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Theory, Search, and Learning

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Abstract. When searching for a solution to a problem, having a theory—an underlying causal structure that explains outcomes as a consequence of antecedents and that allows for the prediction of potential consequences of combinations of choices not yet tried—changes the way in which people explore the solution space. Whether a theory proves useful to search, however, depends not just on its predictive precision. This essay argues that the internal structures of theories—their size, complexity, the extent of their elaboration, and the confidence that their users have in the assumptions—also influences how people search for solutions and the efficiency of their search processes. It offers several conjectures about how theory and theory structure influence search and about which types of theories prove most useful to success.

Keywords: strategy • entrepreneurship • innovation • search • experimentation • philosophy of science

1. Introduction

When searching for the solution to a problem, does being guided by a theory lead to better decisions, more innovative solutions, and improved learning outcomes?

In the Marshmallow Challenge, participants compete to construct the tallest freestanding tower that can support the weight of a large marshmallow.[1] Although the exercise might seem easy and straightforward, it ends up being difficult for most due to the rules regarding the building materials. Teams must build their towers primarily from dry spaghetti.

Thousands of people have participated in this Challenge. At first blush, their results would appear to illustrate the importance to success of having a theoretical understanding of the underlying problem. As a group, architects and engineers perform better than anyone. They build towers that reach roughly twice the height of other groups.

Following on the principle that entering the exercise with a stronger theoretical understanding of the problem improves outcomes, one might then expect that others with advanced degrees—even in subjects further afield from architecture or engineering—would do next best. They do not. In fact, those with postgraduate educations, such as doctors, lawyers, and MBAs, rack up some of the worst records in the Marshmallow Challenge.

Who does next best after architects and engineers? Kindergartners.

Although the success of children might appear to call into question the value of theory in search and learning, close observation of these young participants suggests that they too engage in abductive reasoning. They form hypotheses, test them, revise, and then repeat the process. They differ from the older and more educated not so much in the extent to which they engage in theory-building and in theory-guided search but in the internal structure of the theories that they build and use. They appear to create smaller, simpler theories, and to place less confidence in their assumptions.

These patterns may prove instructive for managers. The theory-based view argues that entrepreneurs and executives usefully build theories that guide their actions and choices (e.g., Felin and Zenger 2009, Camuffo et al. 2020, Sørensen and Carroll 2021). Much of the focus of this literature to date has been on understanding the value of simply having a theory. Potentially competing theories have usually been seen as differing primarily in their predictive precision (e.g., Gavetti and Levinthal 2000, Camuffo et al. 2024).

But theories—causal structures that connect a set of antecedents to outcomes—can vary also on several other dimensions: They differ in their size, the number of assumptions involved. They vary in their complexity, the degree to which the antecedents interact to produce outcomes. They also vary in their degrees of elaboration, the length of the chains of logic connecting premises to conclusions. Those holding and using these theories also have varying degrees of confidence in their assumptions. If these internal features influence search and learning processes, even theories with equivalent predictive precision can differ in the extent to which they lead to better solutions and to finding them faster.

This essay offers several conjectures regarding when and why the structure of a theory might promote more effective search and learning. Of course, those guided by a theory do best when they have an accurate set of assumptions. But when they must test and revise their theories, those with smaller and simpler theories and those with less confidence in their assumptions seem advantaged in their searches for solutions.

2. Theory

An emerging perspective in entrepreneurship and strategy characterizes entrepreneurs, innovators, and executives as being similar to scientists. Inventors and entrepreneurs construct theories of how they can create value (e.g., Fleming and Sorenson 2004, Sull 2004, Felin and Zenger 2009). Strategists build theories of why their firms have a comparative advantage over competitors (Rumelt 2011, Sørensen and Carroll 2021). They can then use those theories to derive sets of hypotheses that they can test (Sull 2004, Camuffo et al. 2020). Entrepreneurs and executives can also use them to guide consequential strategic decisions (e.g., Sørensen and Carroll 2021, Camuffo et al. 2024): Should their firms adopt some policy or practice? Should they consider expanding the scope of their firms?

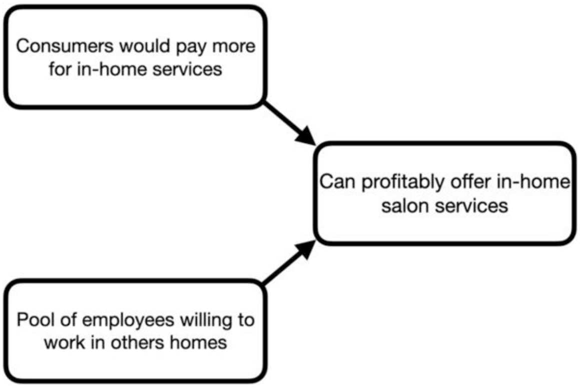
2.1. What Is a Theory?

Interestingly, the various papers contributing to this emerging literature do not always appear to agree on what they mean by theory.

One conception of a theory, common to both the philosophy of science and much of the emerging perspective on the theory-based view, defines theory as a set of antecedents, many assumed, that together imply some consequences (e.g., Felin and Zenger 2017, Sørensen and Carroll 2021, Ehrig and Schmidt 2022). When applied to businesses, the antecedents and assumptions typically represent environmental conditions (e.g., consumer preferences), organizational policies and characteristics (e.g., product or service features), and if-then relationships.[2]

Box-and-arrow diagrams, such as the one depicted in Figure 1, provide a useful means of visualizing these theories. The boxes here represent assumptions about the states of the environment and organizational choices, while the arrows depict the causal relationships believed to connect these antecedents to consequences. In this case, the founders of GharPar had a "theory" that they could profitably offer in-home salon services (Shehryar et al. 2019). That expectation depended on assumptions that customers would pay more to receive these services at home than they would

Figure 1. A Simple Theory of GharPar



at a beauty salon and that they could find employees with the necessary training willing to work in customers' homes. Given the social context of Pakistan, the founders felt uncertain about both assumptions.

Another depiction of a theory, however, has been more common in research related to learning and search. Search processes have often been described and modeled as an actor—an individual or an organization—trying to find the highest point on a landscape (e.g., Levinthal 1997, Rivkin 2000, Fleming and Sorenson 2001).

Theory in these models has then often been portrayed as being analogous to a topographical map (e.g., Gavetti and Levinthal 2000, Fleming and Sorenson 2004, Csaszar and Levinthal 2016).[3] It provides guidance to those navigating the terrain. Gavetti and Levinthal (2000), for example, incorporate theory as being an accurate lower-dimensional representation of the fitness landscape. Many cognitive science- and economics-inspired models similarly treat theory as providing better predictive accuracy (e.g., Friston 2010, Camuffo et al. 2020, Karni 2022, Camuffo et al. 2024, Chavda et al. 2024).

On the surface, these depictions of theory feel disconnected. Topographical maps do not require a causal structure. Just as explorers of yore produced maps based simply on their exposure to the world, maps of ideal product and service combinations might come from experience. At the same time, the boxes and arrows depicted in Figure 1 do not obviously map onto a topography.

We could translate our causal theory into a representation. By focusing on a single ultimate outcome, maybe sales or profitability, the height, or altitude, on our map could reflect the expected outcome. Locations on the map would then correspond to combinations of specific antecedents. More similar sets of antecedents would appear closer to each other on the map.[4]

Depending on how well the causal theory reflects the real world, these maps might vary in their *correctness*, the extent to which they accurately predict the height of any specific location on the underlying landscape, and in terms of their *resolution*, their ability to predict the effects of even minor changes in a set of antecedents on outcomes (cf. Gavetti and Levinthal 2000).

Many features of the causal theory, however, end up lost in this translation. Although often derived through abduction, causal theories usually have a forward-looking component. Executives and entrepreneurs use them to solve specific problems (Felin and Zenger 2017, Ott and Hannah 2024). By contrast, models of search on topographical surfaces generally depict these actors as simply searching for better performance (Posen et al. 2018).

Representations, such as maps, also fail to capture the internal structure of theories. Theories not only suggest what might solve a problem but also *how* and *why*. Consider, for example, Figure 2. Here, the theory of GharPar has been expanded. The founders believe that the higher willingness-to-pay for in-home services might stem from customer preferences for convenience and privacy. They also believe that they can maintain a reasonable employee cost if they train them themselves and if they can prevent them from free-lancing or defecting to competitors.

As a map, the two versions of this theory would appear equivalent. Although the elaborated version of the theory incorporates a larger set of assumptions, both in terms of antecedents and in terms of if-then relationships, without another set of paths to performance implications, they imply the same set of predictions for performance. We therefore cannot translate in the other direction: We cannot convert a representation into a causal theory.

Intuitively, the more elaborated theory seems preferable to the simpler one. It potentially provides a more nuanced understanding of why and when GharPar would have a comparative advantage. At least when developing novel ideas, that better articulation of the theory has been thought to promote more effective testing of the ideas (Gary and Wood 2011, Camuffo et al. 2020, Ehrig et al. 2023). But that elaboration may also have downsides. For example, should the theory prove wrong, it increases the complexity of identifying which assumptions require revision.

Because representations cannot capture these features of causal theories, however, the existing literature on search and learning provides little guidance on how features of a theory beyond its predictive power might influence its use and usefulness. I therefore proceed by first proposing a set of dimensions to characterize the internal structure of causal theories. I then offer several conjectures as to how these structural characteristics might influence the ways in which actors search for solutions and revise their theories (and searches) when confronted with evidence inconsistent with them.

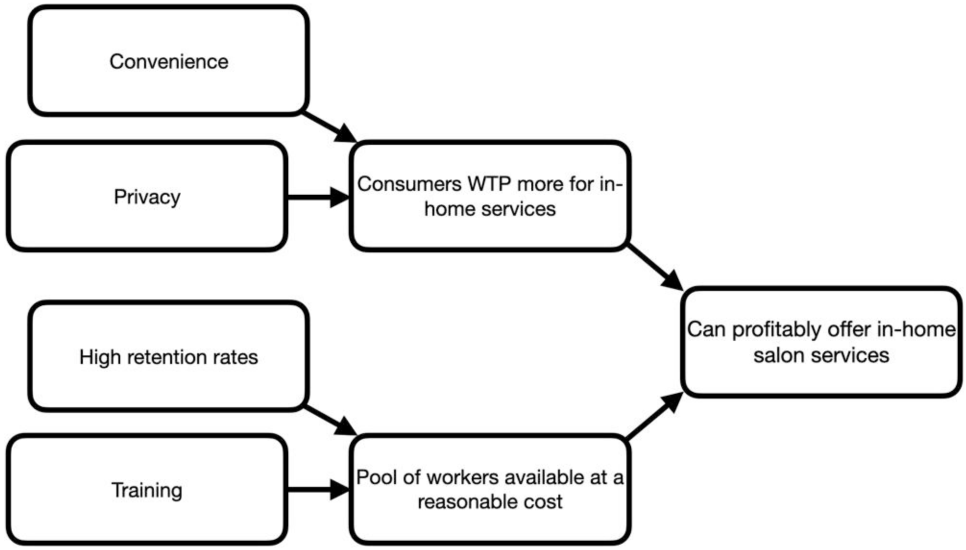
2.2. Theoretical Structure

Theories—causal structures that explain outcomes as a consequence of antecedents—appear to vary on at least six important dimensions. In addition to the *correctness* and *resolution* of their predictions, they also differ in their internal structures: in the *size* and *complexity* of the theory, in their degrees of *elaboration*, and in the *strength* with which actors hold beliefs about the underlying assumptions.[5]

2.2.1. Size. Size refers simply to the number of antecedents and if-then relationships included in the theory—when depicted as a figure, the number of boxes and arrows in the diagram.

2.2.2. Complexity. Complexity generally rises with the number of interactions in a system (e.g., Kauffman 1993, Levinthal 1997, Fleming and Sorenson 2001).

Figure 2. An Elaborated Theory of GharPar



We could apply the same principle to a theory. Theories that involve interactions—multiple necessary but not sufficient conditions—for example, have a higher degree of complexity than those where antecedents produce additive effects on the outcomes.

2.2.3. Elaboration. Degree of elaboration refers to the length of the causal chains. Simple theories, such as the one depicted in Figure 1, might only have a single step between the primitive antecedents—those without their own antecedents—and the final predictions. Greater elaboration comes from specifying the sources of those antecedents. Figure 2, for example, elaborates on Figure 1, by proposing that GharPar's ability to staff its operations depends on training and retention. One could imagine further elaborating the theory in many ways, for example, by expanding it to include the idea that their ability to retain talent would stem from paying employees well and training them on only a small set of procedures (to limit their outside options).

2.2.4. Assumption Strength. People also vary in terms of the confidence that they hold in the assumptions underlying their theories, both in terms of whether antecedent conditions exist and in terms of whether the proposed if-then relationships hold. Not only does this assumption strength vary across people and theories but also, even within a theory, people generally have more confidence in some assumptions than in others (Spohn 2012, Ehrig and Schmidt 2022, Ehrig 2023).

3. Learning Processes

Although search and learning have been important topics in management for more than fifty years, surprisingly little attention has been given to *how* actors search through spaces and the consequences of those processes (Posen et al. 2018).[6]

One large strand of this literature on search and learning focuses on *when* actors search. Building on Cyert and March (1963), much of this research examines the formation of aspiration levels of performance and how performance relative to those aspirations influences the initiation of search (see Posen et al. 2018, for a review).[7]

Models of learning, meanwhile, often relegate search—the "trial" portion of trial-and-error learning—to being random (e.g., Feller 1971, March 1991, Kauffman 1993, Levinthal 1997). (Somewhat) random experimentation probably does occur in many situations. In learning-by-doing, for example, the trials often stem from accidents, from actors unintentionally doing something different. In other cases, actors might choose their attempted solution based on constraints (Sarasvathy 2008) or on their salience (Cohen et al. 1972), rather than based on beliefs about the expected efficacy of a course of action. But those with a theory, those who have beliefs about the relationships between their actions and outcomes, almost certainly experiment in more systematic ways.

To the extent that research has considered the "how" of search, it has primarily focused on exploration versus exploitation (March 1991). Exploitation refers to local search, when actors focus on solutions similar to those that they have tried before. Exploration, on the other hand, occurs when actors test more distant solutions. Theoretical treatments typically assume and empirical studies usually find that people and organizations primarily pursue exploitation, incremental innovation (e.g., March and Simon 1958, Nelson and Winter 1982, Stuart and Podolny 1996, Bryan and Lemus 2017, Valentine et al. 2024). Beyond that distinction in the distance of search, however, the literature on exploration versus exploitation also tends to treat the trials—the testing of alternatives—as being mostly random in terms of their direction.

3.1. Theory and Search

Without a theory, search typically means experimentation or learning-by-doing, actually trying alternative sets of actions. In the context of a theory with an underlying causal structure, however, "search" can also include many other types of activities (Levinthal and Adner 2024, Ott and Hannah 2024).[8] Evaluation of a theory, for example, might include an examination of the tightness of its internal logic (Sørensen and Carroll 2021). It might involve investigating the existence or secondary implications of one or more of its antecedents (Ehrig and Schmidt 2022, Levinthal and Adner 2024, Ott and Hannah 2024). Camuffo et al. (2020), for example, describe how the founders of Inkdome initially tested their theory of value creation not through experimentation but by gathering data on their assumptions. Theory-based search might also involve the testing of one or more intermediate or secondary predictions (Ehrig et al. 2023).

Theory also influences the nature of experimentation, what searchers try. A normative reading of the philosophy of science might lead to the expectation that those with a theory in mind should try to falsify it (e.g., Felin and Zenger 2017). The potential for falsification has been seen as a central distinction between science and nonscience (Popper 1959). From a logical point of view, learning—improvements in our understanding of the world—comes only from falsification, from being able to reject theories inconsistent with observed reality (Popper 1959).

The history and sociology of science, and the more recent philosophy of science, however, would suggest that those holding a theory often search in exactly the opposite way: they search not for information that might contradict their beliefs but for evidence that supports their view of the world (Kuhn 1962, Lakatos 1970).

Scientists often bring this approach in concordance with an understanding that learning occurs through falsification by treating the "null" hypothesis—typically a theory of no effect—as the theory being tested (cf. Ehrig and Schmidt 2022, Camuffo et al. 2024). But this approach may still bias the search process to find evidence in favor of the theory. At the extreme, researchers may intentionally or subconsciously manipulate their analyses to support their expectations (Simmons et al. 2011).

In the context of business, the pressure to search in ways that would confirm rather than reject a theory seem even stronger. Experimentation has high perceived opportunity costs. If Southwest Airlines believes that its ability to turn planes around quickly stems in part from its policy of open seating, trying something different—seat reservations—would not only have a direct cost of implementation but also an expectation of lost profits. Experimentation can also have opportunity costs in terms of changing the available set of future options (Levinthal and Adner 2024). Some changes—such as ones that might negatively affect the reputation of the organization—effectively become irreversible. Entrepreneurs, moreover, may conduct experiments as much to convince potential partners to buy into their vision as to test whether they have an accurate theory of how they can create value (Levinthal and Adner 2024, Ott and Hannah 2024).

More broadly then, scientists, innovators, entrepreneurs, and strategists usually search through abduction (e.g., Peirce 1955, Van Maanen et al. 2007).[9] Based on their observations of the world, they form tentative explanatory theories and hypotheses. They then engage in experiments and search for additional information that would support the antecedents and predictions of these theories. When they encounter evidence that appears inconsistent with their beliefs and expectations, they try to revise their theories to align them both with their previous observations and with the results of their theory-based search.

Consistent with this idea, the elaboration of theories of value or of competitive advantage typically begins with the outcome—a competitive advantage or a value proposition—to determine a set of assumptions, antecedents, and causal relationships, that could explain it (Ott and Hannah 2024). Further elaboration then begins with the antecedents in these simple theories to arrive at a "lower level" set of antecedents and causal relationships that could explain them (such as in moving from Figure 1 to Figure 2).

3.2. Theory and Revision

Learning involves not just search but also revision. How does the existence of a theory influence the revision of beliefs?

In the absence of a theory—a causal structure predicting the consequences of a set of antecedents—searchers often revise their beliefs rapidly (Valentine et al. 2024).[10] They may even arrive at errant conclusions. Those engaged in learning-by-doing, for example, may fail to recognize that some of what produces the outcomes that they observe stems from noise or from hidden factors (e.g., Levitt and March 1988, Denrell and March 2001).

Theories slow this revision process in multiple ways. On the one hand, they restrict the possible set of observations seen as inconsistent with the current beliefs. If a theory does not predict a relationship between some factor and the outcome of interest, the searcher driven by theory will often ignore or dismiss it. Evidence only challenges a theory when it contradicts either a component assumption of the theory or one of its predictions.

Even when evidence arrives inconsistent with their expectations, those guided by theory may nevertheless ignore or discount this information (e.g., Lord et al. 1979, Koehler 1993). Felin et al. (2023) suggest that this bias may even have a biological basis. When searching for something—such as an expected piece of information or result—our brains light up only in response to patterns consistent with that search. We systematically "see" evidence that supports of our expectations but miss that which does not.

Even if those searching do not miss contradictory evidence, however, they may still dismiss it as driven by noise or measurement error (Kuhn 1962, Lakatos 1970). This tendency appears even among scientists. Lakatos (1970) argued that scientific theories have a core but that almost any test of a theory also involves a number of auxiliary assumptions. Auxiliary assumptions, for example, often translate theoretical constructs into real-world objects and measures. When scientists receive an unexpected result, rather than rejecting the (strongly held) core, they instead prefer to reject the auxiliary assumptions. The more strongly held the assumptions, the more they may resist evidence that contradicts it. Some perspectives on theory revision even suggest that theorists *should* retain their most strongly-held assumptions (e.g., Spohn 2012, Ehrig and Schmidt 2022).

The psychological bias for retaining the theory and rejecting the data probably becomes even stronger in the face of mixed information. Experimental results and information that supports the theory increases the searcher's confidence in it, even as they simultaneously ignore or attempt to explain away contradictory evidence. People therefore tend to interpret mixed information as supportive of their beliefs and expectations (e.g., Wason 1968, Kunda 1990, Nickerson 1998).

4. Conjectures on Theory-Based Learning

Building on these ideas suggests a number of propositions for how the internal structure of a theory might influence the learning process.

Conjecture 1. *Larger and more complex theories reduce the range of solutions tested.*

Regardless of its correctness and resolution, search guided by theory probably restricts the range of solutions tested (Fleming and Sorenson 2004, Valentine et al. 2024). The degree of restriction, moreover, seems as though it should increase with the number of assumptions (size) in the theory and the degree to which they interact (complexity). Theories allow for off-line simulation, projecting the probable results of experiments not yet tried (e.g., Levinthal and Adner 2024). Even theories that leave substantial uncertainty in their predictions will typically imply that many choices would lead to poor performance. Many potential combinations of actions will seem impossible as solutions. As the number of (necessary) assumptions rises, so too will the proportion of the solution space seen as infertile. Whether accurate or not, these predictions lead searchers to see many potential experiments as both having a high cost and being unlikely to yield valuable data. They therefore do not try them.

This phenomenon manifests itself visually in the Marshmallow Challenge. Towers, especially those built by adults, almost always look like some version of the Eiffel Tower or of the scaffolding erected for construction projects. Other designs can work but rarely do adults try them because they have theories of what features create a strong structure. As in many settings, the participants, the problem solvers, probably develop these initial theories based on analogies (e.g., Rivkin 2000, Gavetti et al. 2005, Carroll and Sørensen 2024, Ott and Hannah 2024). Many of the towers that they have seen in their lives—though built of wood, brick or stone rather than spaghetti—have an obelisk-like shape.

This restriction of alternatives considered can lead to efficient learning. Architects and engineers quickly produce impressive structures in the Marshmallow Challenge. Perhaps one of the most dramatic recent examples, however, comes from the development of the COVID-19 vaccine. Whereas vaccine development has typically required an average of close to a decade of trial-and-error experimentation, the combination of the full DNA sequencing of the virus together with a theoretical understanding of how the virus spread and evaded the immune system led to the development of more than 100 candidate vaccines in the space of weeks (Le et al. 2020). Widespread vaccination began less than one year after the virus had first been identified.

But this restriction of the range of solutions tested can also prove problematic. Theories based on fallacious assumptions can impede the discovery of novel solutions. Doctors, lawyers, and MBAs in the Marshmallow Challenge often produce detailed plans for their spaghetti towers. But even when those towers fall, they rarely consider less conventional designs. Felin and Zenger (2017) describe a theory of success for Disney, suggesting that it has no particular advantage in live action film production. If executives at Disney believe that theory, they might never try to produce one, potentially at a high cost to the company if that theory had been based on erroneous or incomplete assumptions.

Because of this restriction in search, errant assumptions, when widely held, often create opportunities for entrepreneurs who do not subscribe to them (Felin and Zenger 2017, Felin et al. 2021). Before Sam Walton, the conventional wisdom had been that towns with a population of less than 100,000 would not have sufficient demand to support a discount store. The incumbent discount chains did not even try to put outlets in these places. But Walmart demonstrated that the conventional wisdom had depended on some implicit assumptions about their logistics. By locating its stores so that they could share inventory at centrally-located warehouses, Walmart changed the economics of operating in these smaller cities (Ghemawat 1991).

Corollary 1. *Larger and more complex theories lead to smaller "pivots" in practices.*

A closely-related phenomenon concerns how searchers respond to information and feedback that contradicts their beliefs and expectations. Those who have a theory will try to retain as many elements (assumptions) of the theory as they can (Spohn 2012, Ehrig and Schmidt 2022, Ehrig 2023). To remain consistent with their original abduction, these revised theories must also generate similar predictions regarding what features and activities produce the most desired solutions. The more assumptions and the richer their interactions, the fewer the options available for simultaneously meeting all of these constraints. Theory-based searchers, particularly those with larger and more complex theories, will therefore generally engage only in smaller pivots (i.e., those that change fewer and more peripheral assumptions).

Of course, this limited malleability may open larger and more complex theories to a longer-term fragility. Scientific revolutions, which typically involve the rejection of a number of central assumptions, tend to occur when small incremental revisions to a theory cannot accommodate a mounting number of anomalies (Kuhn 1962). Businesses may face a similar phenomenon, where the difficulty of explaining what has succeeded and what has not eventually leads to the wholesale abandonment of a theory (e.g., Valentine et al. 2024).

Conjecture 2. *Theories based on more strongly-held assumptions lead to slower learning.*

Strongly-held assumptions can slow learning in two ways. The first comes from information restriction. As suggested by Conjecture 1, those guided by theory in their search for solutions will often avoid testing their assumptions or will construct more elaborate experiments that jointly test multiple assumptions. This tendency probably proves even stronger for those who believe more strongly in the assumptions underlying their theories.

Arguably, much of the reason that children do so well in the Marshmallow Challenge stems from the fact that they hold only tenuous beliefs about important factors such as the weight of a large marshmallow and the ability of spaghetti to support it without bending. They therefore almost immediately begin testing these assumptions before they continue to build more elaborate towers (and theories).

Even when searchers do test their theories, strongly-held convictions can slow updating. Searchers may ignore or discount evidence inconsistent with their theories (Lord et al. 1979, Kunda 1990, Nickerson 1998). Even when they do recognize a need for revising their theories, much as scientists try to retain the core of their theories (Lakatos 1970, Spohn 2012), entrepreneurs and strategists probably cling to their most strongly-held assumptions (Ehrig 2023).

Corollary 2. *Variation in the strength of beliefs in assumptions promotes faster theory-based learning.*

Interestingly, variation in the belief strength underlying a theory may promote faster learning. When the searcher has equal confidence in all of the assumptions underlying a theory, it becomes difficult to revise it. In modifying the theory, why would the retention of one assumption be preferred over another?

If, on the other hand, the searcher has more confidence in some assumptions than others, it then provides a natural path for modifying the theory in the face of evidence inconsistent with the predicted outcomes (Spohn 2012, Ehrig and Schmidt 2022, Ehrig 2023).

Of course, that conjecture depends in large part on the strength of the subjective beliefs in the various assumptions being at least somewhat correlated with their objective odds of being true. If not, the searcher might discard the more plausible assumptions when revising the theory in favor of less plausible ones.

Corollary 3. *Theories based on more strongly-held assumptions lead to better solutions.*

One of the problems that any searcher faces concerns when they should stop searching to settle on a solution. Should they experiment with one solution? Ten? One hundred? Ten thousand?

With some information (or beliefs) about the set or distribution of possible solutions, the searcher could turn to an optimal stopping rule (e.g., Robbins 1952, Chavda et al. 2024). They could evaluate the cost of each experiment relative to its expected value.

Without a theory, however, searchers have little basis for predicting the optimal stopping point or even the effectiveness of the best-possible solution (Culberson 1998). This fundamental uncertainty led Simon (1947) to argue that, instead of optimizing, people generally "satisfice"—they stop searching once they find a solution that exceeds some satisfactory threshold.

Because theories provide a projection of the possible, they should encourage searchers to persist longer in their searches, to hold out for better solutions (e.g., Lippman and McCall 1976, Fleming and Sorenson 2004). Strong beliefs in the underlying principles, for example, allowed Thomas Edison to search for a commercially-viable light bulb even in the face of thousands of failed experiments. Strong beliefs in their value propositions similarly allow many an entrepreneur to persist in the face of negative feedback (e.g., Baron 2008).

Corollary 4. *Theories based on more strongly-held assumptions prove particularly advantageous to solving complex problems.*

Of course, slow learning—not responding rapidly to negative feedback—also has advantages. Many experiments fail. They often fail not because the underlying theory had been wrong but instead because it had been incomplete, due to measurement error, or simply because of random variation in the processes.

Without a theory, an entrepreneur, innovator or executive might rapidly abandon a set of potential solutions in response to negative feedback. Denrell and March (2001) discuss the problem of the "hot stove" effect, so-named because of a quip by Mark Twain:

> We should be careful to get out of an experience only the wisdom that is in it—and stop there; lest we be like the cat that sits down on a hot stove lid. She will never sit down on a hot stove lid again—and that is well; but also she will never sit down on a cold one.—Twain (1897, p. 124)

This problem of potentially abandoning a set of solutions too early becomes particularly pronounced with complex problems and systems. Because the elements of the solution interact with each other, even seemingly-insignificant differences in two solutions can lead to large differences in performance. The semiconducting properties of carbon nano-tubes, for example, only emerge with a specific tube diameter and angle of the carbon bonds (Fleming and Sorenson 2004).

Consistent with the idea that theory-based search proves particularly valuable to the solution of complex problems, Fleming and Sorenson (2004) found that the gap in the inventive importance of patents—the number of future citations to the research—building on science versus not widens with the complexity of the underlying components. Much of this advantage, moreover, appeared to stem from persistence (Corollary 1): Science-based patents more frequently iterated on previously-explored combinations of components.

Conjecture 3. *More extensively-elaborated theories further restrict the range of solutions tested.*

Greater theoretical elaboration reduces the range of potential solutions in at least three ways. First, elaboration effectively increases the number of assumptions. Each assumption provides an opportunity for falsification (see Conjecture 1).

Elaboration helps in particular to facilitate off-line forms of search, those that do not necessarily require experimentation. Elaboration requires a more extensive explanation of the logic. The internal consistency of that logic therefore offers one opportunity to reject or revise the theory (Sørensen and Carroll 2021).

As theories become more elaborated, the growing set of assumptions also has a rising probability of coming into conflict with existing beliefs about the world. "Falsification" may come not from the failure of an experiment to match a prediction but instead from the implausibility of one or more of the necessary assumptions.

Second, when more extensively-elaborated theories do get subjected to experimental testing, they offer an even narrower range of solutions for testing (Conjecture 1), and lead to even smaller pivots (Corollary 1). The need for alternatives to satisfy an even larger set of assumptions further reduces the solution space seen as feasible.

Greater elaboration also shrinks the probable solution set for a third reason. As formerly-primitive assumptions become formulated as the consequence of even more primitive sets of antecedents, the variance in the strength of beliefs in these assumptions almost certainly grows.[11] For example, in Figure 2, GharPar's founders might believe more strongly in some of these primitives—such as their ability to train employees effectively—than others. They may therefore restrict their testing of these assumptions (or their implications) to only those most tentatively held (Sørensen and Carroll 2021, Ehrig and Schmidt 2022).

Corollary 5. *More extensively-elaborated theories lead to better learning outcomes.*

Given that more extensively-elaborated theories must potentially survive more intense scrutiny, in terms of their internal logic and their consistency with a wider range of empirical observations, we might expect them to have higher levels of correctness and resolution. They should therefore provide better guidance on where to search.

But, in addition to providing greater predictive power, more extensively-elaborated theories may also allow for "stronger" empirical testing. As suggested in Conjecture 2, one of the potential downsides of strongly-held assumptions stems from an unwillingness to update them, particularly in the face of mixed evidence. Elaboration often allows for predictions on multiple outcomes—more than one "end point" in the language of clinical trials. Experiments that must find evidence consistent with the theory on multiple outcomes provide stronger tests of a theory than those where the theory only provides a single prediction (Felin and Zenger 2017, Ehrig et al. 2023).

5. Discussion

The theory-based view portrays innovators, entrepreneurs, and strategists as being similar to scientists in terms of building theories (e.g., Fleming and Sorenson 2004, Felin and Zenger 2009, Sørensen and Carroll 2021). They build theories of success and of value creation—theories with causal structures that explain outcomes as a consequence of a set of antecedents.

These theories not only provide day-to-day strategic guidance but also influence the ways in which people search for solutions to problems.[12] To date, much of the research relating theory to search has portrayed theory as being similar to a map (e.g., Gavetti and Levinthal 2000, Fleming and Sorenson 2004). Maps can improve the efficiency of search, particularly when they provide accurate and fine-grained representations of the space being searched.

But a map does not require a theory. Indeed, the imagery of a map fails to capture many of the characteristics of theories. People typically develop theories to solve a specific problem. These theories explain not only which set of actions might provide a solution to that problem but also how and why. Theories, moreover, vary in their internal structures, in the length of their causal chains and in the number, certainty, and complexity of the assumptions that they involve.

Consideration of these structural features suggests a number of propositions worthy of exploration. Larger and more elaborated theories, and those based on more strongly held assumptions, reduce the range of possibilities that require testing or consideration (cf. Felin et al. 2023). When relatively correct, when the theory has a high degree of predictive accuracy, these restrictions lead to more effective search. Such theories probably also lead to better overall solutions. It gives those searching a sense of the possible. That understanding combined with a conviction in their theory gives them the confidence to persist in their searches, even in the face of negative feedback (Fleming and Sorenson 2004).

Being able to limit the space in need of exploration may have particularly large advantages in situations where experiments prove unusually expensive. Even producing one live-action film, for example, might cost Disney more than $100 million. In other cases, even an "experiment" might irreversibly alter the set of future options, for the worse (Levinthal and Adner 2024).

But these advantages of theories depend in large part on their correctness. When theories require revision, the number of assumptions, the degree of elaboration, and the strength of the beliefs held in the assumptions slows learning. Those searching may ignore or dismiss evidence inconsistent with their theories (Kuhn 1962, Lakatos 1970, Felin et al. 2023). Even when they recognize the need for revision, the desire to retain strongly-held assumptions means that they will initially revise their theories only incrementally (Spohn 2012, Ehrig 2023). Smaller, simpler theories allow for faster learning.

This downside highlights another interesting feature of the Marshmallow Challenge. Participants have only 18 minutes to build their towers. This time constraint probably gives children some of their advantage. Simpler, less-firmly-held theories allow for more rapid revision. Given more time, adults might have time to revise their more elaborate and more strongly-held theories in ways that would allow them to build even higher towers.

Given these pros and cons, the optimal approach to the abductive development of theory in many contexts may involve starting with simpler, more speculative theories and only later elaborating them (Sørensen and Carroll 2021, Ott and Hannah 2024). Simple theories guide search but impose few constraints on revision. More elaborate ones, though less flexible, potentially facilitate longer-run refinements of solutions.

All of these conjectures, however, involve some degree of speculation. Furthering our understanding of the value of theory to innovation, entrepreneurship, and strategy will likely require a deeper consideration of not just the correctness and resolution of theories but also of their internal causal structure.

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Endnotes

[1] For an extended description of the Marshmallow Challenge, see Tom Wojec's TED talk: https://www.ted.com/talks/tom_wujec_build_a_tower_build_a_team.

[2] Philosophers of science often refer to this last set of assumptions—if-then relationships—as "law-like" statements (Popper 1959). Law-like sentences typically represent the causal relationships in any theory, probably the most important assumptions in a theory and the most difficult ones to assess (Carroll and Sørensen 2024).

[3] Denrell et al. (2004) and Ehrig et al. (2023) have developed hybrid frameworks that incorporate some aspects of both ideas of theory. Denrell et al. (2004) examine the extent to which experiments at the level of the overall theory allow inference to lower-level antecedents while Ehrig et al. (2023) explore the value to the effectiveness of system-level search of being able to connect antecedents to intermediate outcomes.

[4] One of the difficulties in developing an intuition based on the map analogy stems from the fact that topographical maps only represent three dimensions—latitude, longitude, and altitude—but maps of the combinatoric spaces for businesses and products and services might have dozens of dimensions.

[5] Ehrig (2023) also refers to this strength of conviction across assumptions as the "centrality" of one belief relative to others.

[6] Exceptions exist. Denrell, for example, has an important research program on how feedback from prior experiments influences future search (e.g., Denrell and March 2001).

[7] Although this research sometimes labels this search as problemistic, the "problem" stems from falling below aspiration levels not from answering some specific operational or technical issue.

[8] In the literature, these forms of learning have often been described as being "off line" in the sense that they do not involve direct experimentation to test the if-then assumptions (Lippman and McCall 1976, Posen et al. 2018). In contrast, on-line learning has generally referred to the actual manipulation of antecedents to test the theory.

[9] Innovators, entrepreneurs, and strategists might also use deductive and inductive reasoning. Felin et al. (2021), for example, suggest that entrepreneurs might find ideas for interesting companies by deducing the logical conclusions of their assumptions about the world, particularly those assumptions that few others hold. Ryall and Sorenson (2023), meanwhile, portray the data-driven manager as facing similar inference problems to that of an empirical social scientist.

[10] The intuition behind these differences parallels that seen in Bayesian learning, based on the strength of the priors. But the reasons for slower learning in the presence of a theory goes beyond simply having stronger priors.

[11] The confidence in higher-level assumptions—those that depend on multiple lower-level assumptions—should generally represent some form of aggregation of the lower-level assumptions. The literature on belief revision suggests that a person cannot have greater confidence in the conclusion than in the least certain premise (Spohn 2012).

[12] Other factors also undoubtedly influence search and learning processes. By influencing the information available to managers and their allocation of attention, organizational structure, for example, may also affect these processes (for a review, see Joseph and Gaba 2020).

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