Caught in the Middle of Causality: How the Structure of Reality Produces Incorrect and Divergent Understandings in Organizations

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INTRODUCTION

Causal inference, or determining whether observed associations reflect actual cause and effect relationships between events, is a core problem of organizational actors (Rubin, 2010; Ryall & Sorenson, 2021). In order to understand how to rectify a failure or repeat a success, employees inside organizations must observe events that have occurred and determine the causal pathways that led to them (McIver & Lengnick-Hall, 2017; Lippman & Rumelt, 1982; Schon, 1995; Ryall & Sorenson, 2021). Indeed, when organizational members share correct causal models of events, which can be represented by clear strategies, collective frames of understanding, or even shared causal narratives, they perform better (Csaszar & Laureiro-Martinez, 2018; Fiss, 2011; Nadkarni & Narayanan, 2007; Kendall, 2023).

Yet getting to a convergent and correct causal model of events in organizations is a difficult problem (see work in causal ambiguity, e.g. King, 2007; King & Zeithaml, 2000). Particularly, because organizations deal with complex tasks that exceed the informational capabilities of any one individual, they must divide work, which leads to a division of experience of events for employees (Joseph & Gaba, 2020; Levitt & March, 1988; Heath & Staudenmayer, 2000; Clement, 2023). If organizations consistently generate different event experiences for their employees, it is understandable that employees within the organization may have different causal models of these events. And yet, some organizations are nonetheless able to form convergent and correct causal understandings. Given that organizations must divide labor, and thus event experience, why is it that some are more successful than others at forming convergent and correct causal understandings?

To contextualize the importance of the convergence on correct causal understandings in organizations, consider the failure of Sony's Betamax VCR compared to the success of Toyota's expansion into the North American car market. Sony was a major player in the electronics market in the 1970s, manufacturing radios, tape recorders and TVs, when the organization decided to expand into the home video market. Sony successfully manufactured a beta product before any of their competitors had realized the market existed, yet ultimately the Betamax product failed. In post hoc analysis of Sony's strategy, researchers highlight that the organization's strategy was in most ways a great one that was ultimately "undermined when the perfectly reasonable assumptions behind those [Sony's] commitments turned out to be wrong." (Raynor, 2007).

Now consider the success of Toyota expanding into the North American car market. Toyota manufactured small, affordable, fuel-efficient vehicles, a strategic choice that appealed to their mostly regional consumer base prior to 1970. Toyota had considered expanding into other markets with their products, thinking that their strategic model would appeal to a global set of consumers. They broke into the North American market in the 1970s, where the oil crisis led American consumers to start purchasing Toyotas, and consumers who were impressed with their quality, continued to buy them after gas prices stabilized (Raynor, 2007). Thus Toyota, who bet that the global market would like to buy their small, fuel-efficient vehicles, correctly understood the assignment.

In both the case of Sony and Toyota, their respective strategies were reasonable and agreed upon within the organization, so why did Toyota succeed and Sony fail? In Raynor's

book “The Strategy Paradox”, from which both the Toyota and Sony examples are pulled, the author suggests that both organizations had to make commitments under uncertainty, and Toyota’s panned out and Sony’s did not (2007). Work in causal ambiguity would specify that the type of uncertainty that Toyota and Sony faced was that of unclear understanding of the causal relationship between events and actions that would lead to success in their respective markets (King & Zeithaml, 2000). With an uncertain understanding of the causal pathways that would lead each organization to success, both organizations had to implement strategies, which can be thought of as theories of how the world works based on a causal understanding (Lazzarini & Zenger, 2023). Sony’s assumptions about how the world worked were wrong, and Toyota’s ended up being right.

If we conceptualize the difference between Sony and Toyota’s outcomes as a function of causal understandings, with Sony coming to an incorrect causal understanding and Toyota coming to a correct causal understanding, we’re still left with the question as to why this difference in causal understanding occurred and what organizations can do to get it right. Causal ambiguity and uncertainty can explain why there is likely to be noise in determining causal understandings, but it provides a rather unsatisfactory inability to predict when an organization will achieve Sony’s failure or Toyota’s success. While organizational scholars have pointed to many different factors that can improve an organization’s ability to form successful strategy, from visionary leadership (Nanus, 1995; Parry & Hansen, 2007) to organizational learning (Argote & Miron-Spektor, 2011), if strategies are based on causal models of the world, then one factor that has been uniformly underemphasized in organizational research is the causal structure of the world.

In the research of causal induction, one of the core reasons why causal models are predicted to vary is the structure of causal reality (Pearl, 2009). In a world where causal processes cannot be directly observed, and individuals must instead observe co-occurrence of events and infer relationships between them, the structure of the true causal reality that is being observed can often predict the set of causal models formed (see d-separation, Pearl, 2009). Thus, work in causal induction might predict that Sony ended up forming an incorrect causal understanding of its market because the state of the world allowed for many different causal understandings to be consistent with Sony’s observation of events, while Toyota was able to form a correct causal understanding because the structure of the world made it easier to converge on the single, correct version of events.

Yet, the assumptions of causal induction are not so easily applied to the organizational context. Indeed, the disregard of causal reality from previous organizational research has occurred for both theoretical and practical reasons. For example, scholars in organizational learning and sensemaking have suggested that there is no true causal reality outside of experience, because employees cannot experience events outside of their interpretation of them and employees often hold causal understandings inconsistent with reality (i.e. see Levitt & March, 1988; Weick et al., 2005). Or consider the work on causal ambiguity, which concedes that there is ambiguity about the true pathways that contribute to success, but practically considers how this ambiguity can serve as an advantage to organizations, because their success will be more difficult to reproduce by their competitors (McIver & Lengnick-Hall, 2017).

I do not deny that these arguments hold weight against the necessity of considering causal reality within the organizational context. However, in forming my argument with explicit assumptions about both the nature of causal reality and the ways in which organizations shape employees’ ability to observe the nature of causal reality, I show how considering the structure

of causal reality can help predict when organizations may end up with Sony's failure or Toyota's success under causal uncertainty.

In order to illustrate the usefulness of answering this question on the structure of reality's impact on the formation of causal understandings for organizations and to introduce the findings of my theoretical model, I present the following example. Consider the case of a failing start-up, where the start-up engaged in many reorganizations to avoid failure, but these reorganizations ended up generating inefficient workflows ultimately leading to poor performance. I outline this true causal reality in Figure 1 below.

FIGURE 1: The True Causal Reality of a Start-Up Failure

Company Reorganizations →Inefficient Workflows →Poor Performance

Two employees, a manager and an engineer are attempting to form causal understandings about their start-up's failure, but their experience of the causal reality has been divided by their position in the organization. The manager, who the organization holds responsible for improving poor performance, is likely to observe this event more and more saliently than the engineer, who is focused on the recent reorganization in which she was moved to another team. How might the structure of the true causal reality of the start-up's failure interact with these two employees' experience in the organization to generate causal understandings? My theoretical model developed in the sections below would suggest that the manager and the engineer are likely to form divergent causal understandings like those in Figure 2.

FIGURE 2: Divergent Causal Understandings of Start-Up Failure

Manager: Company Reorganizations ←Inefficient Workflows →Poor Performance

Employee: Company Reorganizations →Inefficient Workflows →Poor Performance

The reason why the manager and the engineer will develop these divergent causal understandings in Figure 2 is because their observation of the causal reality in the organizational context is caught in the middle of causality. When organizations divide employee experience, such that employees only observe slices of causal reality, the divisions of causal reality observed overlap, making events in the middle of causal processes more likely to be observed than events that are at the ends of them. For example, if the manager is focused on improving poor performance and the engineer is focused on the impact of the company reorganizations, they both might be more likely to observe the closest causal relationship to their focus, inefficient workflows, but might miss the event further down the causal chain from their focus. A higher frequency of observation of events in the middle of causal processes makes these middle events look more like causes than effects, such that the manager in particular, who does not observe the root cause of the inefficient workflows frequently, might instead conclude that inefficient workflows are the root cause of the poor performance. I call this the Caught in the Middle problem of causality in organizations.

The findings of my model show that a particular type of causal reality is likely to generate incorrect and divergent causal understandings under this Caught in the Middle problem of causality in organizations. Particularly, I find that causal realities that have events in the middle of causal processes that are not root causes (like the causal reality of Figure 1) generate incorrect or divergent causal understandings. I call causal realities with this characteristic non-

middle root cause realities. To generate an intuition for what types of realities contain a non-middle root cause, I outline all possible causal realities that are not cyclical (as cyclical realities do not satisfy the conditions of having a non-middle or root cause) for three events and indicate which ones contain non-middle root cause in Table 1.

Table 1: All Possible Non-Cyclical Causal Realities Between Events A, B, and C And Whether the Reality Contains a Non-Middle Root Cause

	Example Graph	**Non-Middle Root Cause**
No Cause	A B C	No
One Cause	A->B C	No
Repeller	A<-B->C	No
Collider	A->B<-C	Yes
Linear	A->B->C	Yes

Overall, my work unites the theoretical insights of organizational research and causal induction to suggest that the structure of the true causal reality is an important factor to consider when determining whether the division of labor organizations need to get work done will be at odds with correct and convergent causal understandings. I develop a mathematical model to show how under the structured experience we expect in organizations, non-middle root cause realities are likely to generate a fundamental tension between the division of labor and the ability to form convergent understandings.

Practically, in considering the implication of my findings for the divergent understanding formation between the manager and engineer in the start-up as detailed in Figure 2, my work suggests that in order to understand why these two individuals disagree on causal understandings and how best to resolve this disagreement in order to form a successful strategy, it is essential to think about both the underlying process generating events and the underlying organizational division of work influencing their experience of events. My work ultimately provides a set of theoretically grounded propositions for how the division of experience in organizations is likely to matter for the divergence of causal understandings and provides a theoretical framework for more rigorous research of causal understandings in organizations.

THEORY

A Roadmap for Where We Are Going Together

In this theory section I develop my argument for how the systematic division that organizations place on the observation of reality for their employees interacts with the true causal reality to determine whether causal understandings correctly converge. The argument is structured such that I develop the intuition for a series of assumptions I make, and then show that the results of my argument based on these assumptions are likely to fall prey to the Caught in the Middle problem of causality. The theory section progresses by answering a series of questions in order generate this argument, which I provide in a list below to give you (the reader) a sense for where we are going together.

- What is a causal understanding and why is it important for organizations?
- What is the nature of the true causal reality and an individual's ability to form a causal understanding of it?
- How do individuals form causal understandings from event observation?
- How do organizations impact the observation of causal reality for their employees?
- How does the structure of causal reality interact with employees' divided observation of this reality in an organization to generate incorrect or divergent causal understandings?

What is a causal understanding and why is it important for organizations?

A causal understanding is an individual's cognitive representation of the true causal relationships that exist between events (Carey, 1995); or, in other words, a causal understanding is an explanation for why events happened the way they did (Juarrero, 2011). In addition to being core to psychology and cognitive science's work on human reasoning (see Carey, 1995; Goodman et al., 2011; Chen & Bornstein, 2024), causal understandings are central to the function of organizations. This is because forming a successful organizational strategy requires a correct causal understanding of events.

One way to view a strategy is as a proposed set of causal relationships between events, where a strategy is really a theory of how the world works based on a causal understanding (Lazzarini & Zenger, 2023; Carroll & Sorensen, 2021). For example, consider the manager in our motivating example above, who is responsible for resolving the poor employee performance in her organization. If the manager's strategy is to improve the efficiency of workflows in order to increase employee performance, then implicit to this strategy is the causal understanding that inefficient workflows are causing poor performance. Thus, forming a strategy of what to do next relies on a causal understanding of what has happened previously.

If we accept that strategy formation is based on a set of causal understandings, then forming a successful strategy will be contingent on employees having a correct causal understanding. Continuing with our example, the manager's strategy to increase the efficiency of workflows in order to improve performance will only be effective if inefficient workflows are a part of what caused the poor performance. If the manager's causal understanding of the relationship between events is incorrect, the strategy formed is unlikely to be effective. This conceptualization of strategies as theories based on causal understandings is consistent with research that finds that managers that have a correct causal understanding of events are more successful at resolving problems when they arise (Milgrom & Roberts, 1992; Ryall & Sorenson, 2021).

Finding the correct causal understanding in order to generate successful future strategy for an organization may sometimes be a straightforward task. For example, returning to Toyota's expansion into the North American market, Toyota's causal understanding that small, fuel-efficient cars sell was developed from its regional market strategy and continued to be effective and collectively agreed upon by the organization (Raynor, 2007). However, if there are consistent factors that generate either incorrect or divergent causal understandings, and these causal understandings are core to the formation of successful strategies, then organizations ought to be uniquely concerned with uncovering these determinants.

Indeed, work in organizations has addressed several possible antecedents to incorrect and divergent causal understandings. For example, under causal ambiguity, where causal relationships are difficult to infer, trustworthiness is likely to matter for how much information and understandings are shared (Szulanski et al., 2004). Hidden events and factors may also make it difficult for managers to reach a correct causal understanding (Ryall & Sorenson, 2021). And while not necessarily directly based in causal relationships, a large body of work addresses how differences in mental representations may make the search for and formation of strategy less than ideal (Csaszar & Levinthal, 2016; Santos et al., 2021).

However, in considering the broad set of factors that might impact the ability for employees to converge on correct causal understandings, organizational scholars have yet to study in detail the structure of the true causal reality. To the extent that causal reality has been considered in work on organizational understandings, it has often been dismissed, with work citing that employees' interpretations and true events can never be disentangled, and that employees can even hold understandings that are in direct contrast to their experience (Weick et al., 2005; Levitt & March, 1988). While there are no doubt pathways of motivated reasoning and interpretation that generate causal understandings (i.e. see Tappin et al., 2020), work in causal induction suggests that one of the central reasons that causal models diverge when being inferred from observation is because of the underlying structure of the causal reality (see d-separation, Pearl, 2009).

In the next section I turn to this work in causal induction, introducing the structure of true causal reality and a series of assumptions about this reality, which I will build into a theoretical argument for why and how the structure of true causal reality is likely to matter for the inference of causal understandings in organizations.

What is the nature of the true causal reality and an individual's ability to form a causal understanding of it?

A true causal reality is the underlying process that generates the events that individuals, such as employees within an organization, experience. If there is a true causal reality that generates events, then an employee's causal understanding of the world can be defined as this individual's cognitive representation of the underlying true causal reality. While some work within organizations has asserted that there is no true causal reality (i.e. see Skoldberg, 1994; Rhodes & Brown, 2005), the argument in this research generally relies on the fact that humans can never observe the true causal reality independent from their interpretation or perception of this reality (see Weick et al., 2005). While I also assume that the true causal reality cannot be observed, it is analytically useful in my argument to distinguish between the existence of a true causal reality and the ability to observe it. These two first assumptions of the existence, but unobservability, of the true causal reality are formalized below.

Assumption 1: There is a true causal reality, i.e. there is a true causal process that generates events.
Assumption 2: The true causal reality is unobservable to individuals.

It follows from these two assumptions that individuals can seek to find the true causal reality but must infer the true causal relationship between events based on their observation of the events, and not the observation of the process directly. Thus, the act of an individual forming

a causal understanding, or a cognitive representation of the true causal reality, is an act of inference from the observation of events.

Proposition 1: When an individual forms a causal understanding, she uses her observation of a set of events to infer the causal relationship between them.

How do individuals form causal understandings from event observation?

If individuals must form causal understandings through inferring the true causal relationships between events based on their observations of them, the natural next question is how individuals perform this inference. To start, I differentiate between event occurrence and event observation. An event occurring means that an event has been generated by the true causal reality. An event observation means that an individual has observed the event that has occurred. While I differentiate between event occurrence and event observation, crucial to my argument is that individuals who are observing events do not differentiate between the occurrence of events and their observation of them. This is a simplifying assumption, but it is consistent with work on theories of causal induction, where inference of causal relationships based on the observation of even small sets of data is a uniquely human endeavor (Griffiths & Tennenbaum, 2009).

Assumption 3: An employee forming a causal understanding assumes that event occurrence is consistent with her observation of events.

With assumption 3 in hand, that individuals assume that their observation of events is consistent with actual event occurrence, I now turn to how individuals go from observing events to inferring relationships between them. General causal inference proceeds with basic principles about how causality should work. One such principle is that a cause can occur without its effect, but an effect cannot occur without its cause. While this is in some ways a strict assumption in our multi-modal complex world, it is also an assumption ingrained in the definition of the terms cause and effect. Simply put, a cause must occur before its effect, or else the labels of cause and effect are not analytically useful or correct (Gale, 1965). However, effects need not occur with their causes. For example, consider the relationship that a cloud causes rain. A cloud must be present in the sky for it to rain, but it need not be raining for a cloud to appear in the sky. I formalize this assumption below:

Assumption 4: A cause can occur without its effect, but an effect cannot occur without its cause (or causes).

The above assumption helps individuals who are seeking to form causal understandings, but cannot observe the true causal reality directly, make correct inferences about the causal relationships between events. However, we are not just interested in individuals forming causal understandings generally, but in employees forming causal understandings in the structured context of organizations. In considering what causality is like in organizations, and what principles of inference might help employees converge on correct causal understandings, I make one further assumption about the nature of causality. Specifically, while much work in causal induction thinks about deterministic causality, I suggest that the causality in organizations is most likely to be probabilistic.

Deterministic causality means that if A causes B, when A happens B happens. Probabilistic causality means that if A causes B, A occurring increases the likelihood that B occurs. In the context of organizations, we generally say that effective coordination is likely to increase performance (Okhuysen & Bechky, 2009) or that complex problems generally require more coordination (Heath & Staudenmayer, 2000). In fact, much organizational research has come to the conclusion that while there are things we generally believe to be the case, the complexity and variation in organizations yields very few absolutes and very many 'it depends'. Thus, when considering causality in the context of organizations, I assume that employees, consistent with the body of organizational research, will form causal understandings of causal processes that are probabilistic. I formalize this assumption below.

Assumption 5: If a cause occurs the likelihood of its effect occurring is S, where $S<1$.
(Note: S denotes the causal strength of the relationship between a cause and its effect)

A proposition about the formation of causal understandings by employees follows from these assumptions. Since an effect cannot occur without its cause (assumption 4), an effect must occur at a rate lower than its cause (assumption 5), and employees assume that their observation of events is consistent with the occurrence of events (assumption 3), it follows that causes should be observed occurring more often than effects.

Proposition 2: For an employee forming a causal understanding consistent with causal inference principles, causes should be observed occurring more often than effects.

How do organizations impact the observation of causal reality for their employees?

With a series of assumptions and a proposition developed for how employees might infer a causal understanding based on their observation of events, I now turn to how organizations might impact these employees' observation of the true causal reality. A key element of organizations is the division of labor; in order to complete the complex and information intensive tasks of an organization, work must be divided between employees (March & Simon, 1958; Mintzberg, 1989). While the division of labor improves an organization's ability to complete its necessary tasks, work on modularity and organizational design frequently points to the potentially unintended consequence of this division: the division of event experience in the organization (Clement, 2023; Dearborn & Simon, 1958; Joseph & Gaba, 2020).

In considering how to specifically operationalize the way in which organizations divide the event observation of their employees, I rely on Simon's seminal work on this topic which states that "structural boundaries and the division of labor reflect how the organization represents its problems and affect how individuals filter information" (Dearborn & Simon, 1958; Joseph & Gaba, 2020). The structure of the organization then, which limits the scope of work to a small set of tasks, may also limit the scope of events that an employee is likely to see at any given time, which in turn serves to create this employee's causal understanding of events in the organization as a whole. Thus, the core feature that I consider in operationalizing the way that organizations impact the observations of events for their employees, is the way in which organizations limit employees from getting a bird's eye view of the organization, limiting observation of events at any time to related events only. I formalize this assumption below:

Assumption 6: Organizations divide the scope of observation of the true causal reality for their employees, such that while many events may occur in the organization, employees in the organization will only ever observe pairs of related events occurring.

This is the strongest assumption of my work, and it is also the most consequential. To consider why this assumption may be accurate for organizations, I return again to the motivating example. A manager and an engineer are trying to form causal understandings of their start-up's failure. The problem that both employees face in trying to understand the organization's failure is that they cannot see the whole set of events occurring at once. Because the organization silos experience (whether by time, role, or department), neither the manager nor the engineer is likely to observe the company reorganization directly occurring with the poor performance. This could in some ways help the manager and the engineer form correct causal understandings, because they are unlikely to identify spurious relationships between events, like the company reorganization directly causing poor performance (a common problem in the divergence of causal models, see d-separation in Pearl, 2009). However, it also means that when observing pairs of events in the organization, the manager and the engineer will both have the difficult task of connecting their observation of pairs of events into a larger model of causal reality to generate their own causal understandings.

From this assumption it is possible to see how organizations may impact the formation of correct causal understandings for their employees, because if limiting the scope of experience to related events only generates event observation for employees that is inconsistent with event occurrence of the causal reality, it is likely that employees will form incorrect causal understandings of events. To understand when assumption 6 may lead to assumption 3 being inaccurate, which may lead to incorrect inferences being made based on assumption 4 & 5 and proposition 2, consider the following.

Employees who form causal understandings from the observation of pairs of related events only, which is how their organizations' divide their ability to observe events, will observe events at a frequency different from their occurrence. Specifically, because events are observed with their directly related events, and events in the middle of causal processes are related to more events, occurrence of events in the middle of causal reality is more likely to be observed by an employee than occurrence of events at the ends of causal reality. I label this problem the Caught in the Middle problem of causality.

To formalize the exact likelihood of employees observing an event, I consider two potential ways in which organizations may divide the event experience of their employees. First, I consider an organization in which each employee sees pairs of events equally, which could represent small organizations, organizations with generalist employees, or organizations with high transparency (i.e. Ferreira & Sah, 2013; Ball, 2014).

Assumption 7a: Employees in an organization are equally likely to observe any pair of related events.

Even under the equal observation of pairs of events outlined in assumption 7a, the limiting of the scope of observation of events in organizations from assumption 6 makes it such that employees who form causal understandings from the observation of pairs of related events only will observe events at a frequency different from their occurrence. This is because when events are observed in related pairs and events in the middle of causal processes are related to

more events, occurrence of events in the middle of causal reality is more likely to be observed by an employee than occurrence of events at the ends of causal reality. When this difference between observation and occurrence of events will generate incorrect causal understandings will depend on the structure of the causal reality, which I hypothesize about further in the section below.

The second way in which organizations may divide event experience for their employees is having an unequal observation of events by different employees. The assignment of work in a specialized manner, where some employees focus on specific types of work and not others (Dearborn & Simon, 1958; Heath & Staudenmayer, 2000; Thompson, 1961), is likely to have different employees experiencing different pairs of events at different frequencies. Returning to our motivating example, the manager and the engineer are responsible for different tasks in the organization, which likely leads them to experience different sets of events at different frequencies. The manager may be responsible for resolving poor performance, and thus may experience this event and its causes more frequently than the other events in the organization. The engineer, on the other hand, may have moved teams in the recent company reorganization, and thus may experience the company reorganization and its effects more and more saliently than other events.

If we continue to assume that organizations structure the scope of experience to related events only (assumption 6), the implication of differences in the frequency of observation of events in an organization is that employees have different focuses on different pairs of events, where each employee sees their focal event and its related events more than other events in the true causal reality. I formalize this alternative assumption to 7a as assumption 7b below.

Assumption 7b: Employees in an organization will observe the pair of events that they are responsible for at a rate higher than that of all other pair of related events, where the focus pair of events e_A and e_B, for an employee is observed at a rate $F(e_A \& e_B)$ and all other events are observed at a rate $\frac{(1-F(e_A \& e_B))}{k_r - 1}$, such that focus on all pairs of events sums to 1.

This modification of the frequency of observation of events by organizations could either exacerbate or attenuate the formation of incorrect causal understandings, depending on both which pair of events an employee is focused on and the structure of the causal reality. I generate a hypothesis for when the combination of unequal focus on events and structure of causal reality are likely to generate either incorrect or divergent causal understandings for employees below.

How does the structure of causal reality interact with employees' divided observation of this reality in an organization to generate incorrect or divergent causal understandings?

In this theory section, I've developed a series of assumptions about how employees will infer causal understandings from their observation of events and how organizations will influence these employees' observation of events. I have also referenced the problem of being Caught in the Middle of causality, where because organizations limit the scope of observation of events to pairs of related events, middle events of causal reality will appear at a higher frequency than edge events. In this final section of theory, I connect the assumptions and propositions made about employees inferring causal understandings under the divided observation of events in organizations to the Caught in the Middle problem of causality in order to generate two

hypotheses about when employees are likely to come to incorrect or divergent causal understandings in organizations.

Because organizations limit the scope of event experience, forcing employees to observe pairs of related events only, not the entire birds eye view of the causal reality, employees' observation of a focal event will be a function of how many other events the focal event is related to. The reason I call this the Caught in the Middle problem of causality is because 'middle' events (events that are in the middle of causal reality and are thus related to more other events) are likely to be observed more frequently than edge events. However, whether this Caught in the Middle problem of causality will generate incorrect or divergent causal understandings depends on the structure of the true causal reality.

Consider the assumptions made above about employees inferring causal relationships from an unobservable true causal reality. As long as an employee's observation of events is consistent with actual occurrence of events (assumption 3) such that causes are observed occurring more than effects (proposition 2, off of assumption 4 & 5), the fact that organizations divide the observation of events for employees should not interfere with coming to a correct causal understanding of events. However, for certain causal realities, the limitation of the scope of event experience by organizations generating the observation of middle events at higher than occurring frequency will lead employees to observe effects occurring more than causes, which will lead to an inference of incorrect causal understandings.

Specifically, when the true causal reality has a root cause in the middle of causal reality (for example A←B→C), even though employees will observe the middle root cause B at a rate higher than its actual occurrence, the relative rate of observation of events will be consistent with event occurrence (satisfying assumption 3), such that causes will still be observed occurring more than effects (sastisfying proposition 2, off of assumption 4 & 5). However, when causal reality contains a non-middle root cause, such that observing the middle event occurring more often than an edge event means observing an effect occur more than a cause (breaking assumption 3,4, &5 and proposition 2), the inference of causal reality by employees is likely to be incorrect. To generate the intuition for what I mean by a non-middle root cause reality, I reproduce Table 1 below, with all possible non-cyclical realities for three events labeled containing a non-middle root cause or not.

Table 1: All Possible Non-Cyclical Causal Realities Between Events A, B, and C And Whether the Reality Contains a Non-Middle Root Cause

	Example Graph	**Non-Middle Root Cause**
No Cause	A B C	No
One Cause	A->B C	No
Repeller	A<-B->C	No
Collider	A->B<-C	Yes
Linear	A->B->C	Yes

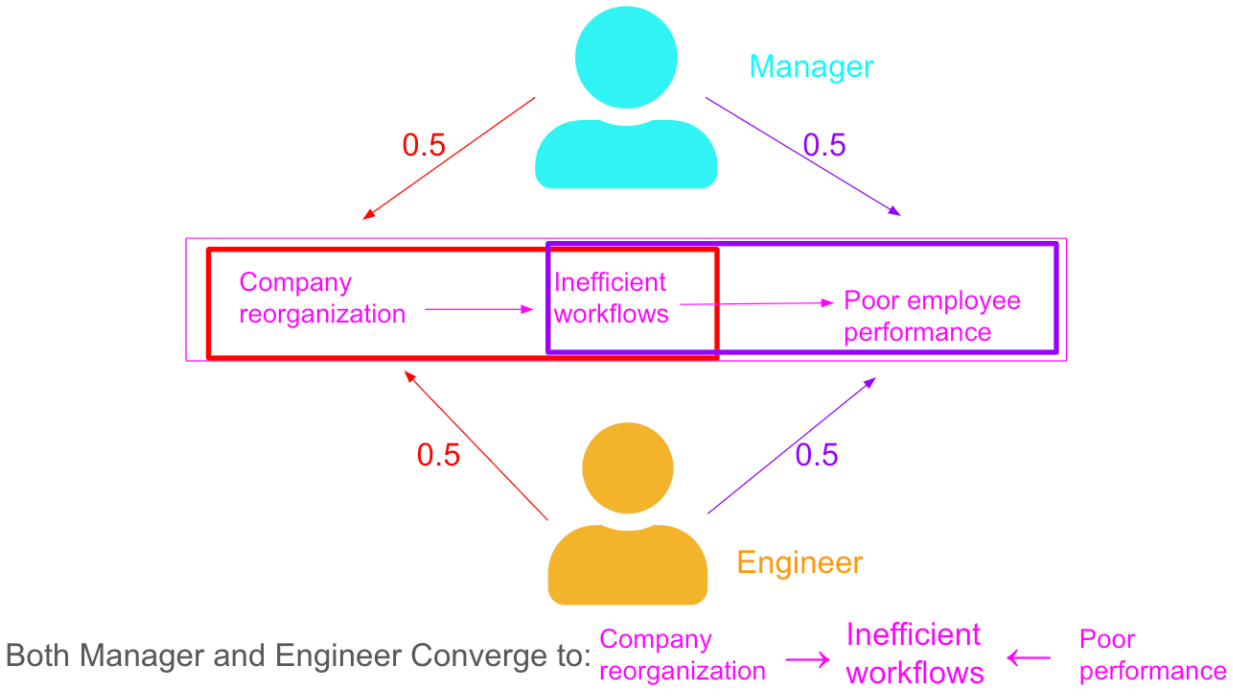
The implication of this Caught in the Middle of causality problem for the causal understandings formed by employees across an organization generates two distinct hypotheses under the two different assumptions of equal and unequal observation of pairs of events (assumption 7a and 7b respectively). First, under the equal observation of pairs of events assumption (7a), all employees are equally observing slices of reality. For non-middle root cause

realities, this means that all employees are over-observing middle event occurrence above the rate of actual occurrence, and thus likely seeing an effect occur more than a cause. This means that under equal frequency of event pair observation all employees are likely to converge on a causal understanding for non-root cause realities, however this agreed upon causal reality is likely to be incorrect. Thus, I hypothesize:

Hypothesis 1: When organizations divide the scope of employee experience and when employees have equal frequency in event experience, causal realities that have a non-middle root cause will lead to incorrect causal understandings being formed.

To visualize hypothesis 1, I use the motivating example to generate Figure 3 that outlines the expected convergence on an incorrect causal understanding based on observation of events in the organization.

FIGURE 3: HYPOTHESIS 1
Manager and Engineer's Causal Understandings under Assumption 6 and 7a



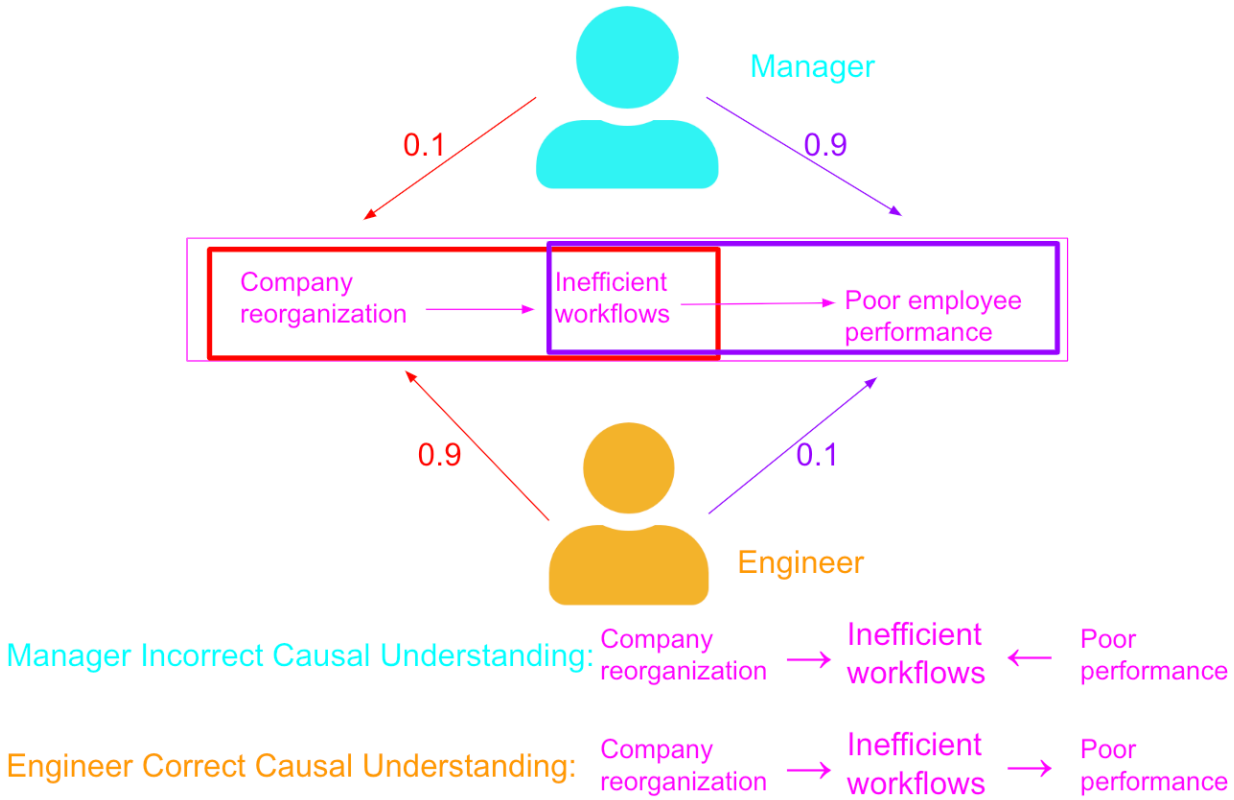
Second, consider organizations who divide the scope of experience, but have employees specialized on different tasks and thus have employees observing different pairs of events at different frequencies. For employees who only see pairs of related events, but are focused on the pair of events that contain the root cause of the causal reality, even though non-middle root cause realities modify the rate of observation of the middle event, because these employees mostly focus on the slice of reality containing the root cause, which occurs at a rate higher than its effect (assumption 5), they are still likely to form the correct causal understanding. However, for employees who see slices of reality that do not contain the root cause, the modification of the frequency of observation of non-middle root cause realities is likely to be especially problematic in generating the observation of an effect at a higher rate than a cause, and these employees are likely to form incorrect causal understandings. Thus, the implication of an unequal observation

of events in an organization under non-middle root cause realities is a divergence in causal understandings amongst employees, which I hypothesize below.

Hypothesis 2: When organizations divide the scope of employee experience and when employees have unequal frequency in event experience, causal realities that have a non-middle root cause will generate divergent causal understandings.

To visualize hypothesis 2, I use the motivating example to generate Figure 4 that outlines the expected divergence on causal understandings based on observation of events in the organization.

FIGURE 4: HYPOTHESIS 2
Manager and Engineer's Causal Understandings under Assumption 6 and 7b



To test the hypotheses above against my developed assumptions and propositions, and to provide a set of mathematically grounded predictions for the role of non-middle root causal realities in generating divergent and incorrect causal understandings under the division of experience in organizations, I develop a mathematical model using the set of assumptions I've outlined above.

MODEL

In this section I mathematically test whether non-middle root cause realities are likely to generate a trade-off between correct causal understandings and division of labor in an

organization. To do this, I operationalize my conception of the division of experience in organizations into a causal model and test the likelihood of incorrect and/or divergent causal understandings across different causal realities. The above section outlined and defended several assumptions about the individual inference, organizations, and the true causal reality, which I present in Table 2 below. From these two assumptions, two propositions about how causal understandings will be inferred by individuals followed, which are presented in Table 3.

My model developed below shows that because non-middle root cause realities break assumption 3, that an employee's observation of events is consistent with actual event occurrence, proposition 2, that causes should occur more than effects, is not valid. This generates incorrect or divergent causal understandings for employees at high causal strengths, depending on whether the frequency of event experience is equal or unequal for employees (assumption 7a or 7b). My causal modeling method provides a proof of concept that when organizations divide experience, non-middle root cause realities will generate either incorrect or divergent causal understandings as predicted in hypotheses 2 and 3.

Table 2: Assumptions

Number	Assumption
1	There is a true causal reality, i.e. there is a true causal process that generates events.
2	The true causal reality is unobservable to individuals.
3	An employee forming a causal understanding assumes that event occurrence is consistent with her observation of events.
4	A cause can occur without its effect, but an effect cannot occur without its cause (or causes).
5	If a cause occurs the likelihood of its effect occurring is S, where S<1. (Note: S denotes the causal strength of the relationship between a cause and its effect)
6	Organizations divide the scope of observation of the true causal reality for their employees, such that while many events may occur in the organization, employees in the organization will only ever observe pairs of related events occurring.
7a	Employees in an organization are equally likely to observe any pair of related events.
7b	Employees in an organization will observe the pair of events that they are responsible for at a rate higher than that of all other pair of related events, where the focus pair of events e_A and e_B, for an employee is observed at a rate $F(e_A \& e_B)$ and all other events are observed at a rate $\frac{(1-F(e_A \& e_B))}{k_r - 1}$, such that focus on all pairs of events sums to 1.

Table 3: Propositions

Number	Proposition	Necessary Assumptions
1	When an individual forms a causal understanding, she uses her observation of a set of events to infer the causal relationship between them.	1, 2
2	For an employee forming a causal understanding consistent with causal inference principles, causes should be observed occurring more often than effects.	1, 2, 3, 4, 5

Event Occurrence vs. Event Observation

The core distinction that allows me to uniquely apply a causal modeling approach to causal understandings an organizational setting is the differentiation between event occurrence and event observation. An event occurrence means that an event has been generated by the true causal reality. An event observation means that an individual has observed the event that has occurred. While traditional work in causal modeling would tend to equate event occurrence and event observation, because I assume that organizations structure the experience of employees, limiting the scope of the observation of events, events can occur in the organization without being observed by an employee. For example, poor performance can occur in the organization without the engineering employee being aware of it. Thus, my general equation for the probability of an event (e_n) for a given employee (i) in an organization is the likelihood of the occurrence of the event $P(c_{e_n})$ times the likelihood that the event is observed occurring $P_i(b_{e_n})$.

$$P_i(e_n) = P(c_{e_n}) * P_i(b_{e_n}) \quad (1)$$

In the below sections I break down how I calculate the likelihood of both event occurrence and event observation.

Event Occurrence: The Likelihood of an Event Given a True Causal Reality and a Probabilistic Causal Strength

Event occurrence in an organization is a function of the true causal reality. One way to understand event occurrence is to conceptualize the possible worlds that a causal reality could create. For all event-generating process with three events (A,B,C) for example, there are eight possible worlds that could occur ranging from all three events not occurring (A:0, B:0, C:0) to all three events co-occurring (A:1, B:1, C:1). We outline all possible worlds for three event causal realities in column 1 of table 2. However, for any specific causal reality with three events, the likelihood of each possible world differs.

For example, consider the true causal reality being a linear graph, as in Figure 2, where company reorganization →inefficient workflows → poor performance (A→B→C). If I assume, as I have above, that effects cannot occur without their causes (assumption 4) then for a linear causal reality, some possible worlds will not be possible, because B occurring without its cause A is not possible. In column 2 of Table 4, we identify which of the 8 possible worlds are possible for the linear graph under counterfactual causality.

Table 4: Likelihood of Event Occurrence for 3 Event Linear Graph (A→B→C) in the Possible Worlds Framework

Possible Worlds	Possible for Linear Graph	Likelihood of World for Linear Graph	Likelihood for Linear Graph at S = 0.9
A:0, B:0, C:0	Yes	(1-S)	0.1
A:1, B:0, C:0	Yes	S*(1-S)	0.09
A:0, B:1, C:0	No	0	0
A:0, B:0, C:1	No	0	0
A:1, B:1, C:0	Yes	S*S*(1-S)	0.081
A:0, B:1, C:1	No	0	0
A:1, B:0, C:1	No	0	0
A:1, B:1, C:1	Yes	S*S*S	0.729

After understanding which worlds of event occurrence are possible, the next step of our model is to calculate how likely each world of events is to occur. The assumption that causality in organizations is probabilistic (assumption 5), i.e. that A causing B means that A occurring increases the likelihood of B occurring, is core to executing this calculation. I use the variable causal strength (S) to identify the amount that a cause increases the probability of its effect by. For example, if the causal strength (S) of the relationship between company reorganization which causes inefficient workflows is 0.7, then a company reorganization increases the likelihood that inefficient workflows occur by 70%. Using this framework, the likelihood of an event occurring given its cause has occurred is S, and the likelihood of an event not occurring given its cause has occurred is 1-S. I assume that the likelihood of an independent cause occurring is also S, which can be interpreted as an unobserved cause of the independent cause occurring. I use this basic logic to generate the likelihood of each possible world for the linear graph in column 3 of Table 4.

Table 4 shows the general intuition that event occurrence in an organization is a function of the structure of the true causal reality and the causal strength between related events. While I show the intuition for these calculations for a linear graph with three events above, this framework can be generalized to any number of events and causal realities, as I formalize in equation 2 below, where the probability of any possible world (w) is a function of the causal strength of the relationship between events (S), the number of events that occur in the possible world (j), the number of independent causes that do not occur in the possible world (i.e. events that do not have a cause in the world, k), and the number of effects of events j that do not occur in the possible world (m).

$$P(w) = S^j * (1-S)^k * (1-S)^m \quad (2)$$

With equation 2 formalized to give the likelihood of a possible world given a causal strength (S) and event-generating process (which determines the values of j, k, and m), to find the likelihood of an event occurring $P(c_e)$, I only need to sum all possible worlds where event e occurs, which I formalize in equation 3, where d is the number of possible worlds.

$$P(c_{e_n}) = \sum_0^d w_d[e_n] * P(w_d) \ (3)$$

I can also calculate the probability of any two events (e_1, e_2) co-occurring together, $P(c_{e_1\&e_2})$, by summing possible worlds where both events occur, as formalized in equation 4.

$$P(c_{e_1\&e_2}) = \sum_0^d w_d[e_1] * w_d[e_2] * P(w_d) \quad (4)$$

The above formalization of my model of possible worlds gives me a way to measure the likelihood of event occurrence in an organization $P(c_e)$ given an event-generation process and strength of causal relationship (S). This portion of the model is similar to work developed in causal modeling (i.e. see Pearl, 2009), but adapted to an organizational setting. In equation 2, I also find a calculation supporting our intuition for why non-middle root cause realities may generate incorrect or divergent causal understandings. Non-middle root cause realities are more likely to generate a smaller number of possible worlds, and when causal strength is high, these graphs are most likely to either generate complete co-occurrence or no occurrence of all events. This uncertainty creates the opportunity for errors in causal understandings, which structure of experience is likely to produce.

However, my key assumption about organizations, that they divide the experience of events for employees, is not incorporated into the occurrence of events, but rather into the observation of events that have occurred $P_i(b_{e_n})$, thus I turn to formalizing the observation of events next.

Event Observation: The Likelihood of an Employee Observing an Event Occur Given the Divided Experience in the Organization

Event observation in an organization is a function of the degree to which experience is divided in the context. For example, if the manager is assigned to resolve the poor performance on her team, the organization can be said to have structured the experience of the manager to focus on this event and its related and necessarily co-occurring cause. This means that the manager is both more likely to see inefficient workflows and poor performance occurring, but it also means that she is more likely to see these events not occur. What the structuring of experience functionally means in an organization is that employees are focused on observing specific sections of the event-generating more than others. One nice metaphor to consider this concept through is the tale of the inebriated man searching for his keys only where the lamp had lit up the street, because it was the only place that he could see. Organizations allow for selective observation of events by 'turning on the streetlight' for certain people on certain events, creating variance in the observation of events given a set of occurrence of events. To formalize this idea of the structure of experience, consistent with our assumption that organizations limit the scope of experience observable to related events only, the likelihood that an individual observes a pair of events (e_1, e_2) occurring in an organization is simply the likelihood that the employee's (i) experience in this organization focuses them on observing this pair ($f_{i,e_1\&e_2}$).

$$P_i\left(b_{e_1\&e_2}\right) = f_{i,e_1\&e_2} \quad (5)$$

In order to find the likelihood of observing any particular event (e_n) given the siloed, pairwise focus of events in organizations, I can simply sum all the pairwise focuses that include event (e_n), giving equation 6 below.

$$P_i(b_{e_n}) = \sum_{y=0, y \neq n}^{N} f_{i,e_n \& e_y} \quad (6)$$

This event observation portion of my model formalizes the assumption that organizations divide the event experience of their employees to specific sets of related events, providing a variable of event focus ($f_{i,e_n \& e_y}$) that maps an organization's division of labor to an observation window for individuals to observe events within the organization. Functionally our event focus variable operationalizes how the division in organizations allows their employees to see only slices of events at any given time, where the engineer may be more likely to experience the effect of the company reorganization and associated events, while the manager may be more likely to experience the poor performance of her employees and associated events. When I assume that employees focus on pairs of events equally as in assumption 7a, this assumption can be formalized by equation 6 being equal for all pairs of events within a single employee (i). When I assume that employees focus on different pairs of events differently as in assumption 7b, this assumption can be formalize by the value of equation 6 varying from equal across different employees (i).

In Table 5 I summarize the parameters of my model that I can vary to generate different likelihood of events.

Table 5: Model Parameters

Parameter	Name	Description	Possible Values	Category of Variance
S	Causal Strength	Given that the cause occurs, the likelihood of also observing the effect.	[0,1)	Probabilistic Causality
$f_{i,e_1 \& e_2}$	Event Focus	The proportion of employee i's focus that is directed by the organization onto events e1 and e2.	[0,1]	Organization
j	Events, Occurring	Number of events that occur in a possible world.	[0,N]	Event-Generating Process
k	Independent Events, Non-Occurring	Number of events that do not have causes that do not occur in a possible world.	[0,N]	Event-Generating Process
m	Effect of Events j, Non-Occurring	Number of effects of events j that do not occur in a possible world.	[0,N-1]	Event-Generating Process

Now that I have developed a model to calculate the likelihood that employees within an organization will observe events, I can turn to how these employees will form causal understandings from these events.

Forming a Causal Understanding of Events from Event Observation

In order to form a model about how an employee will form a causal understanding from event observation, I reference several assumptions and propositions generated in the theory section above. Consider proposition 2, which states that for an employee forming a causal understanding consistent with causal inference principles, causes should be observed occurring more often than effects. The first part of proposition 2 specifies that an employee would need to be trying to form a causal understanding consistent with causal inference principles in order for the second piece of the proposition to be relevant. In the model, I formalize this contingency into an additional assumption, which is that employees are seeking to form the correct causal understanding of events, which means that employees will choose the causal understanding that is the most likely to be correct based on the observed probabilities and causal inferences principles.

Assumption 8: Employees seek to find the correct causal understanding of events through the application of causal inference principles (assumption 3-5).

There is much work in organizational research that references motivated or situated interpretation when it comes to making sense of events in organizations (see sense-making literature, i.e. Weick et al., 2005). However, if successful strategies are based on correct causal understandings, and employees are either motivated or incentivized to generate successful organizational outcomes, this assumption may represent a reasonable set of true scenarios in organizations.

Next, the assumptions 1-5 and their implications proposition 1 and 2, plus the newly minted assumption 8, gives the model a clear way to decide how employees will select their causal understandings. The second half of proposition 2 states that causes should be observed occurring more than effects, and assumption 8 says that employees will select the causal understandings that is most likely to be correct given their causal inference principles. Thus if event 1 is observed occurring more than event 2, then an employee (i) will conclude that event 1 causes event 2.

I formalize this logic into equation 7 below.

$$\begin{gathered} if\ P_i(e_1) > P_i(e_2)\ \ then\ e_1 \rightarrow e_2 \\ if\ P_i(e_1) < P_i(e_2)\quad then\ e_2 \rightarrow e_1 \\ if\ P_i(e_1) = P_i(e_2)\quad then\ e_1 \rightarrow e_2\ or\ e_2 \rightarrow e_1 \end{gathered} \quad (7)$$

By operationalizing our assumption about employees wanting to find the correct narrative and employing causal inference principles to do so, I can form equation 7, which provides a clear way that employees go from observing event co-occurrence to forming causal understandings of these events. In equations 8 and 9, I formalize how the probabilities in equation 7 can be derived from the event probabilities I calculate in equations 1 through 6.

$$P_i(e_1) = P_i\left(b_{e_1}\right) * \sum_0^d w_d[e_1] *\ P(w_d) \quad (8)$$

$$P_i(e_2) = P_i\left(b_{e_2}\right) * \sum_0^d w_d[e_2] *\ P(w_d) \quad (9)$$

When Employees Form Incorrect and Divergent Causal Understandings: True Causal Realities with a Non-Middle Root Cause

The structure is now in place for the model to measure when the division of work enacted by organizations ($f_{i,e_n\&e_y}$) will generate incorrect causal understandings (presented as $P_i(e_2) > P_i(e_1)$ when $e_1 \rightarrow e_2$). Since an incorrect causal understanding occurs when e_1 causes e_2, but e_2 is observed more than e_1, I formalize the likelihood of forming an incorrect understanding in equation 10a and 10b below, where equation 10a represents when an incorrect causal understanding would occur given that the true causal reality has the relationship $e_1 \rightarrow e_2$, and equation 10b represents when an incorrect causal understanding would occur given that the true causal reality has the relationship $e_2 \rightarrow e_1$.

$$P_i(b_{e_2}) * \sum_0^d w_d[e_2] * P(w_d) > P_i(b_{e_1}) * \sum_0^d w_d[e_1] * P(w_d) \text{ , when } e_1 \rightarrow e_2 \quad (10a)$$

$$P_i(b_{e_2}) * \sum_0^d w_d[e_2] * P(w_d) < P_i(b_{e_1}) * \sum_0^d w_d[e_1] * P(w_d) \text{ , when } e_2 \rightarrow e_1 \quad (10b)$$

Both equations 10a and 10b can be rewritten to reflect the relative ratios of event occurrence and event observation for events 1 and 2, where the relative event observation of the two events (represented by $P_i(b_{e_1})$and $P_i(b_{e_2})$)is not consistent with the actual relative event occurrence of the two events (represented by $\sum_0^d w_d[e_1] * P(w_d)$ and $\sum_0^d w_d[e_2] * P(w_d)$), incorrect causal understandings are likely to be formed. I rewrite equation 10a and 10b as equations 10a2 and 10b2 in this form below.

$$\frac{P_i(b_{e_2})}{P_i(b_{e_1})} > \frac{\sum_0^d w_d[e_1] * P(w_d)}{\sum_0^d w_d[e_2] * P(w_d)} \text{ , when } e_1 \rightarrow e_2 \quad (10a2)$$

$$\frac{P_i(b_{e_2})}{P_i(b_{e_1})} < \frac{\sum_0^d w_d[e_1] * P(w_d)}{\sum_0^d w_d[e_2] * P(w_d)} \text{ , when } e_2 \rightarrow e_1 \quad (10b2)$$

Note that this specification of incorrect causal understandings is a direction contradiction to one of the assumptions that the employee is making in her attempt to form a causal understanding, which is that the employee's observation of events is consistent with event occurrence (assumption 3). Functionally what equations 10a2 and 10b2 formalize is that when an employee assumes that her event observation is consistent with event occurrence, but when event occurrence is not consistent with the employee's event observation, then incorrect causal understandings are likely.

I can now calculate when the pattern of observation of events, whether equal or unequal as specified in assumption 7a and 7b respectively, will be likely to generate incorrect or divergent causal understandings. First, consider the case where employees are equally as likely to see all slices of causal reality. This formally means that for any pair of events that are related, the likelihood of observing this pair is one over the total number of relationships in the causal reality (k_r), which is shown in equation 11.

$$f_{i,e_n\&e_y} = \frac{1}{k_r} \quad (11)$$

Now consider what the implication of this is for the observation of a single event by an employee (i). Since each pair of events has an equal likelihood of being observed by employee

(i) in assumption 7a, the likelihood of observing any single event (e_n) is just the number of pairs of events that event (e_n) is in. I formalize this into equation 12 below, where l_{e_n} is the number of relationships that event e_n is in.

$$P_i(b_{e_n}) = \sum_{y=0, y\neq n}^{N} f_{i,e_n \& e_y} = l_{e_n} * \frac{1}{k_r} \quad (12)$$

I now plug in equation 12 into equation 10a2, which specifies when the true relationship $e_1 \rightarrow e_2$ will be mistaken, and the employee will come to an incorrect causal understanding, labeling this equation 13.

$$\frac{l_{e_2}}{l_{e_1}} > \frac{\sum_0^d w_d[e_1] * P(w_d)}{\sum_0^d w_d[e_2] * P(w_d)} \text{ , when } e_1 \rightarrow e_2 \quad (13)$$

What equation 13 shows is that when $e_1 \rightarrow e_2$, but event 2 (e_2) is in more relationships than event 1 (e_1), such that $l_{e_2} > l_{e_1}$, even though the true causal reality will have event occurrence such that the cause (e_1) occurs more than its effect (e_2), employee observation in the organization will generate inconsistent observation with event occurrence, generating incorrect causal understandings.

In considering which true causal realities will satisfy event 2 (e_2) being in more relationships than event 1 (e_1), such that $l_{e_2} > l_{e_1}$, non-middle root cause realities will necessarily satisfy it. I now formally define what a non-middle root cause reality is. First, non-middle root cause realities are realities where the root cause is contained in the event set, such that if $l_{e_{rootcause}} = z_{e_{rootcause}} + t_{e_{rootcause}}$, where $z_{e_{rootcause}}$ is the number of causes of the root cause and $t_{e_{rootcause}}$ is the number of effects of the root cause, $z_{e_{rootcause}} = 0$. Second, non-middle root cause realities have an effect that has more relationships with other events than the root cause, such that $l_{e_{effect}} > l_{e_{rootcause}}$. Thus, realities $l_{e_{effect}} > l_{e_{rootcause}}$ and the effect and root cause co-occur will necessarily satisfy equation 13 and generate incorrect causal understandings at high enough causal strengths. I formalize my definition of non-middle root cause realities in equation 14 below.

Formal Definition of Non-Middle Root Cause Realities: Equation 14

$$l_{e_{rootcause}} = z_{e_{rootcause}} + t_{e_{rootcause}} \quad (14)$$
$$z_{e_{rootcause}} = 0$$
$$l_{e_{effect}} > l_{e_{rootcause}}$$

Where $z_{e_{rootcause}}$ is the number of causes of the root cause and $t_{e_{rootcause}}$ is the number of effects of the root cause.

What my model then shows is a mathematical proof that under equal observation of pairs of events in an organization, employees are likely to generate incorrect causal understandings for non-middle root cause realities, confirming the intuition of hypothesis 1.

Now, consider the second case of organization's dividing event observation, such that employees observe different pairs of events at different frequencies (assumption 7a). This formally means that for any pair of events that are related, the likelihood of observing pairs of events is a specified in assumption 7a, reformalized as equation 15 & 16 below:

$F_i(e_A \& e_B)$, where events A and B are the events that employee (i) are focused on (15)

$F_i(e_n \& e_y) = \frac{(1-F_i(e_A \& e_B))}{k_r - 1}$, where events n and y are any events but the focus pair (16)

In considering what the implication of this focus is for the probability of observing a single event n for employee i ($P_i(b_{e_n})$), I plug our formalizations in equation 15 and 16 into equation 6 to get the following equation 17:

Where if event e_n is in the focal pair with event e_x then:

$$P_i(b_{e_n}) = F_i(e_n \& e_x) + \sum_{y=0, y \neq n,x}^{N} f_{i,e_n \& e_y} = F_i(e_n \& e_x) + (l_{e_n} - 1) * \frac{(1-F_i(e_n \& e_x))}{k_r - 1} \quad (17a)$$

And if event e_n is not in the focal pair, but another event e_y is, then:

$$P_i(b_{e_n}) = l_{e_n} * \frac{(1-F_i(e_y \& e_x))}{k_r - 1} \quad (17b)$$

I now plug in equation 17 into equation 10a2, which specifies when the true relationship $e_1 \rightarrow e_2$ will be mistaken, and the employee will come to an incorrect causal understanding, labeling this equation 18. However, the equation will differ depending on whether event 1 or event 2 are a part of the focus pair of events, thus I formalize equation 18a, where event 1 (e_1) and event 2 (e_2) are both in the focus pair of events and 18b where event 1 (e_1) is not a part of the focus pair of events, but event 2 (e_2) is.

$$\frac{F_i(e_1 \& e_2) + (l_{e_2} - 1) * \frac{(1-F_i(e_1 \& e_2))}{k_r - 1}}{F_i(e_1 \& e_2) + (l_{e_1} - 1) * \frac{(1-F_i(e_1 \& e_2))}{k_r - 1}} > \frac{\sum_0^d w_d[e_1] * P(w_d)}{\sum_0^d w_d[e_2] * P(w_d)} \text{ , when } e_1 \rightarrow e_2 \quad (18a)$$

$$\frac{F_i(e_2 \& e_x) + (l_{e_2} - 1) * \frac{(1-F_i(e_2 \& e_x))}{k_r - 1}}{(l_{e_1}) * \frac{(1-F_i(e_2 \& e_x))}{k_r - 1}} > \frac{\sum_0^d w_d[e_1] * P(w_d)}{\sum_0^d w_d[e_2] * P(w_d)} \text{ , when } e_1 \rightarrow e_2 \quad (18b)$$

What equation 18a and 18b show is that when $e_1 \rightarrow e_2$, but an employee focuses sufficiently on an event pair that contains event 2 (e_2) and not event 1 (e_1) as in equation 18b, if $l_{e_2} > l_{e_1}$ this employee is likely to form an incorrect understanding. However what 18a shows is that even in a world where $l_{e_2} > l_{e_1}$, if an employee focuses sufficiently on event pairs that contain event (e_1) and event (e_2), this employee is likely to form correct causal understandings. Thus in a non-middle root cause world as outlined in equation 14 (such that $l_{e_1} = 0$ and $l_{e_2} > l_{e_1}$), equation 18a and 18b show that employees are likely to form divergent causal understandings.

This calculation supports the intuition of hypothesis 2, which is that when the true causal reality is a non-middle root cause reality and employee see unequal observation of the causal reality, divergence in causal understandings is likely. Thus, the mathematical model, built on the same assumptions as our theory section, supports both hypothesis 1 and hypothesis 2.

A Three Event Example: Causal Understandings as a Function of the Division of Experience, the True Causal Reality, and Causal Strength

In my motivating example, an engineer and a manager diverge on causal understandings about their start-up's failure, coming to following conclusions in Figure 2 (reproduced below).

FIGURE 2: Divergent Causal Understandings of Start-Up Failure

Manager: Company Reorganizations ←Inefficient Workflows →Poor Performance

Employee: Company Reorganizations →Inefficient Workflows →Poor Performance

My theoretical development suggests that if the true causal reality generating events contains a non-middle root cause, then because middle events are observed occurring more than edge events due to the division of experience in organizations, the divergence of causal understandings in Figure 2 is likely. My mathematical equations can be solved to show this is the case, which I generated above.

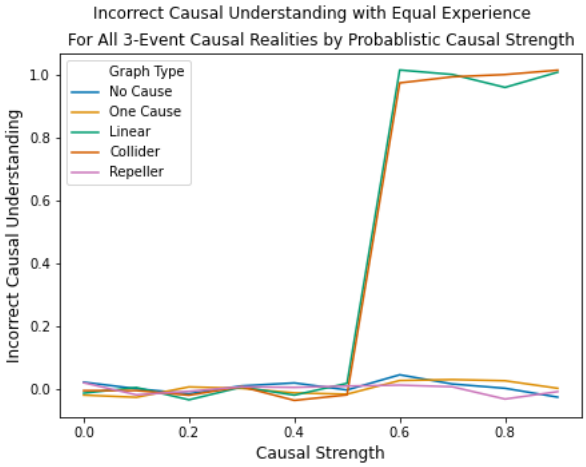
But how does this development matter for how causal understandings are formed in organizations? Calculating the values for the equations above, I show under what level of causal strength and how much division of experience will generate incorrect or divergent causal understandings between the engineer and manager given a true causal reality. In Table 6 I show all possible event-generating processes between the three events company reorganizations (A), inefficient workflows (B) and poor performance (C), identifying which graphs are non-middle root cause.

Table 6: All Possible Causal Realities Between Events A, B, and C

	Example Graph	**Number of Graph in Type**	**Number of Arrows in Graph**	**Non-Middle Root Cause**	**Equations Used**
No Cause	A B C	1	0	No	NA
One Cause	A->B C	6	1	No	12a, 18a
Repeller	A<-B->C	3	2	No	12b, 18b
Collider	A->B<-C	3	2	Yes	12a, 18a
Linear	A->B->C	6	2	Yes	12a, 18a
Total		19	7		

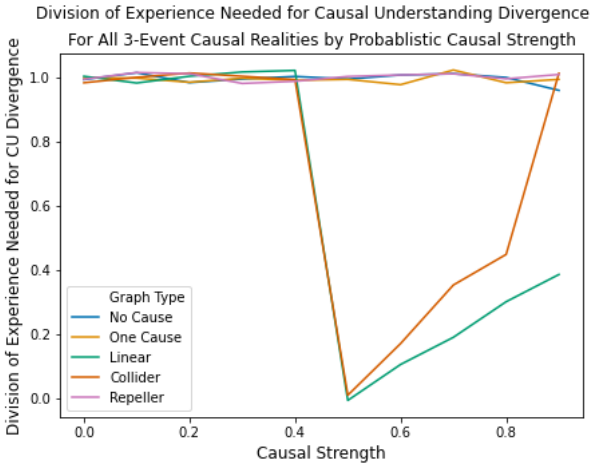
Then, for each possible causal reality listed in Table 6, I first calculate equation 12 for each causal reality, which tells us under the equal observation of slices of causal reality (assumption 7a), when employees will generate incorrect causal understandings. I visualize this in Figure 5, where on the x-axis is the causal strength of relationships between events (S). On the y-axis, if the value is 0, employees converge to the correct causal understanding of the true causal reality, if the value is 1, employees converge to the incorrect causal understanding of the true causal reality. To calculate the 0 and 1 values of the y-axis for each true causal reality, I use either equation 12a or 12b (specified in column 6 of Table 4) depending on whether the true relationship is either A→B or B→A. If equation 12 is satisfied, employees reach an incorrect causal understanding for the true causal reality at that causal strength, meaning a value of 1 on the y-axis.

FIGURE 5



Next, I consider the results of equation 18 for each possible causal reality listed in Table 6, which tells us under the unequal observation of slices of causal reality (assumption 7b), when employees will generate incorrect causal understandings. However, recall from hypothesis 2 and my mathematical development above that what is most likely expected for employees who differ in focus of events it that these employees will diverge in causal understandings. Thus in Figure 6, I visualize employee divergence in causal understandings as a function of causal strength (S) and structure of true causal reality. On the x-axis is the causal strength of relationships between events (S). On the y-axis is the difference between focus on a pair of events that includes the root cause $F_i(e_{rootcause}\&e_x)$ vs. focus on a pair of events that does not include the root cause $F_i(e_y\&e_x)$ necessary to generate a divergence in causal understandings for employees, i.e. to satisfy either equation 18a or 18b (see Table 6, column 6).

FIGURE 6



To show the mechanism for why the results in Figure 5 and 6 occur, for each of the causal realities I generate the observation of events A and B for employees vs. the actual occurrence for event A and B for employees across causal strengths (S) and report them in

Figure 7a-e. When the observation and occurrence line remain on the same side of zero to each other, this means that employee observation in the organization is consistent with event occurrence. However, for the non-middle root cause realities 'Linear' and 'Collider', above causal strength of 0.5, employee observation and occurrence are no longer consistent, breaking assumption 3, and generating incorrect causal understandings.

FIGURE 7

FIGURE 7A: No Cause Reality

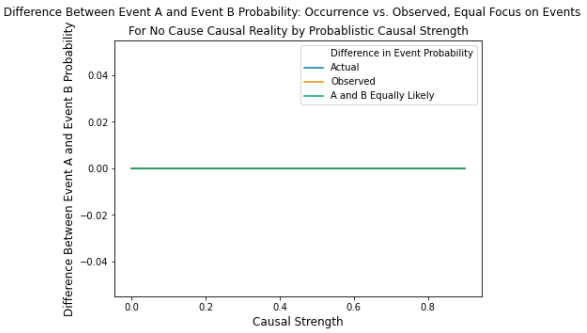


FIGURE 7B: One Cause Reality

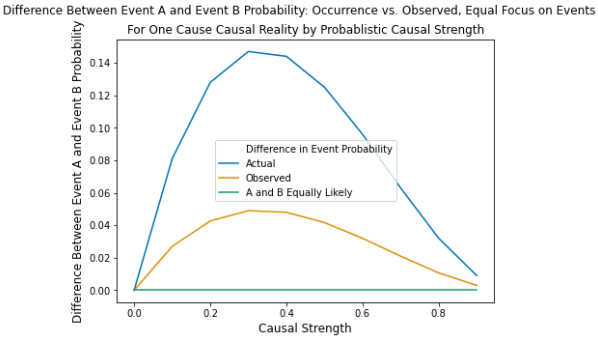


FIGURE 7C: Linear Reality

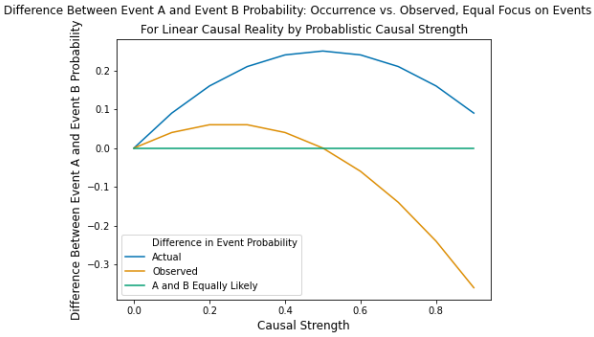


FIGURE 7D: Collider Reality

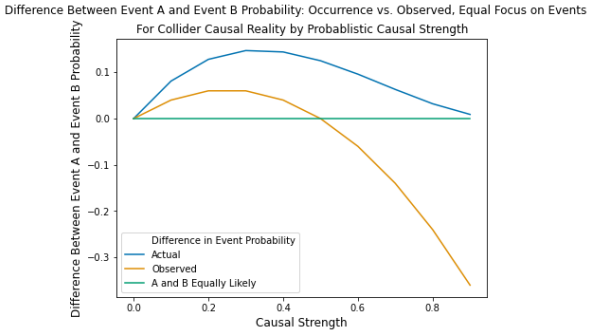
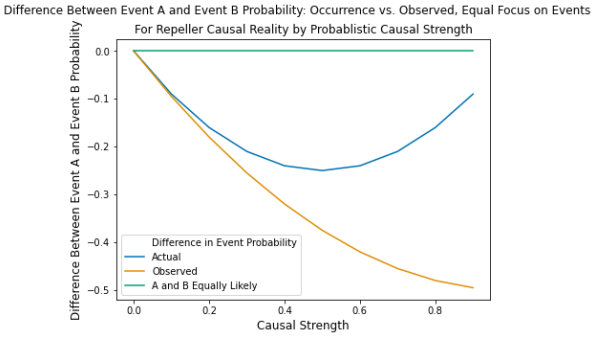


FIGURE 7E: Repeller Reality



Now that I've outlined what our results are, we turn to how these results speak to our hypotheses, and more generally suggest when organizations are likely to experience a trade-off between correct and convergent causal understandings and division of labor. I used the intuition of causal modeling to develop the hypotheses that non-middle root cause realities are likely to generate incorrect or divergent causal understandings under the divided experience of

organizations. My model shows that this is the case. In considering what this finding means for organizations, I return to the motivating example.

The start-up that the manager and engineer are a part of is failing and needs a solution to this failure. In order to generate this solution, employees in the start-up need to understand what happened in a way that allows them to come to a correct and convergent strategy of what to do next. But the start-up also has divided the work of their employees, such that the manager and the engineer are likely to have experienced the start-up's failure in different ways. Given this structure of work and experience, when are the manager and the engineer likely to be able to form a correct and convergent causal understanding of what happened? If the true causal reality does not contain a non-middle root cause, the manager and the engineer are likely to agree on the correct causal understanding even under their differences in experience. However, if the causal reality does contain a middle root cause, either the manager and engineer will agree of the incorrect causal understanding or disagree on causal understandings, generating difficulty forming a successful strategy to address their start-up's failure.

Overall, my model suggests the importance of the structure of true causal reality for when organizations are likely to face difficulty forming correct and convergent causal understandings under the division of labor.

DISCUSSION & CONCLUSION

Below I summarize the findings of my theoretical and mathematical model, suggest a wide set of contexts that this type of model can apply to, and suggest directions for future research on causal understandings in organizations.

What do we gain from considering causal reality in the formation of causal understandings in organizations?

Organizational research has previously ignored causal reality for reasons both theoretical and practical (i.e. Levitt & March, 1988; Weick et al., 2005; McIver & Lengnick-Hall, 2017). While there are arguments against the consideration of causal reality, my model nonetheless suggests that examining the interaction between an organization's division of work and causal reality provides a powerful way to predict when employees within an organization will reach incorrect or divergent causal understandings. Specifically, when true causal reality contains a non-middle root cause, employees will either converge on incorrect causal understandings or reach divergent causal understandings, depending on the division of work in the organization.

The application of this model to real world organizations, however, may be stymied by a particularly troublesome and necessary assumption of it, which is assumption 2, that individuals cannot observe the true causal reality. My model provides a proof of concept for how the true causal reality is important, but in order to identify situations where causal understandings are likely to be incorrect or divergent, knowing the structure of causal reality is essential. So how can a model showing that the structure of true causal reality be useful when it assumes that the structure of true causal reality is unobservable?

Practically, my model is likely to be most useful for organizations in three ways. First, in ex post analysis of organizational failures and success, my model suggests that considering the structure of causal reality might help distinguish why Sony converged to the incorrect causal understanding and Toyota converged to the correct causal understanding, even though both held a reasonable set of assumptions ex ante (Raynor, 2007). My model would provide the hypothesis that the reality that Sony faced was not only uncertain, but also structured in such a way that

converging on the correct assumptions in order to form the right strategy may have been a near impossible task.

Second, my model may be particularly useful to organizations when they are attempting to select the most successful strategy from a set of divergent causal understandings. While motivated reasoning and other factors may be at play in divergent causal understandings, another consistent reason employees in an organization reach divergent understandings of event is because of the division of work, and thus experience in organizations (Dearborn & Simon, 1958; Joseph & Gaba, 2020). However, only certain structures of causal reality are likely to generate divergent understandings from division of labor, non-middle root cause realities. In the case where the structure of causal reality is generating divergent understandings in organizations, my model provides a clear prediction for whose causal understanding will be correct, the employee who observes the root cause and its associated events more.

Because the true causal reality cannot be observed, it may be difficult to directly identify the root cause. However, my model suggests that having a theory for who is most likely to observe the root cause, may help organizations make more principled decisions in choosing a strategy from divergent causal understandings. For example, some work suggests that managers may be closer to the root cause of events, making manager's causal understanding of root cause events more likely to be correct, but potentially generating myopia to the trickle-down effects of higher-order decisions (Hannan et al., 2003). While in other instances, employees on the ground who are doing the work and are closer to the action, may observe the root causes of issues in the organization more saliently, and thus soliciting input, especially divergent input, from employees may generate more successful strategy (Tegarden et al., 2005).

Finally, my model suggests a rather counterintuitive, but hopeful implication for the division of work and divergent causal understandings in organizations. Traditional accounts of modularity in organizations point to how the division of work drives divergence and disagreement, harming coordination and performance (i.e. Clement, 2023; Santos et al., 2021; Heath & Staudenmayer, 2000). This research has an often unified story that, when it comes to making collective decisions, divergence in understandings decreases collective outcomes. While it's likely that the processes to reach a convergent decision will be more difficult under the divergent causal understandings that are formed in my model, the results of division of experience for the likelihood of coming to the correct causal understanding in an organization are uniformly positive.

This is because in non-middle root cause realities, if employees were not differentially focused on different parts of this causal reality, employees would converge on causal understandings, but they would agree on an incorrect understanding. In this light, divergence in causal understandings due to division of work can be seen as a positive outcome of organizational processes. When employees see different slices of reality, then even for non-middle root cause realities in which it is extremely difficult to infer correct understandings, there is a chance that organizations can reach the correct causal understanding, because some employees do hold this understanding.

Ultimately, while the true structure of causal reality is unobservable, my work suggests that having a theory about the structure of the true causal reality may help organizations consider how to better select which causal understanding to form strategy on when causal understandings diverge. In addition, in ex post analysis of organizational failure and success based on causal understandings, perhaps considering the structure of causal reality can provide a more tangible

input to the uncertainty and causal ambiguity that can generate differences in outcomes for organizations (Raynor, 2007; King, 2007).

Where else do the results of the interaction of division of experience and causal reality apply?

While the work above uniformly focuses on the organizational context, my theory on causal reality applies to any context that consistently divides individual scope and frequency of experience. Societal structures, such as the sociodemographic features of race, gender, and income, may also be likely to systematically structure individuals' experience of event (Healey & Stepnik, 2009). Expanding my model to this wider set of social structures, my theory provides a potential explanation for why, for example, low-income and high-income parents may disagree on causal understandings of raising children (Lareau, 2018). Or even why democrats and republicans, whose experience is often stratified by many social features, may observe the same set of political events and come to different understandings on them (Cutler, 2003; Basta, 2017). Thus, while I believe that organizations are particularly likely to exhibit the particular division of experience outlined in my model above, future work might well consider how other societal groups whose experience of events is also structured, may also reach divergent causal understandings as a function of the division of experience and the structure of causal reality.

Where do we go from here?

The goal of the theory developed in the paper is to help future work in organizations and social science research better identify why incorrect and divergent causal understandings occur. I suggest an additional and often overlooked source of this variance in causal understandings, which is the structure of true causal reality. While the structure of true causal reality is not readily observable to researchers and practitioners alike, my work suggests that having a theory of what the structure of true causal reality is may help us better understand the antecedents of division and make principled selections of causal understandings when divergence exists. Several pathways for future work follow.

First, while the propositions above are developed by following the set of assumptions, the first test of my theory is, in a controlled experimental setting, to see whether under this assumption set, individuals form incorrect and divergent causal understandings. Work on causal narratives in economics has run models and sets of experiments that generally support the idea that the observation of co-occurrence of events generates the types of causal inference errors I identify in my theory above (i.e. Spiegler, 2016; Eliaz & Speigler, 2020). However, this work does not test the set of assumptions about how organizations divide work and event experience, thus future work should explore how the formation of causal understandings under the specific set of divided work we expect to see in organizations is likely to generate the theoretical insights developed here.

Second, a major contribution of this work in organizational contexts is that it may help organizations make principled decisions about which causal understandings may generate successful strategy when there is divergence of causal understandings in the organizations. Future work should explore this theoretical insight by specifically examining organizational context where division in causal understandings arise, testing whether forming a model of the structure of causal reality and which set of stakeholders are most likely to observe the root cause of events, may help organization select better strategies and ultimately perform better.

Finally, organizations' division of experience represent similar division of experience that occurs in many different parts of our society. For any social science scholar who studies

populations that diverge on causal understandings, from work on polarization to work on class differences in parenting, considering the structure of causal reality and division of experience of individuals may help explain the divergence of individuals who may ostensibly observe the same reality.

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