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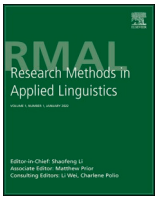

Process Tracing for applied linguistics

Nathan Thomas [a,*], Anna Kristina Hultgren [b], Beatrice Zuaro [b], Dogan Yuksel [b], Peter Wingrove [b], Marion Nao [b], Derek Beach [c]

[a] UCL (University College London), United Kingdom
[b] The Open University, United Kingdom
[c] Aarhus University, Denmark

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ABSTRACT

A key mission of many applied linguists is to understand how language-related processes work. The inner workings of a process can be explained by theorizing about the underlying causal mechanism that enables the process to unfold and evidencing the mechanism with empirical material. However, the methodological repertoire of applied linguistics is limited in this regard. Thus, we step outside of our field-specific literature and showcase Process Tracing, a family of qualitative, within-case research methods often used in political science to trace causal mechanisms. We describe Process Tracing's key tenets that are applicable to most variations. We then refer specifically to the systems understanding of Process Tracing. This variation views mechanisms as systems with interlocking parts. Each part is theorized to transmit causal force from a hypothesized cause to an outcome. Our concentrated focus enables us to provide specific recommendations for researchers looking to maximize the method's practical explanatory power without over-formalizing its procedures. As such, our coverage bridges the gap between broad introductions to Process Tracing currently available in applied linguistics and an increasingly technical literature found elsewhere. We also provide a preliminary state-of-the-art review of studies that have claimed to use Process Tracing in applied linguistics, often to very different ends. Finally, we demonstrate how we have applied the systems understanding of Process Tracing in one of our own studies as a methodological exemplar. We conclude with a call for researchers to explore the affordances of Process Tracing alongside us as we adapt it for future use in applied linguistics.

Introduction

Understanding language-related processes is central to knowledge building in applied linguistics. In recent years, there has been a proliferation of studies in this field that attend to processes in some form: from the inner workings of the mind (cognitive processes) to large-scale social change (social processes). Such studies apply a wide range of analytical tools and are not limited to any one paradigm, approach, or method. However, there are times when researchers seek to do more than describe processes. Knowing what occurred when, where, and for whom is important but tells us very little about how or why a certain phenomenon occurred. Rigorously attending to *how* a process unfolded requires researchers to provide explanations that turn attention to causal mechanisms. A

* Corresponding author.
E-mail addresses: nathan-thomas@ucl.ac.uk (N. Thomas), kristina.hultgren@open.ac.uk (A.K. Hultgren), beatrice.zuaro@open.ac.uk (B. Zuaro), dogan.yuksel@open.ac.uk (D. Yuksel), peter.wingrove@open.ac.uk (P. Wingrove), marion.nao@open.ac.uk (M. Nao), derek@ps.au.dk (D. Beach).

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mechanism exerts causal force that drives a process from a cause through to a specific outcome (C→M→O). It is what enables the outcome to occur and can be broken down into a series of disaggregated parts that explain the causal logic of a process (e.g., C→[Part1→Part2→Part3]→O). Each part consists of actors engaging in activities that propel the process to the next part with productive continuity (i.e., people doing things that trigger subsequent actions/responses). Attempting to unpack causal mechanisms theoretically and empirically enables deeper understanding of processes than mere description or holistic interpretation can provide (Beach, 2016). This is what Process Tracing can achieve: it addresses the fundamental human urge to understand causality via in-depth analyses of seemingly casual processes. It can be applied at micro (e.g., cognitive, psychological, behavioral) and macro (e.g., social, institutional, national) levels of scale.

Causality, however, is a contentious matter among social researchers. Ontological and epistemological beliefs influence the extent to which researchers are willing to accept and/or make claims regarding causality (Kincaid, 2010). Social constructivism, as evidenced in "the posts—postmodernism, poststructuralism, posthumanism, and so on" (St. Pierre, 2021, p. 4), has greatly influenced social research in its propensity to be "attuned to the complexity of contemporary societies" (Block, 2022, p. 40). However, the default position of rejecting views that seek to understand potentially causal relationships in social and applied spaces has been assimilated into the teaching and canonical thought of qualitative research at large (see Denzin et al., 2024). Novice researchers, especially, are often expressly dissuaded from attending to causal relationships on grounds related to the purported paradigmatic beliefs underpinning qualitative research (as if it were a homogenous entity). This view weds paradigm (philosophical orientation) and method (procedures to conduct the study), sometimes unnecessarily (Hampson & McKinley, 2023).

Nevertheless, there is a wide range of issues in which attempting to explain, qualitatively, how X led to Y (and not simply that it did) can be beneficial. Making theorized causal mechanisms explicit can also advance cumulative knowledge building in a specific area. Such investigations can be conducted at multiple levels of scale—independently or to complement other research designs. For example, in applied linguistics, if an intervention was shown to be effective in a particular setting, the researchers may claim that X leads to Y based on their analysis of group-level effects. Yet, one might wonder how the process of knowledge development unfolded for specific participants (e.g., most/least improved). If a case study reports on identity development for a learner over time, researchers might want to theorize how this may have occurred by formulating a process theory and assessing its utility against the available empirical material. There are also processes much larger in scale that would benefit from being traced at program, institution, and national levels, such as the rise of English medium instruction across Europe (which we discuss in our example study below).

The range of seemingly causal processes that an applied linguist might want to understand in depth is endless. There are also some existing methods suitable for doing so. However, as increasing attention is paid to research methods (e.g., Li & Prior, 2022), and new/innovative methods are being introduced to the field (e.g., Li et al., this issue), it is important to take stock in "methodological newcomers" to ensure that applied linguists are exploiting their full potential. As researchers who use various methods—and have worked within various paradigms—attempting to address the vexed issue of causality using qualitative, case-based methods in some of our studies has proven fruitful. For guidance, we have stepped outside of the methodological literature in applied linguistics and gravitated towards Process Tracing, which is often described as a within-case research method that seeks to trace the casual process and underlying mechanism between a hypothesized cause and an outcome.

Researchers who use Process Tracing share an interest in causal mechanisms, though it is not a homogeneous method. There are numerous variations (see Beach, 2022; Trampusch & Palier, 2016), sometimes with incommensurate recommendations for best practices. Given the plurality within the Process-Tracing literature, we believe it is best viewed as a family of methods. However, providing a broad overview of each variation is not our intention. In this article, we describe Process Tracing's key tenets that will be applicable to most variations. We then refer specifically to Beach and Pedersen's (2019) systems understanding of the method. This variation views mechanisms as systems with interlocking parts. Each part is theorized to transmit causal force from a hypothesized cause to an outcome. The constituent parts are disaggregated at the levels of theory and analysis. Our concentrated focus on this variation enables us to provide specific recommendations for researchers looking to maximize the method's practical explanatory power without over-formalizing its procedures. As such, our coverage bridges the gap between the broad introductions to Process Tracing currently available in applied linguistics (e.g., Hiver & Al-Hoorie, 2020) and an increasingly technical literature found elsewhere (e.g., Fairfield & Charman, 2022).[1] Since Process Tracing is still new to the field, we also provide a preliminary "state of the art" by reviewing all—to our knowledge ($N = 6$)—published studies outside of our own that have claimed to use Process Tracing in applied linguistics. Finally, we demonstrate how we applied the systems understanding of Process Tracing as a methodological exemplar. We conclude by discussing future directions for Process Tracing in applied linguistics.

Process Tracing: a primer

Purpose and use

Process Tracing is a qualitative, within-case research method, or family of methods. Its main purpose is to explore causality and make causal inferences within a single case. In Process Tracing, a case is a hypothesized causal mechanism that links a potential cause (or causes) to a known outcome (or set of outcomes). A known or purported outcome is important so that researchers know what they

[1] We recommend this literature for researchers interested in the formal application of Bayesian reasoning for Process Tracing. Informal Bayesian logic guides our preferred version. See also non-Bayesian variations that rely on necessary/sufficiency logic (e.g., Mahoney, 2012) or counterfactuals (e.g., Runhardt, 2015).

are tracing towards or backwards from. Process Tracing can be used to build or test process theories within a case and then combined with other methods to perform cross-case comparisons (optional). Such comparisons enable inferences generated about a process from one case to be assessed against other cases that share similar contextual conditions. If the compared cases are assessed as causally similar, researchers' process theories may be seen as transferable (i.e., as being applicable to other cases). Process Tracing can also be used pragmatically to explain the outcome of a particular historical case (Beach, 2020); though, this usage is rare, forfeits transferability, and is usually not recommended for most studies (De Ville et al., 2023, p. 188).

As a versatile method, Process Tracing has found different applications in various fields. It originated in the cognitive/behavioral sciences, where it is typically viewed as a general approach to researching processes rather than a formalized method (Juslin & Montgomery, 1999). Researchers in this area use Process Tracing to follow how thoughts lead to actions at a micro level, with studies mapping the decision-making processes individuals undergo to make certain choices in favor of others (see Schulte-Mecklenbeck et al., 2019). However, Process Tracing is perhaps best known as a causal, case-study method in political science (Beach & Pedersen, 2016). To political scientists, Process Tracing offers a tool for understanding the path between a political decision and its outcome, usually at a macro level (e.g., Smeets & Beach, 2023; Winward, 2021). It is within this domain, and at this level of scale, that Process Tracing has experienced the most growth and methodological development (see Beach & Pedersen, 2019; Bennett & Checkel, 2015). For these reasons, the study we use as an exemplar later in this article represents our understanding of Process Tracing applied at a similar, macro level, guided by methodological literature and training we received from political scientists.

The use of Process Tracing in applied linguistics is still new. Beyond our example study, it has been applied to very different ends, often as a general approach that lacks the methodological specificity we typically see from the systems understanding of Process Tracing in political science. Existing studies in applied linguistics tend to focus more intently on micro-level processes and apply Process Tracing quite loosely (see our review below). Thus, there is scope for future work to address the methodological implications of bridging this gap in the level of scale at which Process Tracing can be applied—doing so carefully, rigorously, and transparently. This work will have to account for researchers' varying orientations to causality and their understanding of mechanisms, which we discuss next and apply to our review of existing studies in applied linguistics that follows.

Orientations to causality

Part of the appeal of Process Tracing lies in its structured and theoretically grounded toolkit for researchers to tackle the contentious notion of causality. While studying causation in the natural sciences is difficult, the challenges are even more complex in the social sciences: we study social processes that involve reasoning human beings (Little, 2023). Hence, numerous factors exist at various levels of scale. These factors often coalesce to yield particular outcomes that are sometimes unpredictable. This makes it difficult for social scientists to say with confidence that X caused Y or attempt to unpack the causal mechanism in between (Kincaid, 2010). Thus, some scholars regard it as naïve for social scientists to embark on a quest to establish causality. They argue that definitively proving causality is never possible outside of a carefully controlled lab experiment. We agree—if causal claims are viewed as lawlike. However, others have argued that the "central project" (Byrne & Ragin, 2009, p. 1) or "fundamental task of any science which seeks both to explain and to be useful" (Byrne & Callaghan, 2014, p. 11) is to, at minimum, seek conjectures regarding causality and causal explanations. These conjectures may have implications beyond a single case of interest (i.e., they may be transferable to other cases). Importantly, researchers who engage in rigorous Process Tracing constantly challenge and update their conjectures from a probabilistic, Bayesian-inspired logic. The aim is to be "*less and less wrong* as repeated meetings with empirical evidence provide us with a better understanding of how causal mechanisms work and the contextual bounds in which these relationships hold" (Beach & Pedersen, 2019, p. 25, emphasis in original).

In applied linguistics, proponents of Complex Dynamic Systems Theory (CDST) are at the forefront of such discussions. Hiver and Al-Hoorie (2020, pp. 66–70) argue convincingly for a more "nuanced view of causality" (*complex causality*) than what has been passed down to social scientists from neopositivism. This view problematizes oversimplified causal explanations by taking human agency, context, and dynamism seriously. This shift in perspective can be understood as an extension of critical realism (*complex realism*). Critical realism posits that there is a separation between what can be described scientifically and the very "real" social reality that exists. Researchers' understandings of this reality are always a relative/interpreted view, since we are limited by our perceptual abilities as humans and the access our methodological tools can provide (Danermark et al., 2019). We can never know with 100% certainty how X caused Y. Therefore, making objective claims about causality in social research is impossible. However, we can theorize and attempt to evidence the most plausible explanation in a specific case. Doing so transparently enables other researchers to assess our interpretations and, perhaps, add their own, leading to new insights from the same data.

In line with CDST principles, the extension that complex realism makes accommodates the possibility of multi-causality, equifinality, and emergence in such processes. Yet, it still seeks to provide an account of that which can be meaningfully researched and posited with whatever information is available at that time (e.g., an always imperfect process theory). Hiver and Al-Hoorie (2020, p. 52) state:

> Complex realism holds that there is a "real" reality. However, given that reality is dynamic, shaped by inside and outside forces, and emerges over time, it is not meaningful to try to isolate and grasp all aspects of it. Because of the nature of reality, it can only be apprehended imperfectly and probabilistically. This reality must also be properly qualified to allow an active role for agency. Complex realism treads a middle way between realism and relativism, and adopts a problem-driven approach to research by relying on a pragmatic balance of methods determined by the object of inquiry.

Whereas Process Tracing has historically been grounded in positivist ontologies of causal explanation (Pickering, 2022), recent

developments have also accommodated diverse perspectives such as interpretivism (see Norman, 2021; Pouliot, 2015; Van Meegdenburg, 2023) and critical realism (see Kaas et al., 2024). It is the middle way that critical realism provides that we believe is needed for most Process-Tracing studies in applied linguistics (similar to Hiver & Al-Hoorie's argument above). This middle way could account for the elusive nature of the constructs that many applied linguists research, while also providing an infrastructure that supports exploring causal mechanisms (see also Bouchard, 2021; Williams, 2021).

Critical realism's stance is that there is some objective reality in the world, but that reality is always an interpreted one. Still, interpretations are not "anything goes," rather, there are "rational grounds for preferring one to another competing … belief or theory" (Bhaskar, 2016, p. 25). The stratification between the "real" (ontological realism) and the "empirical" (epistemological relativism) is important for Process Tracing's claims regarding causal mechanisms. However, it is the third philosophical position (judgmental rationalism) that is crucial for justifying how causal mechanisms are presented in Process-Tracing studies: often in a linear and seemingly deterministic manner. Judgmental rationalism "moves away from a certain 'anything goes' default position … while maintaining a healthy skepticism towards the positivist certainties displayed by those working in more self-assured research environments" (Block, 2022, p. 41). For Process Tracing, this means that we make rational judgments about a mechanism's causal logic (i.e., what enabled what else to occur, and how it did so).

Similarly, although Beach and Pedersen's (2019) systems understanding of Process Tracing can be viewed as generally positivistic (re. testing hypotheses and relying on empirical observables), in practice, social researchers applying the method likely do so from critical, complex, or social realist perspectives—whether they realize it or not. It is from such perspectives that we have adapted the systems understanding for our own use (see below). Further advancing how critical realism can be applied to Process Tracing, Kaas et al. (2024) have recently proposed Social Process Tracing, which makes the links between positivist Process Tracing and interpretivism explicit, with suggested methodological amendments.

Taken together, there are different views as to how to address social complexity in applied research. Acknowledging these views, different variations of Process Tracing have theoretically grounded guidelines to enable social scientists to establish or, at the very least, assess the likelihood of a given causal mechanism yielding a certain outcome. These guidelines often call for detailing procedures for case selection, developing—and constantly updating—process theories, and for evaluating the probative value of empirical evidence for each part of the process.[2] Therefore, a key strength of Process Tracing is its insistence to maintain the alluring appeal of making causal claims about processes. However, it does so with the caveat that a proposed process theory/mechanism is always a work-in-progress construction. It exemplifies what researchers believe to be representative of reality within a certain case, and at a certain time. This view will inevitably be limited by the partial and interpreted nature of reality researchers have access to. Nevertheless, researchers' conjectures are guided by judgmental rationalism. The process theories they produce should be useful to the extent that the theories further knowledge building in a particular area (though, never seen as complete or perfect), and are grounded, as best as possible, in a theoretically coherent set of guidelines.

The systems understanding of Process Tracing

Understanding mechanisms

There is consensus among the various forms of Process Tracing that the method's ambition lies in tracing causal mechanisms within specific cases. However, disagreement occurs over what this means in practice, and, more fundamentally, what causal mechanisms actually are (Beach, 2020). We provided our stance on what "causal mechanism" refers to in the first paragraph of this article: a series of interlocking parts that, together, produce the causal force that drives a process from a cause through to a specific outcome. Since this is the most salient distinguishing aspect between the different variations of Process Tracing, it is important to expand on that here.

"Process" implies a degree of temporality. This temporality is what enables researchers using Process Tracing to make claims about causality. X is presumed to have happened in order for Y to occur, although the temporal interval between X and Y can, in theory, be almost zero. Of course, temporality itself does not entail causality. For example, someone may have lunch after breakfast, but that does not mean that having breakfast caused someone to have lunch. Thus, "mechanism" is a way of moving from general temporality to causality in a process. Beach and Pedersen (2019) state:

> The essence of process-tracing case studies is that we shift the analytical focus from causes and outcomes to the hypothesized causal mechanism *in between*. That is, mechanisms are *not* causes but are causal processes that are triggered by causes and that link them with outcomes in a productive relationship. (p. 1, emphases in original)

Mechanisms are thus the interlinking steps that, through their catalytic power, connect a cause with its outcome. To establish or assess causality, the task for researchers using Process Tracing then becomes to disentangle the parts of mechanisms. They do so by explaining how actors perform activities and, through their interactions with each other, constitute an interlocking sequence that links the cause and outcome. Disentangling the different parts of a hypothesized mechanism enables researchers to make informed inferences about causality (Beach & Pedersen, 2019). Admittedly, the implied linearity in most Process-Tracing studies may perturb some researchers. However, process theories are not limited to any specific number of parts or levels of scale (often, with interactions at different levels). They can also incorporate complex, non-linear patterns of interaction (e.g., through feedback loops, thresholds, multiple mechanisms in interaction, and so on; Van Meegdenburg, 2023). Nevertheless, it is important to consider the potential

[2] This paper does not have space for a detailed account of the Process Tracing toolkit. Readers are referred to Beach and Pedersen (2019) and Kaas et al. (2024).

Table 1
Different Ways of Operationalizing Causal Mechanisms.

	How mechanisms are explained	Compatibility with tracing mechanisms within cases
Descriptive Narratives	Descriptions of events in chronological order	No
Intervening Variables	Controlled comparisons of variables across cases (assessing variation)	No
Minimalist Mechanisms	Highly abstract and/or incomplete descriptions of mechanistic evidence	Partially
Mechanisms as Systems	Fully unpacked, disaggregated mechanisms, with their causal logic explained in detail	Yes

usefulness of the process theory generated from a study: complex theories are not necessarily better than simpler theories that prioritize the most salient, seemingly crucial, component parts.

Beach and Pedersen (2019, pp. 30–41) describe four ways in which studies under the broad umbrella of Process-Tracing methods tend to operationalize causal mechanisms (see Table 1).

Unfortunately, and contrary to the aims of the researchers who employ them, narratives limited to a description of events in chronological order and mechanisms as intervening variables are not compatible with the goal of tracing mechanisms within cases. Regardless of how detailed they are, purely descriptive narratives do not achieve the same function (i.e., mechanistic explanation) as explicitly unpacking the hypothesized causal mechanism in the form of a process theory. Rich description of what happened in a case is necessary in Process Tracing; however, the causal logic that is theorized to link the parts of the mechanism must be clearly explicated. Similarly, treating mechanisms as intervening variables requires controlled comparison *across* cases and transforms *within*-case tracing into a study of difference-making (i.e., assessing variation that may or may not produce causal force towards an outcome). If the aim is to trace causal mechanisms, treating mechanisms as intervening variables risks losing focus of the process itself. Looking at variables across cases without tracing each individual case in detail leaves the causal linkages between parts of the mechanism being explored black-boxed. Thus, only minimalist mechanisms and mechanisms as systems are compatible with the goal of tracing mechanisms within cases.

The key distinctions between minimalist mechanisms and mechanisms as systems is the level of theoretical abstraction and detail in which the theorized causal mechanism is unpacked. In minimalist mechanisms, unpacking may not occur at all, which renders the theorized mechanisms either superficial (i.e., highly abstract) or incomplete (i.e., causal logic unexplained). Minimalist explanations do not inform us as to how each part of the process worked. Conversely, the systems understanding of mechanisms emphasizes unpacking each part of a causal mechanism by explicating the causal linkages that are hypothesized to bind the interlocking parts of the mechanism with productive continuity (i.e., explaining, in detail, how one part enables the next part to occur). In this way, the level of analytical abstraction is lower. Each part of the causal mechanism describes actors engaging in activities that are productive: they "transmit causal forces in an uninterrupted process that links causes(s) and outcome[s]" (Beach & Pedersen, 2019, p. 64). Conceptualized as systems, the constituent parts do not exist independently (unlike variables). The entire system cannot simply be viewed as the sum of its parts or separate from the context in which it exists holistically. Therefore, mechanistic explanations must be accompanied by descriptions of their contextual conditions. These conditions provide the context within which the theorized mechanism has the affordances necessary to unfold in the real world (see Fig. 1 and the worked example below).

Hypotheses, evidence, and validity

In line with the philosophical underpinnings described above (i.e., ontological realism, epistemological relativism, and judgmental rationalism), researchers who use Process Tracing should be aware that implied linearity lies in a careful distinction between the level of theory/hypothesis and the level of empiricism (something many scholars may not be used to). This distinction offers qualitative researchers the means to be clear, at the level of hypothesis, in their articulation of a particular causal process. It also allows them to learn, at the level of empiricism, that the reality is often far more complex than what they had expected. A process theory is an analytical simplification that directs the researchers' attention to the central, seemingly crucial, interactions between actors that can be thought of as key episodes in a series or interlinked parts in a causal sense.

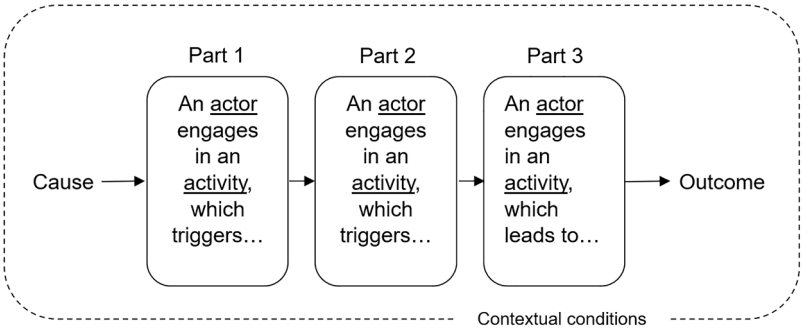

Fig. 1. Constituent Features of a Mechanism as a System.

Table 2
Three Types of Process Tracing.

Types of Process Tracing	Research process
Theory-testing Process Tracing	Researchers start from a hypothesized causal mechanism and then proceed to test/evidence it empirically.
Theory-building Process Tracing	Researchers start from empirical data to generate a plausible causal mechanism.
Explaining-outcome Process Tracing	Researchers craft a minimally sufficient, case-specific explanation for a particular historical case.

Many researchers using Process Tracing start by hypothesizing a processual chain before they move on to reasoning about the type of evidence that would need to be present for the hypothesis to be confirmed. Then, researchers proceed in a way that can be likened to detective work to collect data (i.e., *observables* or *empirical fingerprints*) to assess, empirically, the validity of the hypothesized cause and process (Beach & Pedersen, 2019). Moving between the level of hypothesis and the level of empiricism means that data collection and data analysis are part of an iterative process. It can often be long and resource intensive. For example, as researchers work with new data or reinterpret existing data, they often revisit their earlier conjectures to update their working theory—a process that has no objective end point. Importantly, data may come from any source that can provide insight into the process being examined (see Rose et al., 2020). Interviews, document analysis, and other generally qualitative methods are most common, but quantitative methods can also be employed to provide evidence of the workings of the investigated mechanism. Process Tracing incorporates such data through a qualitative interpretation of what activities and linkages in the process the data could be evidence of. We encourage researchers to be creative regarding data collection techniques.

While distinguishing between hypothesizing and collecting empirical evidence clearly differentiates Process Tracing from most qualitative methods currently used in applied linguistics, the order in which hypothesizing and data collection takes place can vary. Beach and Pedersen (2019) distinguish between three types of Process Tracing compatible with the systems understanding of the method (see Table 2).

The choice between the different types of Process Tracing depends on how much one knows about a case in advance and whether an end-goal is to arrive at a process theory that may be transferable to other cases. Theory-testing and Theory-building Process Tracing aim to develop theories that may be transferable to other cases. Explaining-outcome Process Tracing does not. In practice, these types of Process Tracing may overlap and be difficult to distinguish. Most applications are more abductive, even though they are often presented in deductive/testing terms in published studies.

Irrespective of the type of Process Tracing used, analysis begins at the highly idiographic, case-specific level. It must start here. Confidence in one's hypotheses is achieved by understanding a single case in great depth and updating hypotheses as additional evidence is considered. Theorizing at the individual level affords inferential granularity that researchers would be unable to achieve with larger samples. This idiographic focus affords high internal validity for the target case (i.e., high likelihood that case-level explanations accurately represent what has been theorized to have occurred in the target case, with all relevant details included). However, remaining at the case-specific level will inevitably result in low external validity that limits how far the causal theory can travel. To increase external validity when theorizing, and, in turn, increase transferability, researchers may zoom out from the case-specific level to a slightly higher level of theoretical abstraction to arrive at a contingent or mid-range mechanistic theory (see Fig. 2). In doing so, some case-specific details will be lost (e.g., those details not deemed essential, core components of the mechanism); however, the theory will likely be more transferable to other cases. As mentioned above, researchers must consider their fidelity to a case with the potential usefulness of the causal theory they produce: more complex is not always better, depending on the aims of the research.

From the systems understanding of Process Tracing, arriving at a highly abstract theory to maximize external validity and transferability is not recommended. The loss of internal validity is too great to justify the use of Process Tracing in the first place (see minimalist mechanisms above). Ideally, most studies would be informed by case-specific insights, keep their internal causal logic intact, and explicate that logic clearly; they then zoom out to produce contingent or mid-range mechanistic theories that can travel, as per our own study we share below (see also *contextual sensitivity* and *mechanistic heterogeneity* in Beach & Pedersen, 2019, pp. 77–81).

With this overview of Process Tracing as a primer, we now take stock in how it has been interpreted and used in applied linguistics.

A review of Process-Tracing studies in applied linguistics

To provide a review of Process-Tracing studies in applied linguistics, we focused solely on studies that explicitly claimed to use Process Tracing as a method and excluded studies that focused on processes in general terms. Within each study, we sought to identify a) the context; b) some form of process (i.e., what is being traced); and c) evidence that the process was traced empirically in some form. We describe what the authors of each study reported doing and how it aligns (or does not align) with what we have described above as Process Tracing.

We acknowledge that as a new method in applied linguistics, the researchers that conducted these studies worked innovatively and without field-specific studies as exemplars. Any critique is privileged by having the benefit of hindsight, method-specific training, experts on the review team, and a view that the systems understanding of Process Tracing is the only variation that enables researchers to harness the full potential of the method (though, see also very recent developments in Kaas et al.'s [2024] Social Process Tracing and van Meegdenburg's [2023] analyticist approach). We begin with a brief discussion of the early use of the term "Process Tracing" in applied linguistics to avoid confusion over its application.

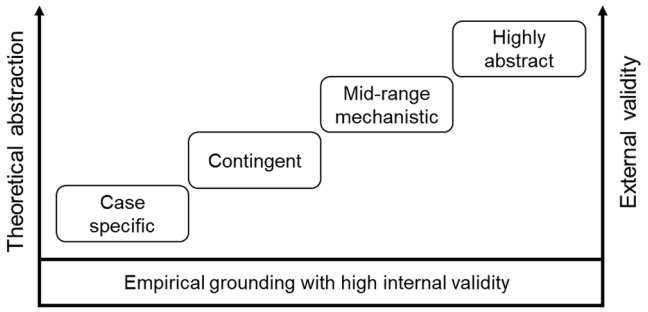

Fig. 2. Levels of Theoretical Abstraction and External Validity
Note: As external validity increases, internal validity decreases.

Initial use

Initial use of the term "Process Tracing" in applied linguistics can be traced back to methods texts on verbal reports. For example, Gass and Mackey (2016) stated that "what is meant by process tracing is that one can trace the mediating processes of participants during the performance of a specified task" (p. 10). They cite Shavelson et al. (1986), who provided three types of Process Tracing as introspective methods for data collection: think-aloud, retrospective interviews, and stimulated recall. Although using the same term, Process Tracing as a verbal-report data collection method does not represent what most scholars familiar with the method today would identify as Process Tracing (cf. work in cognitive/behavioral science that views it as more of an approach than a method, e.g., Schulte-Mecklenbeck et al., 2019). Instead, current scholars tend to refer to Process Tracing using language representative of its analytical tools and specify their data collection methods separately. If applied linguists use verbal reports, they usually refer to the specific type of verbal report and conceptualize process[es] in general terms (e.g., Révész, 2021; Wang & Pellicer-Sánchez, 2023).

Originators

While Gass and Mackey (2016) helpfully referred to the historical use of "Process Tracing" as an umbrella term for various verbal-report methods, Hiver and Al-Hoorie (2016) can be credited with bringing the more familiar analytical toolkit of Process Tracing in political science to the discourse of applied linguistics. The authors introduced Process Tracing as one of five case-based methods that they suggest can be used to put CDST into practice. They describe it as "a within-case (i.e., single system) method used to explain complex causal mechanisms at a micro level of granularity" (Hiver & Al-Hoorie, 2016, p. 751). The inclusion of "micro level" in their description is important, as the level of scale in Process-Tracing studies in applied linguistics is usually—though not by definition—much smaller than what we typically see in political science. Nevertheless, the analytical aim to remain granular in one's explanations (regardless of the scale of the process) is the same across disciplines. Hiver and Al-Hoorie (2016) also note that at the time of writing, they were "not aware of any study in the L2 field that has applied this method" (p. 751).

In the first of such studies, Hiver and Whitehead (2018) investigated the role that teacher agency in classroom interactions played in teacher identity formation for four focal participants in South Korea. The researchers focused on moments of agency identified in classroom observation footage and later discussed in individual interviews. Reflective journals collected four times over one year provided most of the process-oriented data (juxtaposed with the interviews). Reporting centered on critical incidents within the much longer process of identity formation. The closest readers get to a process theory are two "blueprints" for identity formation, which home in on episodic, narratively configured events rather than a causal chain (see *Descriptive Narratives* above). However, a trigger and subsequent phase shift are clearly described in each blueprint and evidenced interpretatively in the data (e.g., "autobiographical reasoning primes a transformation narrative" or "reinforces a contamination narrative" pp. 75–76). While attention to process is evident, and Hiver and Whitehead (2018) provide what may be considered the start of a process theory, the method appears only lightly applied as a way "to report indirectly on the utility of complexity theory as a framework for empirical research" (p. 78), with Process Tracing being one appropriate method for researching dynamic processes.

In the second study we identified, Papi and Hiver (2020) used Process Tracing "to construct a developmental blueprint of how learners' L2 motivation adapts and changes over the years of their L2 learning experience" (p. 224). Retrospective interviews with six Iranian doctoral students in the US traced the quasi-narrative accounts of key phases in the participants' language learning histories. Conceptually, the study is full of innovation, illustrating how a global theoretical framework of motivation can bring together various motivation theories and be viewed temporally through the lens of CDST. The process is described as adaptive and dynamic, with specific temporal reference points identified where significant adaptations took place. In reporting the process, Papi and Hiver (2020) acknowledge their focus on "commonalities across [all] six participants" (p. 227) rather than individual trajectories. This illustrates a move from the case-specific level—where high idiographic detail results in low transferability to other cases—to a mid-range theorization of the process that enables transferability (see *Theoretical Abstraction* above). However, while the factors that influence the participants' motivational trajectories are presented, the study is reported more as an aggregated narrative than an explicated causal theory.

Early adopters

Following their brief introduction to Process Tracing mentioned above, Hiver and Al-Hoorie (2020) expanded on their initial coverage of the method in a subsequent book chapter. This was the first methods-oriented text in applied linguistics to discuss Process Tracing. It quickly became the *go-to* text for early adopters (see Amerstorfer, 2020; Shahnama et al., 2021; Shirvan et al., 2021; Yazdanmehr et al., 2021) and proponents (e.g., Yan, 2023) of the method in applied linguistics. In line with Hiver and Whitehead (2018) and Papi and Hiver (2020), these early adopters combined CDST as a metatheoretical framework[3] with Process Tracing as a method suitable for researching dynamic processes.

Amerstorfer (2020) re-analyzed a single-participant case from a larger study to explore whether CDST could offer new insights into the learner's use of language learning strategies at an Austrian vocational school. The re-analysis was comprised of data originally collected over four weeks and included an initial interview (aided by a questionnaire) and three semi-structured stimulated recall interviews (following classroom observations). Process Tracing is briefly presented as the study's methodology. Amerstorfer (2020) cites the method's utility to test hypotheses as a rationale for using Process Tracing; however, the two hypotheses she presents do not concern causal processes (see p. 28). In fact, it is difficult to see the presence of a clear process being traced at all. The findings are presented as rich descriptions of what the participant said about her L2 strategies in the context of learning but lack a temporal structure. Therefore, while the study provides conceptual fodder for an increased focus on *context*, the lack of clarity regarding *process* renders this study unrecognizable as Process Tracing.

Shahnama et al. (2021) explored the challenges that an English-as-a-foreign-language teacher faced throughout a one-month online course at a private language institute in Iran. Conducted during the COVID-19 pandemic, the single-participant case study drew on three semi-structured interviews—one at the beginning, middle, and end of the course—to elicit data about the teacher's challenges and their potential causes. Thus, while data were collected over time, the actual process being traced is unclear. Each challenge is linked to a purported cause, but the mechanism that may be hypothesized to connect each cause to its outcome is not unpacked. The authors claim that their use of "a process-tracing approach showed not only the prevailing challenges in each step of the course, but also unraveled the causal mechanisms involved" (p. 183); however, they seem to assume that a cause is itself a mechanism, identifying 11 potential causes and charting their prevalence throughout the course. As such, Shahnama et al. (2021) appear to have 11 possible mechanisms that could have been unpacked (or likely reconfigured/condensed after further review) but presented them like themes in the data over three time points instead of as a mechanistic theory.

Yazdanmehr et al. (2021) investigated an L3 German learner's experience of boredom throughout a three-month online speaking course. The single-participant case study drew on semi-structured interviews conducted after each of 13 online sessions, a learner journal, and a scale to document the level of boredom the learner experienced at different stages of each session. Though seemingly situated in methodological literature on Process Tracing, as with Shahnama et al. (2021) above, there appears to be confusion as to what mechanism(s) the researchers sought to unpack. After reporting the intensity of the learner's boredom, the authors state that in the second phase of the study, they aimed to "unpack the black-box (intervening causal mechanism) of her boredom in the course" (Yazdanmehr et al., 2021, p. 722). However, presenting causes within a descriptive narrative is not the same as unpacking causal mechanisms (see *Understanding Mechanisms* above). The study would likely look very similar if described as a narrative inquiry with the researchers' identified causes as theoretical explanations for the learner's experiential account.

Finally, Shirvan et al. (2021) examined an L2 English teacher's grit during a four-week online English course at a private language institute in Iran. The course started just 12 days after the course reported in Shahnama et al. (2021), with the same teacher-participant. Similar to Yazdanmehr et al. (2021), the researchers conducted semi-structured interviews after each session. Shirvan et al. (2021) report on the fluctuation of the teacher's effort and interest in each session as indicators of her grit. The findings are presented as descriptions of four distinct patterns in the teacher's grit that are attributed to different stages of the course. As with the two previously reviewed studies, there appears to be no difference in this "Process-Tracing" study and a standard longitudinal study. No clear mechanism is presented or unpacked. As above, causes, factors, and intervening variables are not inherently mechanistic. Researchers must do the analytical work of explaining how causal forces are transmitted through disaggregated parts of a purported mechanism if they claim to "unravel the mechanisms" (p. 48) or "open the black box of the mechanisms involved" (Shirvan et al., 2021, p. 50).

Key takeaways

The recent attention Process Tracing has garnered in applied linguistics is a net positive for the field. As scholars seek to answer a wide range of research questions, they will inevitably make methodological decisions that distance them from what may be seen as more traditional or formalized versions of Process Tracing. While we expect and encourage such variation, if researchers claim to use Process Tracing as a method and use language that expresses a focus on unpacking causal mechanisms, it is important that they understand and make clear what it is they are tracing, how, and provide insight into *how the process works* (i.e., its causal logic). We do not offer this critique to attempt to police the use of the term "Process Tracing" in the field; rather, we hope to ensure that researchers are harnessing the full potential of the method and producing studies that offer insights only Process Tracing can provide. As Beach (2016) states: "like an electron microscope, it has only a few different uses, but what it does, it does powerfully" (p. 471). Following the systems understanding of Process Tracing, it is the explication of the causal logic within disaggregated mechanisms that gives the

[3] —to varying degrees. The application of CDST could be subjected to a separate review.

method its power. Without doing so, other methods are just as, if not more, appropriate; they have their own methodological literature, variations, and recommendations for study quality.

Furthermore, since all four "early adopters" reviewed above were single-participant studies, it is important to note that in Process Tracing, a single case ($N = 1$) refers to the mechanism being unpacked and not necessarily the number of participants. Although it can be the case that one participant is all that is needed to explain a hypothesized mechanism within a specific case in subfields of applied linguistics (e.g., individual differences, psychology of language learning, etc.), studies that research processes that are larger in scale will benefit from a broader pool of data. Once generated, to test whether a causal theory is transferable, cross-case comparisons using additional methods can be employed. Both suggestions are in line with what is typically seen in Process-Tracing studies in political science (De Ville et al., 2023; Pickering, 2022), and in the larger processes traced by the project described below. We share one case from this project in detail as a methodological exemplar rather than including it in the brief review above. It represents Process Tracing at a macro level and embodies what we have described throughout the paper as the systems understanding of Process Tracing. Although its relevance to applied linguists is more sociolinguistic in nature, we encourage readers to think creatively about how each stage of the research process can be adapted for their own projects. Whether at micro or macro levels, and regardless of the topic, the key stages of the research process remain the same.

Process Tracing on the ELEMENTAL project

The ELEMENTAL (English as the Language-of-Education Mechanisms in Europe: New Transdisciplinary Approaches in Linguistics) project works from the systems understanding of Process Tracing to identify causal processes related to the rise of English as a Medium of Instruction (EMI) in European higher education (see Hultgren & Wilkinson, 2022; Hultgren et al., 2023; Nao et al., 2023; Yuksel et al., 2024). EMI is defined as "the marked policy and practice of adopting English as a medium of instruction where this has not usually been the case" (Hultgren in Coleman et al., 2018, p. 703). Process Tracing is used to arrive at a new understanding of EMI that has not been possible with existing methods in applied linguistics. In particular, we seek to link academic governance more closely to language shift, by engaging in Theory-testing Process Tracing. That is, we start out with an overarching project hypothesis that governance reforms, largely neglected in applied linguistics, drive EMI. We then proceed to verify, empirically, this project hypothesis in seven distinct case studies. Each case represents a university in seven different European countries. Additionally, we employ a quantitative approach in a cross-country study, which is not discussed here (see Wingrove et al., under review).

ELEMENTAL's overarching project hypothesis is that governance reforms centered on *steering at a distance* are a key driver of EMI. Steering at a distance is an approach to governance, predicated on a neoliberal philosophy, that seeks to enhance the organizational performance and cost-effectiveness of public sector institutions by granting them greater autonomy and putting into place extensive accountability mechanisms. Many governments in Europe have reformed their university systems in line with steering at a distance, but the reforms vary in form and extent between countries (Hultgren et al., 2023). Our project hypothesis predicts that those countries that have granted their universities greater autonomy will also have more EMI programs, a hypothesis that has been preliminarily confirmed by the quantitative component of our project (Wingrove et al., under review). Given the variation across Europe in both reforms and EMI, our project hypothesis is a high-level, generalized theory aimed at capturing the process across Europe. How the causal mechanism that drives EMI unfolds empirically is likely to vary across our seven European cases. This will result in seven unique causal theories at the case level that, if deemed causally similar, may contribute to a mid-range mechanistic theory in the end (see *Theoretical Abstraction* above). The project is ongoing.

Rationale for using Process Tracing

There are three main reasons for using Process Tracing as ELEMENTAL's primary qualitative method. First, we are essentially interested in establishing a causal process theory that explains how EMI has arisen in European higher education. While there has already been research on the drivers of EMI, the focus has been on supranational drivers such as internationalization, the Bologna Process, and intensified global competition and collaboration. However, these supranational drivers do not happen out of the blue; they are the results of government decisions at the national level—in this case, the decision to reform the governance of higher education along with steering at a distance. Such reforms have received little attention in the applied linguistics literature on EMI, despite forming an important basis for understanding the context of EMI research. Thus, Process Tracing enables us to hypothesize about a hitherto neglected and potentially relevant contributory causal theory for the rise of EMI.

Second, the implied linearity in most Process Tracing studies aligns well with our overarching theory, steering at a distance. Because steering at a distance is predicated on a neoliberal philosophy of "self-interested individuals and organizations and the role of material incentives in motivating them" (Dougherty & Natow, 2020, p. 458), the theoretical premise is that an action is triggered by the promise of a reward or the threat of punishment if not enacted. This aligns well with the concept of mechanisms in Process Tracing, as parts of mechanisms are conceptualized as being in a productive or catalytic relationship with one another. In other words, an action triggers another action, although what actually happens is often not what was originally intended.

Third, in the EMI literature, it is often stated that institutions, lecturers, and students are utterly unprepared for EMI. Process Tracing, having been utilized by political scientists to research governance and those involved in it, offers an opportunity to work with "powerful" or "elite" research participants, including Ministers of Education, University Rectors, Faculty Deans, and Program Leaders, to reveal their often-obscure decision-making processes and the motivations underlying particular actions in the process. Thus, tracing and mapping more precisely why, how, and by whom EMI is brought about—perhaps unintentionally—may pave the way for greater institutional preparation, ensuring that the implementation of EMI is accompanied by requisite resources.

Hypothesized causal mechanism

ELEMENTAL's overarching hypothesis is that reforms implementing steering at a distance to govern universities lead to a greater number of English-taught programs. This hypothesized causal process can be conceptualized as a four-part mechanism between our hypothesized cause and its outcome (see Fig. 3). Each part of the mechanism is logically reasoned and explicitly articulated. Each part differentiates between an actor and an action. An actor is someone who does something. An action is something that is being done. In a steering-at-a-distance framework, the interaction will often take place between the national level and the institutional level, with the governments explicitly or implicitly requesting universities to do something. Thus, in Part 1 of our hypothesized process, the government puts into place legal frameworks to reform the university sector with the intention to increase the autonomy and accountability of higher education institutions. In Part 2, advancing on the frameworks in place, the government takes the logical next step of making public funding to universities contingent upon meeting certain performance targets. This incentivizes our case universities, in Part 3, to begin to compete for students. In Part 4, competition leads to a decision by universities to offer English-taught programs to be able to recruit students internationally and meet the government's target. This is our hypothesized causal mechanism. The next step is to devise empirical propositions.

Empirical propositions

Devising empirical propositions in Process Tracing entails reasoning about the type of evidence that would need to be present if the activities and linkages we hypothesized were present in a case. ELEMENTAL draws on interviews and documentary data. The empirical propositions are conveyed in Fig. 4. In Part 1, the government's reforms of the university sector are expected to be observable in the establishment of new higher education legal frameworks, centered on devolving powers to higher education institutions. In Part 2, we would expect to find evidence of the administrative apparatus to support the new legal frameworks (e.g., key performance indicators that universities are required to meet to gain public funding). In Part 3, we would expect the university's response to be empirically manifested in university mission statements or annual reports describing how they have met the key performance indicators. We might also expect university leaders in power at the time to give an account of how the universities became more proactive and tell us about some initiatives they engaged in as a result. Finally, in Part 4, we would expect to find evidence in university documents (e.g., annual reports or course catalogues) of new programs being launched in English.

Empirical evidence

Having now established our hypothesis, articulated it as a disaggregated, four-part mechanism, and predicted the empirical fingerprints that would have been left if our hypothesis was confirmed, we then go on to examine how the data collected in each of ELEMENTAL's seven cases measures up against the hypothesized causal process. Each of our seven cases will have its own process. In this paper, we discuss the Dutch case.

The Dutch case is a historical account of how and why EMI came to be implemented in our case university in the 1980s. Part 1 of the process (the government's reforms of the university sector) is empirically evidenced in both documents and interviews. The publication of the white paper "Higher Education; Autonomy and Quality" in 1985, spearheaded the concept of steering at a distance. An interview with the then Higher Education Minister of the Netherlands, Jo Ritzen, confirms the importance of university governance reforms for the rise of EMI (see Hultgren & Wilkinson, 2022, p. 54).

Part 2 of the process (makes public funding contingent on meeting performance targets) is evidenced in a range of policy initiatives, of which one is the introduction of the "Plaatsen Geld Model" (Place Money Model), introduced in 1983, which rewarded those institutions who had "active students;" thus, drop-outs or students who take too long to complete their studies would have a negative effect on a university's income. This policy was one among others that introduced a new performance culture whereby more graduates would generate more income for an institution and drop-outs would decrease it.

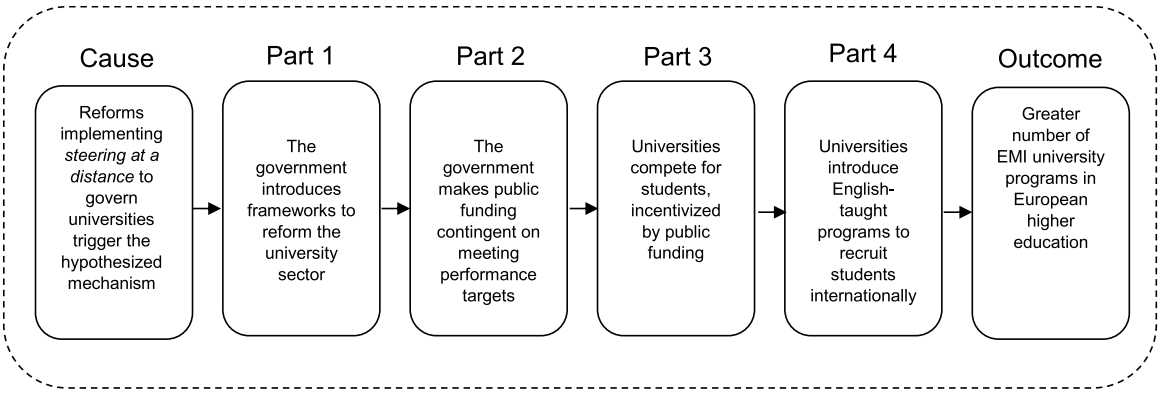

Fig. 3. Hypothesized Causal Mechanism for the Rise of EMI in European Higher Education.

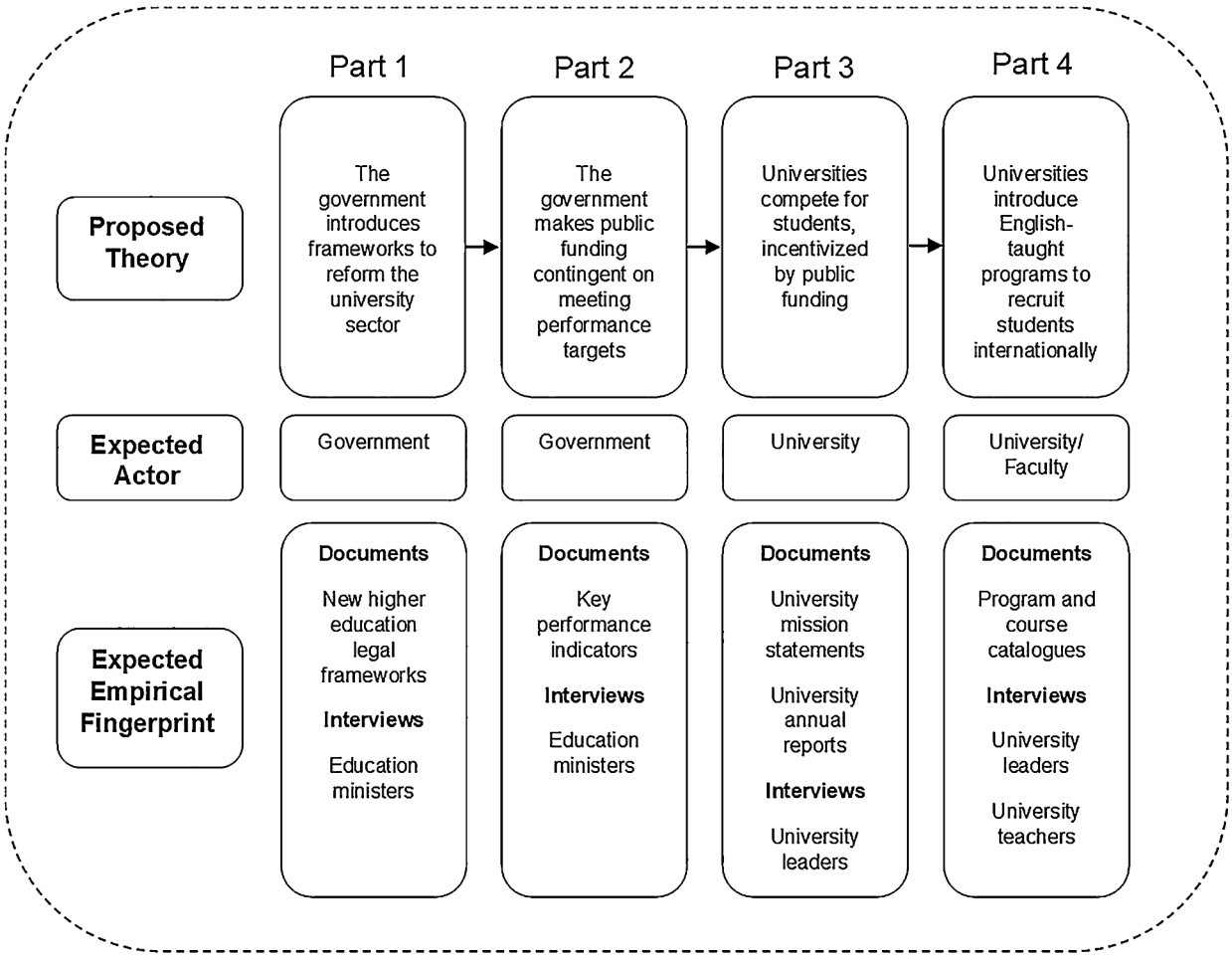

Fig. 4. Empirical Propositions for Our Causal Mechanism.

Although we found no direct evidence of the "Plaatsen Geld Model" in Part 3 of the process, we found other evidence of government-imposed performance indicators and student recruitment targets. A parliament-imposed target for our case university to recruit 6000 students by 1990 is frequently referenced in the university's annual reports in the late 1970s and 1980s. Despite no evidence of the target being directly linked with the government funding model at the time, it may have come about in parallel with the introduction of the new performance-related funding models described above (while the annual reports do not make an explicit link between the 6000-student target and the funding model, they do mention financial challenges). The pressure to recruit students is also empirically evidenced in interviews with those involved in the management of the university at the time (Hultgren & Wilkinson, 2022, p. 54).

Finally, in Part 4 of the process, we find evidence in institutional documents and interviews of the establishment of the first non-Dutch program offered by the university in the late 1980s. There is no explicit indication that recruitment should be international. However, interviews reveal that because the university felt that the Dutch-speaking student market had been exhausted, the university decided to attempt to attract students from neighboring French-speaking Belgium and Germany. Initially, the program was trilingual (English, German, and French) to attract such students. The program ran in its trilingual form for a few years in the late 1980s, until it was abandoned in favor of an English-only program—likely the first in Europe (see Hultgren & Wilkinson, 2022).

Reflections

In reflecting on our use of the systems understanding of Theory-testing Process Tracing, we focus on two main aspects. First, we found the clear demarcation between the level of hypothesis and the level of empiricism in Process Tracing helpful, as it encourages a clear and specific articulation about a potential causal explanation. A possible criticism of Process Tracing is cherry picking/confirmation bias, whereby the researcher seeks out evidence that proves their theory. A response to that criticism, however, is that engaging in Process Tracing in a transparent and informed manner partially controls for such risks, especially compared to other qualitative methods. In Process Tracing, it is not enough to find information that could be relevant; the information's connection to the rest of the

process must be clearly demonstrated. Importantly, what is found/generated should be assessed in relation to the whole empirical picture and, if possible, corroborated through multiple instantiations or sources of evidence within the case. Moreover, researchers rarely go into any study blind: most researchers have a hunch that drives their research. Process Tracing encourages researchers to be transparent about what that hunch is and explicit in their articulation of it. If evidence enables them to confirm their hypothesis, then it does not mean that other causal explanations are not valid; the researchers have simply uncovered one out of potentially many causal processes. However, even if the hypothesis is not confirmed, or the reality looks different from predicted, new knowledge is likely to have been uncovered. Researchers can then revise their theory accordingly.

Second, one critical reflection has to do with the extent to which the concepts of *certainty* and *uniqueness* help us to evaluate what our evidence tells us about whether a process worked as hypothesized. Certainty relates to the extent to which we can be confident that, if the empirical fingerprint is found, the proposed part of the mechanism has occurred; uniqueness refers to the "plausibility of alternative explanations for finding mechanistic evidence" (Beach & Pedersen, 2019, p. 191). While these concepts are well-intended, devised to aid the researcher to rigorously assess their claims about causality, in practice, we have found them difficult to operationalize in a meaningful way. Often, the proposed mechanism and empirical propositions will be partly evidenced or evidenced alongside many other factors. Thus, certainty and uniqueness will still require subjective interpretations that cannot unequivocally account for causality. However, even relatively weak confirming evidence gives us some indication of how things may have worked within a case. Acknowledging the complexity of the real world, these concepts should prompt researchers to be reflexive and hedge their causal claims. It is for this reason, especially, that we recommend situating Process Tracing within a critical, complex, or social realist perspective (see *Orientations to Causality* above) and to think reflexively about their work (see Consoli & Ganassin, 2023).

Concluding discussion

In this article, we have shown how Process Tracing can be adopted for rigorous, case-based qualitative research in applied linguistics. Although general introductions to Process Tracing for use in the field of applied linguistics exist, they tend to present the method in an under-specified way. As demonstrated in the review we provided, this under-specification has resulted in ambiguity as to what Process Tracing can/should look like if researchers seek to harness its full potential. To mitigate such ambiguity, we focused on a specific variation, Beach and Pedersen's (2019) systems understanding of the method (which includes three types: Theory-testing, Theory-building, and Explaining-outcome). This variation gained its popularity in political science and has proven fruitful in our own research. The systems understanding maximizes the explanatory power of Process Tracing by disaggregating the constituent parts of a hypothesized causal mechanism and explaining how those parts transfer causal force from a cause through to an outcome in a specific case. It provides theoretically grounded guidelines for hypothesizing, evidencing, and validating/updating propositions. It aims to use case-specific (idiographic) insights to inform contingent and mid-range mechanistic theories that may be transferable to other cases. Finally, we provided a worked example of how we applied the Theory-testing type of Process Tracing on the ELEMENTAL project to explain the rise of EMI in European higher education.

With limited space, we address the elephant in the room: all of the self-identified Process-Tracing studies we reviewed in applied linguistics explored processes that were much smaller in scale than our study (though, our example most closely resembles how the systems understanding of method has been applied elsewhere). Thus, if Process Tracing is to make meaningful inroads into the methodological repertoire of applied linguists, it is important for this difference in scale to be considered carefully and for informed adaptations to be made if deemed necessary for certain types of studies. This would help to align the systems understanding of Process Tracing with interests that appear to be predominantly psychological in nature. Formulating these adaptations is an endeavor we are currently engaged in. For now, what we can offer is reassurance that the extensive methodological toolkit of the systems understanding of Process Tracing can be applied carefully at all levels of scale. This includes studies on the micro-level decision-making processes of individual learners engaged in specific tasks to the macro-level processes of nations jockeying for better global positioning. In line with the Bayesian logic that underpins most variations of Process Tracing, we encourage interested readers to explore its affordances alongside us, as we update, adapt, and develop it in various ways. We hope that these adaptations will shed new light on longstanding questions in applied linguistics as well as those we have yet to encounter.

Author statement

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CRediT authorship contribution statement

Nathan Thomas: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Anna Kristina Hultgren:** Writing – review & editing, Writing – original draft, Formal analysis. **Beatrice Zuaro:** Writing – review & editing, Formal analysis. **Dogan Yuksel:** Writing – review & editing, Formal analysis. **Peter Wingrove:** Writing – review & editing, Formal analysis. **Marion Nao:** Writing – review & editing, Formal analysis. **Derek Beach:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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