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Theory Construction Methodology: A Practical Framework for Building Theories in Psychology

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Abstract
This article aims to improve theory formation in psychology by developing a practical methodology for constructing explanatory theories: *theory construction methodology* (TCM). TCM is a sequence of five steps. First, the theorist identifies a domain of *empirical phenomena* that becomes the target of explanation. Second, the theorist constructs a *prototheory*, a set of theoretical principles that putatively explain these phenomena. Third, the prototheory is used to construct a *formal model*, a set of model equations that encode explanatory principles. Fourth, the theorist investigates the *explanatory adequacy* of the model by formalizing its empirical phenomena and assessing whether it indeed reproduces these phenomena. Fifth, the theorist studies the *overall adequacy* of the theory by evaluating whether the identified phenomena are indeed reproduced faithfully and whether the explanatory principles are sufficiently parsimonious and substantively plausible. We explain TCM with an example taken from research on intelligence (the mutualism model of intelligence), in which key elements of the method have been successfully implemented. We discuss the place of TCM in the larger scheme of scientific research and propose an outline for a university curriculum that can systematically educate psychologists in the process of theory formation.

Keywords
philosophy of science, mutualism, abduction, formal modeling

Scientific theory is one of humankind's most powerful inventions. The most impressive scientific theories—Copernicus's heliocentric model, Darwin's theory of evolution, Einstein's theory of relativity—facilitated radically new intellectual viewpoints that have marked unique moments in our collective history as a species. But theories are also deeply practical (Lewin, 1943): By improving our understanding of empirical phenomena, they allow us to predict and control our environment through strategic interventions and technologies. In fact, as far as the canonical goals of understanding, prediction, and control are involved, the only thing that beats a scientific theory is a better scientific theory.

As psychology arose as a new science, it was ready to reap the theoretical fruits of the scientific method as older scientific disciplines had. This, however, turned out to be a more tedious affair than anticipated. In fact, the worrisome status of psychological theory has been a concern for psychological scientists from the beginnings of psychology as a scientific discipline. Articles lamenting the limited success of theory construction in psychology have appeared with clockwork regularity over the past century (Gigerenzer, 1991, 2010; Meehl, 1978; Muthukrishna & Henrich, 2019; Lykken, 1991). Several contemporary scholars have suggested that the lack of strong theory may have contributed to the "reproducibility crisis" (Borsboom, 2013; Klein, 2014; Muthukrishna & Henrich, 2019; Smaldino, 2017). These concerns have led some to declare the current situation

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no less than a *theory crisis* (Oberauer & Lewandowsky, 2019).

Although psychology is a broad discipline and one cannot easily generalize across its subdomains, we take the characterization from Oberauer and Lewandowsky (2019) to be largely correct. Small theory-rich bubbles certainly exist in psychology, but our field lacks an overarching theory-construction program as exists in other disciplines (e.g., theoretical physics, theoretical biology, theoretical economics) in which scientists work collectively on theory building (Borsboom, 2013). In psychology, theories are typically products of (small groups of) individuals, a feature that Mischel (2008) identified as the *toothbrush problem*: "psychologists treat other peoples' theories like toothbrushes—no self-respecting person wants to use anyone else's" (para. 3). Thus, we may not necessarily have a shortage of theories; however, we do lack a coordinated program of theory construction.

The problematic status of psychological theory may stem from the fact that psychologists' methodological repertoire is generally limited to skills used to *test* empirical hypotheses (e.g., null-hypothesis testing, experimental design). In contrast, skills that are conducive to *constructing* theories, such as theoretical modeling by mathematical means or computer simulations, are seldom taught in psychology. Likewise, philosophical work on the nature of theory construction is rarely featured in our curricula. As a result, every psychologist knows how to conduct statistical tests by using familiar analysis of variance (ANOVA) machinery, but few would know where to begin modeling psychological processes using, say, dynamic systems, simulation techniques, or agent-based models.

The lack of explanatory theories in psychology hinders progress in at least three ways. First, it creates the danger of inventing the wheel over and over again because we do not have a good grasp on how different phenomena relate to each other and whether phenomena emerge from the same underlying principles (Kruglanski, 2001; Vallacher & Nowak, 1997). Second, without strong theories we cannot identify the most effective interventions for changing a system in the desired way. For example, a well-specified theory of depression would greatly help in designing more effective clinical interventions (Borsboom, 2017; Cramer et al., 2016). Third, without theories we often do not know where to look when designing new studies. For example, physicists were able to detect the Higgs particle only because they knew which of the 0.00001% of the 150 exabytes of data produced daily by the Large Hadron Collider at CERN they needed to analyze (West, 2017).

Where does the strong focus on testing in psychology come from? An important factor lies in psychology's adherence to an austere theory of scientific method, to wit, the hypothetico-deductive method—the idea that science progresses through repeated empirical tests of hypotheses entailed by theories. Even a cursory look through methodology textbooks in psychology shows that an endorsement of the hypothetico-deductive method is widespread in the discipline; the idea that hypothesis testing should be psychologists' primary focus when it comes to the scientific method, or even that science is *defined* by hypothesis testing, is deeply ingrained in psychology's research culture (Rorer, 1991; Rozeboom, 1997).

The hypothetico-deductive method, however, embodies a restrictive approach to evaluating theories. For instance, it places theory generation outside the realm of systematic methodology (Popper, 1959), as theories are understood as products of the free use of the scientist's imagination; they are not brought about by methodological means, and neither does the process by which a theory is generated feature in the evaluation of that theory. On the contrary, once brought to the attention of scientists, theories are simply subjected to immediate testing. Accordingly, successfully predicting empirical test outcomes is, in psychology, the primary criterion for theory evaluation, whereas explanatory qualities of scientific theories are at best of secondary importance. In short, the hypothetico-deductive method fully focuses the attention of researchers on testing and discourages the use of systematic methods for generating, developing, and appraising theories.

Thus, psychologists (a) lack a collective, coordinated research program on theory formation; (b) are rarely trained to develop skills conducive to theory development; and (c) live in a research culture that endorses the norm that science is defined by its methods of hypothesis testing rather than theory construction more broadly. The central idea of this article is that to break this theoretical stalemate we need a methodology that organizes the practice of theory formation so that it can be developed, practiced, and taught in psychology. To achieve this aim, in this article, we develop a *theory construction methodology* (TCM), a method for explanatory theory formation that is designed to assist researchers in the development of theories. The methodology is based on Haig's abductive theory of method (Haig, 2005, 2014), which depicts scientific inquiry as a two-phase process in which empirical phenomena are detected and then explained by theories that are built to understand them. Accordingly, TCM adopts the view that there are in fact logics of discovery and promotes methods that facilitate the generation of theories. It regards theories as developing entities and creates ample methodological space for their growth. Further, it maintains that theories have both predictive and explanatory virtues. Thus, TCM adopts a multicriterial perspective on theory evaluation and harnesses methods and strategies that enable scientists to comprehensively assess the worth of explanatory theories.

An outline of this article is as follows. First, we present a distinction between theories, data, and phenomena that identifies central elements in theory construction. Second, we outline TCM in terms of a set of steps that researchers can follow to generate explanatory theories. Third, we articulate the iterative character of theory formation in terms of a theoretical cycle that can organize theoretical research similar to how the empirical cycle (De Groot, 1969) organizes empirical research. Finally, we sketch a curriculum for teaching theory construction on the basis of TCM.

Phenomena, Data, and Theories

It is common in scientific discourse to speak about theories in relation to data; theories are said to explain data or to be tested in terms of their concordance with data. However, these ways of talking are misleading because they mask the fact that theories typically do not explain "the data" but rather the empirical phenomena that are evidenced by these data. Because empirical phenomena are more realistic targets for constructing explanatory theory than data themselves, the methodology presented in this article adopts the idea that theories relate to data *indirectly*, primarily via the phenomena from which they are abstracted (Haig, 2014; Woodward, 1989). For example, theories on intelligence do not explain IQ subtest scores but stable features of correlations between these subtest scores that are present across different data sets, for example, the phenomenon that these correlations are invariably positive (the *positive manifold*, a central example in this article). This section briefly characterizes the concepts of theories, data, and phenomena.

Phenomena

Empirical phenomena are stable and general features of the world that scientists seek to explain (Bogen & Woodward, 1988; Haig, 2005, 2014; Woodward, 1989). For present purposes, it is best to think of phenomena as empirical generalizations, such as the positive manifold of intelligence (Spearman, 1904), the high comorbidity between major depression and generalized anxiety disorder (Kessler et al., 2005), or the fact that instructing people to think about a topic polarizes their attitude (Tesser & Conlee, 1975). Although the identification of phenomena with empirical generalizations is slightly simplified,[1] it has the advantage of framing phenomena in a way that is closely connected to the practice of much psychological research.

Data

Data are relatively direct observations or reports thereof. For example, a typical data set in research on intelligence would consist of a set of structured reports (e.g., a spreadsheet) of how participants answered individual IQ items. Whereas phenomena are general (i.e., are typically evidenced across many research situations), data, by contrast, are distinctive to specific investigative contexts. In other words, in the current article, the concept of data is understood as involving a particular empirical pattern (i.e., as a concrete data set) rather than a general empirical pattern (which would typically be an empirical generalization, i.e., a phenomenon). Thus, data can be thought of as particular, pliable, and ephemeral, whereas phenomena are general, robust, and stubborn (Haig, 2014; Woodward, 1989).

Theories

In this article we focus on methods for constructing *explanatory theories*. Such theories are essential to science because they are the primary vehicle for facilitating the important goal of scientific understanding. At a general level, explanatory theories are prized because they help to explain the empirical phenomena that they are devised to explain. Explanatory theories can be expressed in terms of a set of linked propositions, at least one of which expresses a general principle. For example, the positive manifold of intelligence has classically been explained by positing a general intelligence factor (Spearman, 1904); a person's level of general intelligence is then seen as a property that determines one's ability to solve problems. This constitutes a *general* explanatory principle in part because it explains the positive correlation between many cognitive tests (i.e., not between any two tests in particular) in many different populations.

Relations between theories, data, and phenomena

Theories, data, and phenomena relate to each other as follows (Fig. 1): First, data provide evidence for the existence of empirical phenomena. As noted, phenomena can often be understood as robust generalizations of patterns in empirical data; for example, the positive manifold is a generalized feature of correlations between cognitive tests. Mirroring generalization, abstract phenomena support specification into concrete data patterns. For instance, the existence of the positive manifold implies that if we select two specific cognitive

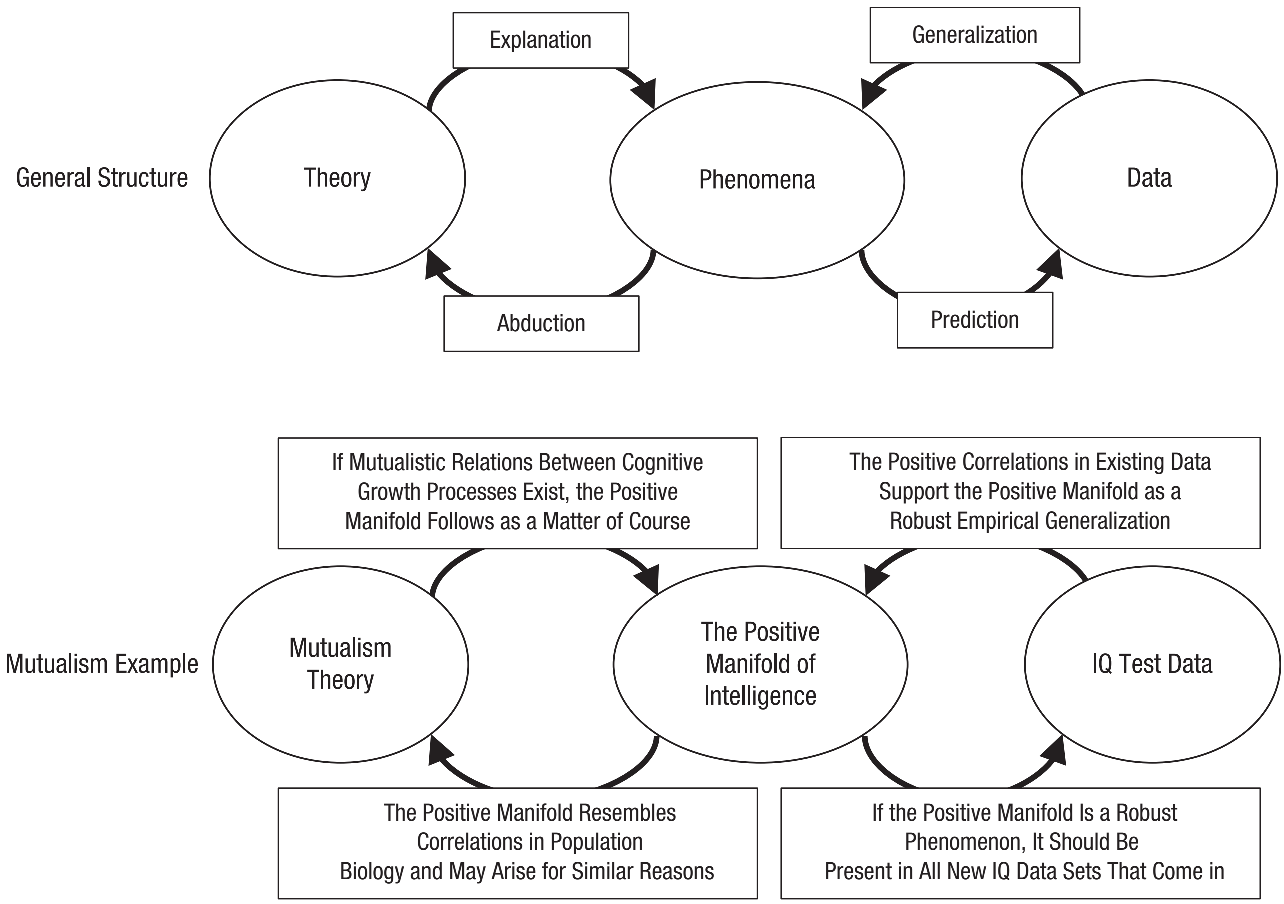

Fig. 1. General structure of relations between theories, data, and phenomena and a concrete set of examples in the context of the mutualism model of intelligence (Van der Maas et al., 2006).

tests or develop two new ones we should expect these tests to correlate positively. In other words, phenomena predict specific patterns in data.

Scientific theories, in turn, are constructed to explain the empirical phenomena that are evidenced by data. Such explanations invoke the notion that the theory somehow implies the phenomena. Although the nature of implication is subject to ongoing philosophical work, as a working definition we suggest a variant of Charles Sanders Peirce's (1931, 1932, 1933a,b, 1934, 1935, 1958a,b) maxim of abduction: "theory T putatively explains phenomenon P" means "if the world were as T says it is, P would follow as a matter of course." Although this notion of explanation is arguably incomplete, it has the advantages of being close to the commonsense understanding of the concept and being easy to implement in a formal model—namely by creating a virtual world in which theory T is true and showing that this world will indeed produce phenomenon P. For this reason, this minimalist conception of explanation offers a useful starting point for TCM.

TCM

A scientific methodology is an ordered series of steps that assist a researcher in reaching a desired end state from a specified starting point. In the standard hypothetico-deductive scheme, the starting point of scientific research is a putative theory that is subsequently submitted to testing. In contrast, with TCM the starting point is a set of relevant phenomena, whereas the end state is a theory that offers a putative explanation of these phenomena.

We propose that the following five sequential steps constitute a minimal methodology for theory construction:

1. Identifying relevant phenomena
2. Formulating a *prototheory*
3. Developing a formal model
4. Checking the adequacy of the formal model
5. Evaluating the overall worth of the constructed theory

Table 1. Theory Construction Methodology Steps Illustrated With Mutualism Examples

Step	Example
1. Identify empirical phenomena	IQ subtest scores form a positive manifold; cognitive abilities increase during development; IQ scores show a hierarchical-factor structure; heritability increases over development
2. Develop prototheory	Perhaps cognitive abilities are like mutualistic species—they promote each other's growth
3. Formalize theory and phenomena	Lotka-Volterra equations taken from population biology; these equations mathematically characterize or create an artificial world (e.g., through computer simulation) in which cognitive abilities develop mutualistically; phenomena formalized as relations between measures of cognitive abilities
4. Check explanatory adequacy	In simulated mutualism scenarios, the positive manifold arises as a matter of course; other phenomena require several rounds of theory improvement (e.g., making growth nonlinear, introducing individual differences in upper bounds of growth, structuring the matrix of interactions to accommodate hierarchical-factor structure); in the eventual simulated world that incorporates mutualism, all intended empirical phenomena follow as a matter of course
5. Evaluate theory	Pros: • Theory is substantively plausible. • Theory exhibits explanatory power. • Theory supports new predictions: Mutualistic relations imply as yet unobserved statistical patterns in developmental data that motivate novel lines of research. Cons: • Parsimony: Theory uses highly parameterized complex networks to explain simple phenomena. • Mathematical structure: Theory contains strong mathematical idealizations that may not be plausible.

We discuss these steps in turn and illustrate the process using the mutualism model of intelligence from Van der Maas et al. (2006), which systematically incorporates this approach. Table 1 gives an overview of the steps involved in TCM and the concrete implementation of these steps in the mutualism model.

Step 1. Identifying relevant phenomena

If the primary goal of scientific theory is to generate explanations of phenomena, then the first step in theory construction must involve the identification of phenomena to be explained, that is, robust, stable, reproducible empirical generalizations that function as explanatory targets. Although phenomena detection and theory construction are different sorts of undertakings, we take the identification of relevant phenomena as a part of our TCM precisely because the building of explanatory theories requires their successful prior identification.

To illustrate, for van der Maas et al. (2006) the relevant phenomena to be explained include the positive manifold of intelligence (all cognitive tests correlate positively in the population), growth (cognitive performance increases from childhood to adolescence), increasing heritability (IQ scores become more heritable over development up to adulthood), and the hierarchical structure of intelligence tests (intelligence tests are typically not unidimensional but form subfactors that themselves correlate positively, as in hierarchical-factor models).

The phenomena most useful in theory building are not necessarily the most spectacular ones. Instead, it is vitally important to select phenomena that are well established, or even self-evident, because a solid foundation is essential to successful theory construction. In addition, developing theories to explain pseudophenomena lacks proper motivation and wastes valuable scientific resources. For example, psi phenomena currently have the epistemic status of pseudophenomena (Wagenmakers et al., 2011); thus, Bem and Honorton's (1994) theorizing about the mechanism that might produce psi phenomena is both idle and potentially harmful to science. Because it is essential that theory constructors satisfy themselves that claims about relevant phenomena are sufficiently well established to function as explanatory targets, it will almost always be necessary for them to collaborate with empirical researchers who have the expertise to judge the creditworthiness of candidate phenomena claims.

Step 2. Formulating a prototheory

After phenomena have been identified, an initial explanatory model is formulated. The generation of this model takes place by a process of abductive reasoning. Abduction is typically contrasted with induction (the process of inferring generalizations from particular cases) and deduction (the process of deriving implications from general laws) and represents a process of explanatory inference: coming up with hypotheses, models, and theories to explain relevant phenomena (Haig, 2014; Magnani, 2009; Peirce, 1931, 1932, 1933a, 1933b, 1934, 1935, 1958a, 1958b). A model in this second step typically involves a small set of general principles that putatively explain the phenomena. For example, in van der Maas et al. (2006), the general principle is simple: As cognitive processes develop, they influence each other mutualistically. In other words, if one is (or becomes) better in one domain (e.g., verbal), this facilitates growth in other domains (e.g., numerical). In these initial stages, theories are usually expressed verbally: They sketch a general story of how the phenomena would arise as a matter of course (Haig, 2005, 2014) if the theory in question were true.

Of the steps in TCM, the step of generating prototheories is the least methodologically developed. One methodological approach that is available is *analogical abduction*: If one finds a similar set of phenomena in another field that is better understood, then one can "borrow" explanatory principles from that field to inform one's own. For example, van der Maas et al. (2006) take their lead from ecosystems in which different species may mutualistically interact (i.e., promote each other's population growth). The joint development of species is better understood than the joint development of cognitive abilities and thus provides valuable ideas, models, and approaches for further understanding this process.

Step 3. Developing a formal model

After theoretical principles have been articulated, one can develop a formal model. A formal model captures the principles of the explanatory theory in a set of equations or rules (as implemented in a computer program or simulation). In the case of Van der Maas et al. (2006), the theory is implemented in a set of coupled differential equations taken from population biology (Lotka-Volterra models). These equations encode the central principle of mutualism because they entail that the growth of one variable (which represents a cognitive ability) facilitates the growth of another variable (a second cognitive ability). Thus, the formal model is a "stand-in" for the theory in which the most important theoretical entities and their interactions are represented. Although there are cases in which interpreted formal models and theories virtually coincide (e.g., in highly formalized fields such as physics), in most cases the formal model is best understood as an implementation of the theory that is typically abstracted and idealized to facilitate computational modeling.

Formal models, in this context, should not be confused with "data models" that involve fitting parameters to data (e.g., correlational analysis, ANOVA, regression models; Haslbeck et al., 2019; Robinaugh et al., 2019). Instead of tools used to understand data, formal models are better seen as "thinking tools"; they allow us to track the consequences of our theoretical principles. Formal models are typically used to construct simulations in which theoretical scenarios sketched in the prototheory are implemented. Such simulations teach us what we should expect to find if the theory were true and thereby enable us to transcend some of our cognitive limitations; human beings are not very good at assessing the implications of anything but the simplest of theories. Moreover, a lack of formalization can impede progress by being insufficiently precise to reconcile different research approaches or by being unable to refine or update theories in light of new evidence—crucially, when such verbal theories are ultimately formalized, they are often found wanting (e.g., Mills et al., 2014).

Step 4. Checking the adequacy of the formal theory

Once a theoretical model has been sufficiently formalized to be implemented in a simulation program or a set of equations, the question becomes whether it indeed can explain the empirical phenomena. To investigate this question, one must parse the phenomena in the same formal language as the theory. This means that the phenomena themselves have to be formalized. In the van der Maas et al. (2006) example, phenomena are formalized in terms of statistical patterns that would arise in hypothetical research scenarios (e.g., the positive manifold: "if the mutualism model were true, and a sample of individuals were assessed for their performance on cognitive tests, we would find positive correlations between the relevant test scores"). The theorist can then examine whether the theory, as implemented in the formal model, does in fact generate the phenomena as a matter of course, either in a simulation study or through analytic derivations (see van der Maas et al., 2006, Appendix).

Step 5. Assessing the overall worth of the theory

Once the ability of the theory to explain the phenomena is established in the manner indicated in Step 4, it becomes appropriate to systematically evaluate its overall worth. In this step one investigates the quality of the explanatory theory with respect to an array of relevant evaluative considerations. Several options for organizing this process exist. The most familiar option is to use the hypothetico-deductive method and assess the theory in terms of its predictive success. An alternative is to use a number of different criteria to do the

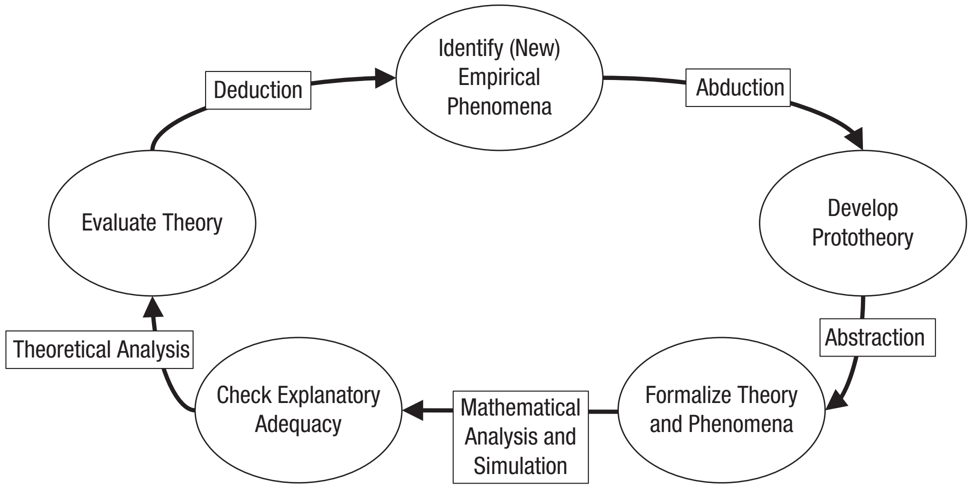

Fig. 2. The theoretical cycle. The cycle starts with the identification of empirical phenomena. Through abduction, putative explanatory principles are encoded in a prototheory. By abstracting these principles in mathematical form, one constructs a formalized model of theory and phenomena. This is used as a simulation model that is used to check explanatory adequacy. Theoretical analysis results in an evaluation of the theory. If the theory is suboptimal, it can be adapted in various ways; if it is beyond plausible repair, it can be abandoned; if it is satisfactory the theory may fuel new research through the identification of new (as yet unknown) phenomena.

evaluative work, such as Kuhn's (1977) five properties of a good theory (accuracy, consistency, scope, simplicity, and fruitfulness). With TCM, our preference is to evaluate theories with respect to explanatory criteria. The reason for this preference is straightforward: Theories that are prized for their ability to *explain* phenomena should be evaluated with respect to their explanatory virtues.

Evaluating theories in this way is known as *inference to the best explanation* (Haig, 2009; Harman, 1965; Lipton, 2004; Thagard, 1992). One attractive formulation of this approach is the theory of explanatory coherence (Thagard, 1992). This method depicts inference to the best explanation as a comparative judgment about the most explanatorily coherent theory, that is, the theory that holds together best because of the cohesiveness of its explanatory relations. The method is underwritten by a number of principles that together enable its users to assess explanatory goodness with respect to three criteria: explanatory breadth, analogy, and simplicity. Explanatory breadth refers to the number of phenomena a theory can explain, the criterion of analogy judges the process of analogical reasoning described in Step 3 of TCM in terms of its continued success, and the criterion of simplicity assesses the economy of the explanation. For example, Darwin used a precursor to the theory of explanatory coherence in judging his theory of natural selection to be superior to the creationist alternative: His theory explained a wider variety of facts, offered a simpler explanation, and was enhanced by its analogical connection to the process of artificial selection.[2] Although evaluating explanatory theories via inference to the best explanation is a core commitment of TCM, it is important to acknowledge that other theoretical virtues can also come into play, such as whether the theory is consistent with accepted background knowledge, has plausible or implausible consequences outside the space of the empirical phenomena it was built to explain, and possesses the attributes to develop into a progressive research program.

We have presented TCM heuristically as a series of steps. However, because an initially constructed theory will not normally achieve all of the virtues sought in a single run of TCM, theorists will typically have to repeatedly apply the methodology until the theory is either judged sufficiently adequate or rejected. In addition, researchers may deem it appropriate to double back to one or more of the earlier stages in the sequence; for example, theory evaluation may lead to adaptations of the formal model. Successfully deducing as yet unidentified phenomena may require researchers to empirically investigate these phenomena, possibly leading them to reconsider the explanatory breadth of the theory (e.g., in the case of mutualism, see Kievit et al., 2017, 2019). This reconsideration gives rise to a theoretical cycle (Fig. 2) that "spirals up" to form a staircase of knowledge by subsuming ever more phenomena under the explanatory breadth of the theory, especially when the evaluation of the theory leads to the implied existence of as-yet-unknown phenomena.

An Outline for a Course on Theory Construction

Because TCM contains clearly formulated steps, we can teach students how to progress through the theory-construction cycle. Indeed, in our experience, the best way to develop this skill is to practice it. Two of us (D. Borsboom and H. L. J. van der Maas) have taught a course that walks the student through the different phases of TCM. This works in three phases.

In the first phase, students learn to distinguish between data, phenomena, and theories. In groups, students practice the relevant distinctions by choosing a scientific theory inside or outside psychology (e.g., the theory of evolution) and identifying phenomena the theory is designed to explain (e.g., the existence of species or subspecies that occupy distinct ecological niches), as well as data that support these phenomena (e.g., Darwin's observations of finches). Finally, they identify the theoretical principles used to explain the phenomena (e.g., mutation and selection). By doing this for several theories, students learn to distinguish phenomena from data and to identify the central principles of explanatory theories. By having students present these results to each other, the first phase ends with a diverse collection of data sources, phenomena, and theoretical principles.

In the second phase, students choose a topic of interest in psychology (e.g., psychosis). Within this topic, they identify robust empirical phenomena (e.g., delusions and hallucinations often occur together and have similar contents, the transition to psychosis is a relatively sudden process). Students are challenged to search the literature for similar phenomena in other fields (e.g., biology, physics, economics). For example, they may discover that coupled processes can synchronize (e.g., coupled oscillators, feedback processes) and use existing literature to develop the theory that hallucinations and delusions may reinforce each other, leading to a feedback process that spins out of control to produce a psychotic episode.

In the third phase, students use existing software for simulations (e.g., NetLogo, R, Vensim, MATLAB) to create models that instantiate their theory (students without much programming background can adapt existing programs). In this way, students could, for instance, find that reciprocal feedback between hallucinations and delusions would produce sudden transitions into psychotic episodes if the reciprocal coupling is sufficiently strong. However, students will also encounter model limitations; they would, for instance, find that interactions cannot be linear because that leads the process to spiral into infinity. In this way, students learn to evaluate not only the explanatory power of their model but also its limits. Finally, students deduce the new phenomena their theory entails and explore how empirical research could investigate these phenomena. At the end of the course, students present their theory to the group.

Our course at the University of Amsterdam took about 8 weeks half-time (i.e., around 160 student hours altogether) with two meetings a week and a variety of take-home assignments. In our experience, students love this type of education. They thoroughly enjoy looking at the literature through phenomena-detection glasses, as well as fighting with simulation software. Even for students who have little affinity with numbers and formulas, the creativity of generative modeling is exciting, especially when they are developing their own theory.

As flanking literature for such a course, one can use several interesting articles and books; we especially recommend Smaldino (2017), Oberauer and Lewandowsky (2019), and Haig (2014). It is useful to include classic works on (the absence of) good psychological theory such as those of Meehl (1978), Gigerenzer (1991, 2020), Newell (1973), and Simon (1977), as well as critical evaluations that highlight cases in which formal modeling may be less applicable or overshoot (e.g., Shapiro, 2005). For students who want to dig deeper, an accessible gateway into the voluminous philosophy of science literature is the Stanford Encyclopedia of Philosophy (https://plato.stanford.edu). In our experience, however, doing is more important than reading when it comes to theory construction, and it is preferable to have students wrestle with theories before immersing them in the philosophy of science.

Conclusion

The TCM developed in this article presents a practical sequence of steps to facilitate the formation of explanatory theories. The manner in which TCM is organized makes explicit that theory construction is a skill; it requires instruction as well as deliberate practice. Just as students cannot be expected to test statistical hypotheses or develop decent experimental designs without extensive training, they cannot be expected to master theory construction out of the blue. To emphasize this point, we have illustrated how TCM can support educational programs designed to further theory construction in psychology.

In contrast to some prominent philosophies of science on theory testing, TCM is not intended to be universal and prescriptive. TCM is not universal because its focus on formal modeling limits its applicability to fields in which formalization can be realistically aspired to; it is not strongly prescriptive because many alternative methodological approaches to theory formation could be successfully followed. TCM is also not a philosophy of science. It is exactly what its name says it is—a methodology, nothing more and nothing less. In our view, many more such methodologies should be developed if we are to promote theory formation in psychological science.

In this respect, this article is only a first step in charting our TCM. The proposed processes of abductive inference, formalization, and theory evaluation could be further developed. For example, the processes of formalization and analysis could be supported by simulation tools geared specifically for psychology and represented in widely usable software. Theories developed with such tools could then be tested against a corpus of empirically identified phenomena that ideally would be represented inside such software in stylized form. The development of the readily accessible programming implementations of Thagard's (1992) theory of explanatory coherence and Meehl's (2002) delineation of the criteria that scientists use to appraise theories would be invaluable contributions to theory-evaluation methodology. There would seem to be no technological obstacles to developing such systems.

Our articulation and systematization of theory construction as a methodological domain will hopefully be a useful addition to the psychological literature, but of course the substance of the TCM proposal is not original. TCM codifies procedures that are commonly followed in many scientific fields, including subfields of psychology (e.g., mathematical psychology); it also bears similarities to other articulations such as Hawkins-Elder and Ward's (2020) perspective on theory construction, which was devised for the domain of psychopathology and based in part on Haig's theory of scientific method. Finally, some existing methodological doctrines can be understood in terms of TCM. In one interpretation, for instance, structural equation modeling (SEM) instantiates a version of TCM. In its customary use, SEM can be regarded as a hypothetico-deductive strategy concerned with the predictive testing of statistical models. However, if (a) phenomena are interpreted as covariance structures, (b) the theoretical space is limited to include only systems of structural equations, and (c) model-fit criteria are interpreted as indicative of explanatory adequacy, SEM can be seen as an exercise in theory construction. In this interpretation, models are compared in terms of their goodness of fit to the empirical phenomena, in which the weighting of the fit statistics is expressed in indices of parsimony (e.g., Kaplan, 2000; Markus et al., 2008; Rodgers, 2010). This aligns with causal interpretations of SEM (e.g., Bollen & Pearl, 2013) and realist interpretations of its latent variables as hypothetical entities (Rigdon, 2016).

Theoretical work is perceived as a risky career path in psychology, and PhD students are sometimes discouraged from engaging in theory construction. We do not believe that this assessment is necessarily correct. TCM is an explicit articulation of a research process some of us have followed in the past with considerable success. Although the mutualism theory we used in this article was the first to be constructed in this manner, we have since implemented the same process in a series of articles in distinct areas such as psychopathology (Borsboom et al., 2011; Robinaugh et al., 2019), attitudes (Dalege et al., 2016, 2018), and personality (Lunansky et al., 2020). Contrary to popular belief, theory construction can be a viable career path that can have a significant impact in empirical psychology, and we hope ambitious young scholars will consider this career option.

Although our article is written with psychology firmly in mind, the methodology it deals with applies to behavioral and social science generally. Research methodology in psychology is dominated by adherence to an orthodox hypothetico-deductive account of the scientific method. This top-down sequence of inquiry contrasts with the bottom-up nature of our TCM, in which inquiry moves from phenomena to explanation. As pluralists, we think that both sequences have their merits in the panoply of science. Theory construction via TCM is characterized by charting phenomena, creative theorizing, generative formal modeling, and assessing the best of explanatory theories. Rigorous hypothetico-deductive theory testing through deduced predictions is an important complementary alternative. These approaches ideally work in tandem to realize the combination of creative speculation and stringent evaluation that are the methodological hallmarks of science.

Transparency

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Notes

1. Phenomena can also take other forms; for example, in cognitive psychology they may sometimes be understood as capacities (e.g., the capacity to learn a language; Cummins, 2000).

In fact, the distinction presented is a functional rather than an ontological one: Phenomena are characterized in terms of their *role* as the proper objects of explanation rather than as some special ontological type. Thus, we should allow phenomena to potentially be objects, states, processes, events, and other types of entities.

2. Although a criterion of predictive success is used in Step 4, it should be noted that the theory of explanatory coherence does not take predictive accuracy to be a necessary consideration because the three criteria of explanatory goodness suffice to make adequate judgments of the best explanation.

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