in psychology, EFA being but one of these. Grounded theory method (Strauss, 1987), for example, can be employed to generate theories that explain the qualitative data patterns from which they are derived. Also, Gardner's (1983) theory of multiple intelligences was generated by the author using a "subjective," nonstatistical factor analysis. Furthermore, it is plausible to suggest that structural equation modelers sometimes abductively generate theories by non-factor analytic means before submitting them to CFA scrutiny. As with factor analytic abduction, this could only be done by exploiting our naturally given cognitive abilities to abductively generate explanatory hypotheses and theories.

In this article, I have been concerned to argue that EFA has a legitimate, and important, role as a method of theory generation, and that EFA and CFA should be viewed as complementary, not competing, methods of common factor analysis. However, a number of factor analytic methodologists have expressed views that discourage such an outlook in factor analysis. For example, Gorsuch (1983), in his well-known book on factor analysis, expresses a view about the relative importance of exploratory and confirmatory factor analysis that seems to be quite widely held today:

> The space and time given to [EFA] is a function of the complexity of resolving its problems, not of its theoretical importance. On the contrary, confirmatory factor analysis is the more theoretically important—and should be the much more widely used—of the two major factor analytic approaches. (p. 134)

Although Gorsuch (1983) makes his claim in emphatic terms, he provides no justification for it. There are, I think, at least two reasons that can be given for his conclusion. However, I do not think they add up to a convincing justification. First, there is a widespread belief that the essence of scientific research is to be found in the prevailing hypothetico-deductive conception of scientific method with its emphasis on theory testing for predictive success. However, this belief is difficult to defend, given the fact that there are many other important phases of scientific inquiry that together demand most of the researcher's methodological time. As the broad abductive theory of scientific method makes clear, these additional phases embrace the detection of empirical phenomena, and the generation, development, and full comparative appraisal of theories. Viewed in this light, theory testing is just one, albeit important, part of scientific method. Given the fact that science is as much concerned with theory generation as it is with theory testing, and acknowledging that EFA is a useful abductive method of theory generation, EFA deserves to be regarded as one important instrument in the theory constructor's tool-kit.

Moreover, both hypothetico-deductive orthodoxy (Rorer, 1991; Rozeboom, 1972), and a good deal of current CFA practice, are in need of some confirmational rehabilitation. Both suffer from the tendency to take theory evaluation as a noncomparative undertaking in which theories are assessed with respect to the empirical evidence, but not in relation to alternative theories. Arguably, the hypothetico-deductive method can be repaired in this respect (cf. Giere, 1983), while some CFA methodologists (e.g., Kaplan, 2000) have sensibly expressed the need to compare theories or models when assessing them in respect of their goodness-of-fit to the empirical evidence. It is here that the problem of UTEE arises for CFA, for associated goodness-of-fit indices sometimes fail to adjudicate between two or more competing factor analytic models. In these cases, CFA has to broaden its announced goal of testing for empirical adequacy through goodness-of-fit tests. This can be achieved in part by obtaining fit statistics weighted by parsimony indices, and more fully by invoking a number of additional superempirical criteria of theory goodness to supplement goodness-of-fit judgments.

It should be emphasized that the use of goodness-of-fit is a minimum criterion of empirical adequacy (Rodgers & Rowe, 2002) that alone provides insufficient grounds for assessing the credibility of competing theories. The goodness-of-fit empirical adequacy of theories can be strengthened by also ascertaining their predictive worth. Hypothetico-deductive testing is often assumed, or recommended, in this regard, but this confirmational strategy faces a number of difficulties well known to philosophers of science. Of particular relevance here is the fact that standard hypothetico-deductive confirmation founders on the problem of UTEE. This shortcoming brings us back to the recommendation advanced earlier that criteria of empirical adequacy need to be supplemented by the so-called superempirical, or complementary, virtues to do with explanatory power, fertility, and simplicity (cf.

McMullin, 1983). Criteria such as these "reduce the gap" between theory and empirical evidence, but they do not close it. This is because scientists do not strongly agree on the criteria employed in theory evaluation. Moreover, even when scientists do agree on the evaluative criteria to be used, they will sometimes differ in the relative weight they assign to the various criteria. Nevertheless, with the employment of a composite of empirical and theoretical criteria, the problem of UTEE becomes manageable even though theory evaluation will seldom be a determinate exercise. To meet the challenge of UTEE, CFA, along with EFA, needs to supplement its judgments of empirical adequacy by appealing to the theoretical virtues.

A second reason for downplaying the importance of EFA is the supposition that, while EFA has a role in generating knowledge claims, it does not have a role in evaluating them. Rather, full evaluative responsibility is assigned to CFA embedded within a hypothetico-deductive framework. However, as claimed earlier, the use of EFA as an abductive method of theory generation enables us to judge the initial plausibility of the hypotheses it spawns. Positive judgments of initial plausibility are stamps of epistemic approval that signal that factorial hypotheses have sufficient merit to warrant further investigation. Assessments of initial plausibility are undertaken to gauge the pursuit-worthiness of hypotheses, but they do not provide sufficient warrant for treating such hypotheses as credentialled knowledge claims. Those who recommend that the hypotheses thrown up by EFA should be tested subsequently through the employment of confirmatory factor analysis are right to stress the need for their consequentialist justification. However, it is important to appreciate that EFA provides a provisional generative justification for the hypotheses it produces.

SUMMARY AND CONCLUSION

In examining the methodological foundations of EFA, I have said many different things about the nature of this method. It might be useful, therefore, to bring together the main points in the form of a summary and a conclusion. Although the summary is presented in declarative form, it should be stated that this article is a work in progress; additional methodological work is needed in order to give both the summary points and the general conclusion a full justification.

In summary:

1. The main goal of EFA is to generate rudimentary explanatory theories in order to explain covariational data patterns. As a preliminary to this goal, it is noted that EFA functions as a data analytic method that contributes to the detection of empirical regularities.

2. The inferential move from manifest to latent variables in EFA is abductive in nature. The particular form of abductive inference typically involved is existential abduction. Existential abductions postulate the existence of objects or attributes, but they do not specify their natures.

3. EFA's use of abductive reasoning is facilitated by its employment of the principle of the common cause, which restricts factor analytic inferences to correlated effects and their common causes. This principle lies at the inferential heart of the method.

4. EFA has a modest, albeit important, role in theory generation. It is a serviceable generator of elementary plausible theory about the common causes of correlated variables.

5. The abductive logic of EFA enables the method to confer a generative justification on the theories it produces. This form of justification involves judgments that the theories are the result of sound abductive reasoning and that they have sufficient initial plausibility to warrant further investigation.

6. Theories generated by EFA have the status of dispositional theories. The latent variables postulated by such theories can be genuine existents, even though the theories say very little about their nature.

7. Despite their elementary nature, dispositional theories afforded us by EFA do have genuine, although modest, explanatory power. This power resides both in their existential or explanatory depth, and their consilience, or explanatory breadth.

8. EFA is able to satisfactorily confront the problem of factor indeterminacy in theory generation by screening candidate factorial theories for their initial plausibility in an environment where theoretical pluralism is to be expected.

9. In order to satisfactorily meet this problem of factor indeterminacy, it is recommended that CFA research embraces superempirical criteria in addition to both the goodness-of-fit and predictive criteria of empirical adequacy.

10. Because EFA and CFA tend to serve different methodological functions in multivariate research—theory generation for the one, theory testing for the other—they are best viewed as complementary rather than competing methods. It will sometimes be advantageous to employ the two common factor analytic methods in tandem.

11. Nevertheless, theories about common causes can be generated abductively without appeal to EFA, while theories generated by EFA may be tested by using methods other then CFA.

12. A broad abductive theory of scientific method provides a useful framework within which to locate EFA. There, EFA can function as a submethod of theory generation in domains with a common causal structure.

13. CFA can contribute to the goal of empirical adequacy in the subsequent hypothetico-deductive appraisal of common causal theories.

To conclude, despite the fact that EFA has been frequently employed in psychological research, the extant methodological literature on factor analysis insufficiently acknowledges the explanatory and ontological import of the method's inferential nature. Arguably, abduction is science's chief form of creative reasoning, and the principle of the common cause is a maxim of scientific inference with important application in research. By incorporating these two related elements into its fold, EFA is ensured an important, albeit circumscribed, role in the construction of explanatory theories in psychology and other sciences. In this role, EFA can serve as a valuable precursor to CFA. I believe factor analytic research would benefit considerably by returning to its methodological origins and embracing EFA as an important method for generating structural models about common causes.

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