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ORIGINAL ARTICLE

Rapid validity testing at the front end of innovation

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Abstract

To efficiently and effectively reduce the uncertainty inherent in the front-end of innovation processes, recent literature emphasizes new approaches that facilitate rapid knowledge generation and learning such as design thinking, lean innovation, and pretotyping. However, these approaches differ in their conceptualizations and, despite their popularity, the empirical evidence on the performance relevance of such approaches for established organizations is limited. In this research, we propose rapid validity testing (RVT), in which we conceptualize and harmonize existing approaches toward a unique and comprehensive set of front-end activities necessary to reduce uncertainty and equivocality inherent to this phase and enable planned flexibility. Drawing on information processing theory, we argue that organizations implementing RVT also increase the probability of achieving innovation outcomes of superior quality on time and within budget. We further argue that the effectiveness of RVT depends upon internal and external environmental factors. Drawing on multirespondent data collected from 1022 informants in 129 firms, we find empirical evidence that organizations implementing the RVT approach in their innovation activities achieve higher performance of their innovation programs, and that the performance relevance of RVT depends upon technological turbulence and the organization's long-term orientation and risk propensity. We contribute to the literature by conceptualizing RVT as a set of activities that enable planned flexibility. Furthermore, we overcome empirical shortcomings of studies on popular approaches that relied primarily on anecdotal or case study evidence and imply the generalizability of their effectiveness. Our findings highlight that organizations indeed not only benefit from RVT but also challenge the notion of a one-size-fits-all approach to the front end of innovation.

KEYWORDS

environmental turbulences, experimentation, formalization, front end, innovation process, organizational culture, planned flexibility, prototyping, rapid validity testing

1 | INTRODUCTION

The main body of literature on the front end of innovation (FEI) agrees on the relevance of this early phase for innovation success and fuzziness as its main defining characteristic (Eling & Herstatt, 2017; Kim & Wilemon, 2002a, 2002b; Reid & de Brentani, 2004). The main causes of this fuzziness are traced back to uncertainties about how an idea for a new product, process, or service will be received by its intended users once it is implemented (Schweitzer et al., 2018), the activities that will lead to the implementation of the idea (Eling & Herstatt, 2017), and the exogenous and endogenous elements (resources, contingencies, etc.) that will influence this phase (Zhang et al., 2019). This fuzziness is aggravated by the nonlinearity of the processes required to reduce uncertainty at the FEI, which is characterized more often by iterative and simultaneous learning processes (Chappin et al., 2019) rather than a stepwise approach toward the final configuration of the concept to implement (O'Connor & DeMartino, 2006). The early validation of ideas as to their feasibility and potential has been identified as a key determinant of the success or failure of innovation processes (Schweitzer et al., 2018; Williams et al., 2019).

Frameworks like agile project management (Highsmith, 2009) and agile-stage-gate processes (Cooper & Sommer, 2016), embedded in innovation management literature, offer general principles on how to enable iterative learning and development in the entire innovation process to guide the refinement of ideas (Brock et al., 2020). Previous research on the particular FEI process, which is the focus of this study, has shown evidence on the feasibility of addressing this phase as "the resolution of a series of problem-solving cycles" (Buganza et al., 2009, p. 310) in an efficient way (Cooper, 1990) while allowing for the flexibility needed to operate under dynamic environments (Buganza et al., 2009). Consequently, particular approaches have emerged, among which figure pretotyping (Savoia, 2019), prototyping (Bogers & Horst, 2014; Mascitelli, 2000), lean innovation (Blank, 2013; Ries, 2011), and design thinking (Brown, 2008), which also enjoy wide popularity in practice.

These practices have mostly been developed and studied in isolation and, when looking at their application, are characterized by their lack of concreteness: They materialize, as "bundle(s) of attitudes, tools, and approaches" (Brock et al., 2020; Liedtka, 2015, p. 929; Ries, 2011; Solaimani et al., 2019). Commonalities in their defining elements can be observed, as in the case of the application of prototyping, but no consistent set of elements underlying these approaches have been conceptualized and assessed with respect to their innovation performance effect. This lack of a comprehensive conceptualization limits our understanding of the defining elements that enable an iterative learning and development process at the FEI. Thus, it is currently difficult to propose a set of particular actions necessary to implement rapid learning and development in the FEI at the organizational level as well as to investigate the effectiveness of such an implementation.

Practitioner Points

- The rapid validity testing (RVT) concept proposes an approach to the front end of innovation based on the premise of planned flexibility, or the balance of anticipation and reaction capabilities, to address the fuzziness inherent to this phase of innovation processes.
- We provide a set of activities that go beyond what is proposed by popular approaches, such as design thinking or lean innovation, and empirical evidence on their effectiveness to facilitate innovation projects to meet goals on time and within budget.
- To achieve superior outcomes, the RVT approach emphasizes the relevance of problem framing, prototyping for testing and communication, user integration, product, and business model iterations; in addition, it stresses the relevance to integrate *commercial learning*, that is, feasibility and economic considerations, in this early stage, which is not an integral part of prior approaches and prevents overstressing customer needs solution fit at the cost of technical, economic, and commercial aspects.

Linked to the latter, a second shortcoming of this body of research is that despite the popularity of approaches such as design thinking and lean innovation among scholars and practitioners, empirical evidence of their effectiveness in facilitating the performance of the FEI remains limited. With few exceptions (e.g., Cui & Wu, 2017; Roth et al., 2020), the majority of the empirical validation of these approaches relies on anecdotal evidence and qualitative case study designs, giving rise to calls for quantitative evidence by scholars (Elsbach & Stigliani, 2018; Nakata & Hwang, 2020; Solaimani et al., 2019). Furthermore, prior studies have mainly investigated these approaches in the context of single innovation initiatives of start-ups and small businesses (Blank, 2013; Nakata & Hwang, 2020), equally contributing to the limited basis for generalization of their effectiveness (Elsbach & Stgliani, 2018; Liedtka, 2015; Razzouk & Shute, 2012). Although proponents of these approaches frame them as ultimate silver bullets to overcome the challenges of the FEI, others see them just as another management fad (e.g., Johansson-Sköldberg & Woodilla, 2009). Whether established organizations investing in the broad implementation of such approaches will also benefit by increasing overall innovation performance remains unclear. Generalization also requires taking contingencies into account, which past research has yet failed to provide (Nakata & Hwang, 2020). Our knowledge on which factors of the internal and external environment of the organization influences reaping benefits from implementing such approaches, is equally, at best, limited.

These gaps give rise to the following two research questions of this study: How can we conceptualize a comprehensive set of activities, going beyond individual practices that enable iterative learning and development in the FEI? What is the performance relevance of this concept for established organizations and does this depend upon their internal and external environment?

To address the first question, we build on Verganti's (1999) planned flexibility framework to extract and organize defining elements and to develop rapid validity testing (RVT) as a theoretically grounded concept. In order to answer the second research question, we apply organizational information processing theory (Daft & Lengel, 1986; Mackenzie, 1984) to hypothesize how RVT is related to innovation performance. In particular, we argue how the elements of RVT facilitate outcomes of the innovation project portfolio in terms of meeting objectives on time and within budget. Next, we argue on the generalizability of the proposed RVT–performance relationship. On the one hand, we take industry differences into consideration with respect to the market and technological environment that might impact the effectiveness of RVT. On the other hand, we consider the long-term orientation and risk propensity of the organization. As previously noted, scholars emphasize the universal application of practices such as lean innovation and design thinking but have developed and studied those mainly in the context of start-ups and small businesses. We recognize that small, entrepreneurial, and established organizations face different internal contexts (Ganco & Agarwal, 2009) and therefore consider these internal contingency factors that take differences in time horizons and risk attitudes into account. These contingencies are presumed to vary more between established organizations as opposed to firms in the founding or entrepreneurial stage. Finally, we empirically test our hypotheses with multirespondent data collected from 1022 informants from 129 firms.

Our contribution to the literature is twofold: First, we join the conversation on how to enable the organization to effectively master the challenges associated with the FEI and develop the concept of RVT. With its seven core, activity-based elements that contribute to an optimal balance of anticipation and reaction capabilities to enable planned flexibility in the FEI, RVT goes beyond what has been proposed by prior individual practices such as lean innovation, prototyping, design thinking, and pretotyping. RVT aggregates prior approaches, closes gaps in their defining elements, and provides a comprehensive bundle of activities that can function as a blueprint to study the strength and weaknesses of prior approaches. Second, we provide empirical evidence on the positive relationship between RVT and FEI performance and its contingency upon factors of the internal and external environment of the organization. Thereby we contribute to the ongoing discussion of whether organizations that apply approaches facilitating iterative learning and development in the FEI actually benefit from such measures at the innovation program level, drawing on more than just anecdotal and case study-based evidence. The identified contingencies also contribute to a clearer understanding of which organizations may benefit more than others from implementing RVT. Consequently, we highlight the need for future studies to consider factors of the internal and external environment to obtain a fine-grained picture on the effectiveness of RVT and related concepts.

2 | THEORETICAL FOUNDATION

2.1 | Rapid validity testing: A conceptual outline

Planned flexibility, as conceptualized by Verganti (1999), denotes the organizational capability of combining and balancing anticipation and reaction capabilities in order to identify sensitive issues in a project and deliberately anticipate and prompt actions to address these issues. This concept offers an approach to address the information processing needs of the front end of innovation as highly uncertain, highly equivocal processes. Anticipation capabilities refer to the use of approaches that engage users in cycles of trial-and-error learning (von Hippel & Katz, 2002), the early inclusion of relevant stakeholders (Bogers & Horst, 2014; Buchenau & Suri, 2000; Klemmer et al., 2006), and the use of management tools like target life cycle and target costing (Verganti, 1997, 1999). Reactive capabilities are conceptualized by Verganti as resource flexibility, overlapped development activities, and resource slack (Verganti, 1997, 1999). Possessing and deploying anticipation capabilities will contribute to address uncertainty by identifying, gathering, and analyzing relevant information as early as possible in the process. The capability to rapidly pivot and introduce changes once the process underway supports the organization in counteracting equivocality (Verganti, 1999).

A close examination of the particular FEI practices enabling planned flexibility, that is, pretotyping (Savoia, 2019), prototyping (Bogers & Horst, 2014), lean innovation (Ries, 2011), and design thinking (Brown, 2008; Carlgren et al., 2016; Hassi & Laakso, 2011), through the lens of Verganti's conceptualization reveals that each approach provides particular activities for anticipation and reaction, which are summarized in Table 1. No approach covers all aspects put forward by the concept of planned flexibility, and they only

TABLE 1 Synoptic overview of approaches to planned flexibility and defining elements of RVT

Planned flexibility capabilities (Verganti, 1999)	RVT elements	RVT labels	Pretotyping (Savoia, 2019)	Prototyping (Bogers & Horst, 2014)	Lean innovation (Ries, 2011)	Design thinking (Carlgren et al., 2016)
Anticipation	Early establishment of central assumptions	Problem framing	Yes	./.	Yes	Yes
Reaction	Continuous and rapid experimentation to test assumptions	Prototyping as test	Yes	Yes	Yes	Yes
Anticipation	Use of prototypes as instruments for communication and assessment	Prototyping as communication	Yes	Yes	Yes	Yes
Anticipation	Early user integration through prototype tests and other assessment techniques	User integration	Yes	Yes	Yes	Yes
Reaction	Development of alternative and overlapping prototypes throughout the FEI	Product iteration	./.	Yes	Yes	Yes
Anticipation	Early evaluation of market potential, pricing, and implementation costs	Commercial learning	./.	./.	./.	./.
Reaction	Development of alternative and overlapping business models	Business model iteration	./.	./.	Yes	./.

./.: It is used as an indicator of the absence of this factor in the referenced article.

show commonalities with respect to *testing of assumptions through continuous experimentation and prototyping* and the *use of prototypes as an internal communication tool* as well as *an instrument for user involvement* (Bogers & Horst, 2014; Carlgren et al., 2016; Savoia, 2019). As shown in Table 1, our conceptualization systematizes approaches existing in literature along with planned flexibility capabilities as identified by Verganti (1999) and, by including *early evaluation of market potential, pricing, and implementation costs* as an anticipation capability, goes beyond those proposed by the popular approaches listed above. In light of the scattered research landscape delineated in the previous sections, which provides, at best, sets of normative statements with little empirical validation, our proposed RVT concept offers, thus, a comprehensive systematization of activities at the FEI that goes beyond those proposed by the popular approaches listed above.

Together, the activities determine the concept of RVT, which represents a balance between anticipation and reaction (Verganti, 1999). Such a balance epitomizes a planned approach to the activities at the FEI processes (Salomo et al., 2007), while allowing for the flexibility necessary to accommodate the information that may emerge early on in the innovation process.

Verganti (1997, 1999), lists multiple mechanisms behind anticipation and reactive capabilities. Mechanisms linked to anticipation are the application of existing knowledge to the early identification of critical areas of the product life cycle, the early inclusion of relevant actors, and the encouragement of proactive thinking through early prototyping and the application of management tools to estimate future costs. RVT elements corresponding to anticipation through the application of existing knowledge are as follows: (i) The *early establishment of central assumptions*. This refers to developing hypotheses on business and technical aspects of the idea anticipated as crucial to the success of its realization and to be validated over the course of FEI activities. At the FEI, the knowledge available to generate assumptions typically builds on experiences with past projects, and thus the ability to activate and apply this knowledge to new projects at the FEI becomes a crucial capability (Verganti, 1997). The second and third elements of RVT are (ii) *prototypes as an internal communication tool to visualize, assess, and communicate the concept with internal stakeholders*, and (iii) *user integration through prototype tests and other assessment techniques*: Prototypes increase the visibility of concepts, opening opportunities for the exchange of information with users (Cui & Wu, 2017) and across functional departments (Bogers & Horst, 2014) that may contribute to create clarity on internal and external potential barriers or opportunities (Bogers & Horst, 2014; Verganti, 1997). As such, prototypes have a dual purpose: on the one side, communicating, in a more tangible way, the vision of the organization in a specific context toward potential users and offering a tangible interface to identify potential constraints and opportunities. In addition, one aspect not explicitly mentioned by any of the traditional approaches refers to (iv) *early evaluation of market potential, implementation costs, and pricing scope*: This element of RVT derives from the need to include commercial considerations early in the process to anticipate potential economic success over the entire product life cycle (Verganti, 1999). The ability to make estimations of market potential, implementation costs, and pricing scope also rests on the capability of the firm to transfer knowledge between projects (Elmquist & Le Masson, 2009).

Central mechanisms relating to reacting capabilities are, according to Verganti (1999), overlapped development activities and redundancies. The corresponding RVT elements include (v) *continuous and rapid experimentation to test assumptions* and (vi) *the development of alternative and overlapping prototypes* which take place throughout the whole duration of the FEI. Together, the continuous experimentation and solution iteration accelerate learning and reducing uncertainty through overlapping trial-and-error cycles. Furthermore (vii) *the development of alternative and overlapping business models* ensures to find the optimal approach for value creation, delivery, and capture early in the process. This early and continuous validation of information reduces the need for costly corrective actions at later stages (Verganti, 1997) with respect to the product/service as well as the business model.

This conceptualization of RVT provides a unique set of activities that extend prior FEI practices in order to realize planned flexibility.

2.2 | RVT and its performance relevance

While research on the relevance of the front-end phase of innovation processes is not scarce and has produced valuable knowledge, a number of issues remain to be explored. In particular, this includes the question of which activities actually take place and to what degree they need to be planned and formalized (Dziallas & Blind, 2019; Eling & Herstatt, 2017; Reid & de Brentani, 2004; Zhang et al., 2019). The relevance of this issue becomes clear when considering that decisions made at the front-end phase of innovation processes have been shown to have a considerable impact on the performance of the innovation process (Cooper & Kleinschmidt, 1986; Eling et al., 2014; Florén et al., 2018; Khurana & Rosenthal, 1998). The concept of RVT with its set of activities might provide an answer to this call for guidance in the FEI.

To link RVT with innovation performance and taking into consideration fuzziness as the major challenge of the FEI (Khurana & Rosenthal, 1998), we take an organizational information processing view. The lack of clarity in the FEI can be traced down to both external as well as internal uncertainty and equivocality (Daft & Lengel, 1986; Winkler et al., 2015). Equivocality is rooted in the complex nature of innovation processes (Salomo et al., 2007) while uncertainty emerges from the inherent need of organizations as social systems to process information (Mackenzie, 1984). Uncertainty or the lack of sufficient information necessary to perform a specific task (Galbraith, 1967; Souder et al., 1998) can stem, in the context of innovation projects, from competitive market environments, information asymmetries among departments, and from technological developments (Tushman & Nadler, 1978; Zhang et al., 2019). Equivocality, on the other hand, refers to the simultaneous existence of conflicting information about a situation in projects and the lack of clarity on the cause–effect relationships (Daft & Lengel, 1986). In the context at hand, equivocality can arise from unclear customer expectations, unclear supplier involvement, conflicting frames of reference of the departments involved in projects (Dougherty, 1992), and unexpected technological developments (Reid & de Brentani, 2004; Zhang et al., 2019). Therefore, information processing to systematically reduce uncertainty and equivocality over the course of innovation projects is assumed to be key to success.

Following organizational information processing theory, gathering, interpreting, and synthetizing information within organizations tend to follow specific models that allow for efficient processes and effective information processing. This happens mostly through the establishment of plans and standards that structure how an organization gathers and processes information (Tushman & Nadler, 1978). The capability to revisit existing and gather new knowledge in order to ensure the alignment of an emerging product or service concept with customer needs and expectations is of particular relevance at the FEI. In this context, RVT offers a way to establish such a model for information gathering and processing. Our reasoning behind the assumption of RVT as leading to higher performance of innovation projects rests on the following arguments:

2.2.1 | Quality of results

One of the main, if not the central, outcome of innovation projects in the front end of innovation is the development of a robust concept definition (Florén et al., 2018) that can be developed into a feasible product or service with clear profit potential (Dziallas & Blind, 2019; Florén et al., 2018; Kim & Wilemon, 2002a; Seidel, 2007; Verganti, 1999). As such, the key activities during this phase concern acquiring information to reduce uncertainty and processing of information to address equivocality. Together, these activities should lead to more robust concept definitions (Daft & Lengel, 1986; Verworn, 2009; Zhang et al., 2019).

Early *user integration through prototypes and other assessment techniques* expands the amount of information available on user needs and the need-solution fit, which contributes to the refinement of concepts in terms of quality (Bogers & Horst, 2014; Carlgren et al., 2016; Cui & Wu, 2017; Elsen et al., 2012; Hassi & Laakso, 2011; Highsmith, 2009; Thomke, 1998; von Hippel & Katz, 2002). *Repeated and overlapping iterations* of the concept alleviate ambiguity around concept goals, which should help increasing the probability of achieving quality goals (Bhattacharya et al., 1998). Last, the development of *alternative and overlapping prototypes as well as business models* builds a knowledge base on which efficient decision-making, in terms of the choice of the concept to pursue, can draw on. Over the course of an innovation project, this knowledge supports the generation of new opportunities not initially considered and facilitates taking into consideration, early in the process, further aspects of the business model that go beyond the product/service concept itself (BenMahmoud-Jouini & Midler, 2020; Cui & Wu, 2017; Highsmith, 2009; Ries, 2011; Savoia, 2019; Täuscher & Abdelkafi, 2017; Thomke, 1998; von Hippel & Katz, 2002). The RVT elements support learning, early in the project, about the actual customer needs, which concept caters best to their needs and technical requirements, and which business model to use for value creation, delivery, and capture, increasing the likelihood that projects following the RVT approach likely arrive at a robust high-quality product and business concept.

2.2.2 | Development time

Early user involvement contributes to rapidly examining and validating concepts and thereby reduces implementation time (Calantone et al., 2003; Huchzermeier & Loch, 2001). Similarly, the early procurement of information through *experimentation and prototyping* can contribute to anticipate problems further down the project, avoiding time delays (Roth et al., 2020; Tatikonda & Montoya-Weiss, 2001), and contributing to meeting project time goals. Communication and alignment between functional departments through the early *establishment of central assumptions* and *prototypes* helps establish a common understanding of and consensus on the concept and its implications, thus reducing uncertainty and avoiding lengthy implementation time (Kim & Wilemon, 2002b). Thus, the RVT elements accelerate the development of a robust concept early in the project by gathering information and feedback from both customers and internal stakeholders and by aligning all involved departments on the market, technological, service, and production-related matters already when the project is still in the FEI.

2.2.3 | Development costs

Overall, activities contributing to the exhaustiveness in the procurement of information on potential sources of uncertainty are vital to direct flexibility to the areas in which it is needed, avoiding high costs typically related to high levels of flexibility (Huchzermeier & Loch, 2001). Gathering *user-related information through prototypes* can contribute to save costs further down the project life cycle by establishing the solution-needs fit in the very early stage of conceptualization (Brown, 2008; Roth et al., 2020). Through *prototyping* and the early *estimation of implementation costs and commercial aspects*, uncertainties about product deliverables can be anticipated and addressed early on, avoiding costly changes in the downstream activities in the innovation process (Calantone et al., 2003; Cooper & Sommer, 2016; Liedtka, 2017; Roth et al., 2020). Thus, the RVT approach allows the project to achieve an early and validated freezing point for the concept that is not subject to costly change in later implementation stages of the project such as redefining product specifications or architecture due to overlooked manufacturing restrictions.

Following the presented arguments and the tenets of planned flexibility, we assume RVT to have a positive effect on innovation program performance (Jissink et al., 2019; Schultz et al., 2013). Organizations implementing and deploying the concept of RVT broadly across its innovation projects are thus assumed to cope better with reducing the uncertainty and equivocality inherent in this innovation phase resulting in its innovation outputs to be more likely to deliver superior quality on time and within budget.

Hypothesis 1 *The use intensity of an RVT approach at the front end of innovation processes has a positive impact on innovation program performance.*

2.3 | The RVT–performance relation: A contingency perspective

As noted earlier, past research on approaches implementing elements of planned flexibility was mainly analyzed in case studies and very particular contexts, but popular science postulates them to be universally effective to resolve the challenges of the FEI (Ries, 2011). Scholars have criticized such implied generalizations (Elsbach & Stigliani, 2018; Liedtka, 2015; Razzouk & Shute, 2012) and have particularly emphasized to take contingencies into account (Nakata & Hwang, 2020; Roth et al., 2020). This coincides with the central tenet of contingency theory (Emery & Trist, 1965; Scott, 1981) which highlights the role of and an adequate fit between organizational design and environmental factors for organizational performance. Organizational contingency theorists challenge the idea of the existence of a "one-best-way" of organizing and identify environmental uncertainty as a central factor in the choice of organizational design (Lawrence & Lorsch, 1967, Van de Ven et al., 2013). As technologies, markets, and the tasks organizations have to perform in them vary according to the environment they operate in, organizations and their subsystems need to adapt their internal structures in response to the characteristics of said environments in order to achieve their performance goals. (Lawrence & Lorsch, 1967, Scott, 1981). In the context of this study, investigating the relevance of RVT requires considering both the external and the internal environment of the organization.

The external environment in which FEI processes take place is often subject to rapid and unpredictable changes (Bourgeois & Eisenhardt, 1988; Dess & Beard, 1984). The situations brought on by these conditions have been grouped under the concept of turbulences (Calantone et al., 2003; Jaworski & Kohli, 1993; Li et al., 2020). A turbulent environment is understood "as one in which frequent and unpredictable market and/or technological advances accentuate risk and uncertainty in the strategic planning process" at the FEI (Calantone et al., 2003, p. 91). These conditions, then, influence the formulation of plans and forecasts (Morgan et al., 2019), as they may cause, for instance, sudden modification in consumer preferences (Glazer & Weiss, 1993; Homburg et al., 2017; Jaworski & Kohli, 1993) in the case of market turbulence, or the rapid obsolescence of technologies used when technological turbulence is involved (Li et al., 2020; Schultz et al., 2019). Seeing RVT as an uncertainty-reducing approach at the FEI, it is reasonable to assume variations in terms of the performance relevance of RVT dependent on the level of turbulence of the external environment causing these uncertainties.

An aspect internal to the organization that influences the relationship between FEI activities and innovation performance relates to the shared norms that guide both beliefs and social behavior in an organization (Moorman, 1995; Shane, 1995). Innovation activities are embedded in the specific cultural setting of the organization. Not the least due to their relative stability, these settings become a contingency to the performance of innovation activities (Atuahene-Gima & Ko, 2001; Calantone et al., 2003; Kleinschmidt et al., 2010). Past research on FEI practices has mostly not taken internal contingency factors into account (Nakata & Hwang, 2020), which creates the problem of limited generalizability of their effectiveness. Due to the uncertainty in the FEI and the general risk associated with innovation activities, the performance relevance of certain practices might also depend upon the organization's general willingness to take risk (Nakata & Hwang, 2020). As RVT aims to systematically reduce uncertainty and risk in the FEI, it is reasonable to assume that its efficacy might depend upon its fit to the organizational risk propensity. Furthermore, RVT facilitates rapid trial and error processes to learn fast, but organizations differ in their time orientation, that is, their preferred planning horizons and their adherence to those plans. Thus, RVT's performance relevance might also depend upon its fit to organizational time orientation.

2.3.1 | External environment

First, we suggest that the performance relevance of RVT will be dependent upon market turbulence. Innovation activities, aimed at achieving competitive advantage (Calantone et al., 2010; García-Manjón & Romero-Merino, 2012; Glazer & Weiss, 1993; Mahoney & Pandian, 1992), are inherently linked to the markets for which the outcomes of innovation development are intended (Atuahene-Gima, 2003; Atuahene-Gima & Ko, 2001). Instances of changing customer needs and expectations as well as dynamics in the competitor structures (Atuahene-Gima, 2003; Glazer and Weiss 1993; Homburg et al., 2017; Morgan et al., 2019) lead to varying degrees of market turbulence (Calantone et al., 2003; Morgan et al., 2019; Souder et al., 1998). With increasing market turbulence, markets are in a state of constant change, contributing to an uncertain state of information (Atuahene-Gima & Wei, 2011). Gathering and building on market information is conceptualized as a fundamental element of RVT. As such, in contexts of market turbulence, organizations might benefit even more from RVT: Product and market-related assumptions need to be explicitly defined and tested early and constantly in each project in order to anticipate and react timely to changes in the environment (Christensen & Bower, 1996), which RVT ensures. Testing these assumptions through experimentation enables validation and procurement of information that allows for continued refinement of the innovation goals (Jissink et al., 2019; Kaplan & Orlikowski, 2013; Nakata & Hwang, 2020; Urban et al., 1996). Development of early prototypes allows to visualize and communicate the features of the new product or service to customers and value chain partners, which contribute to the further establishment of the validity of project assumptions (BenMahmoud-Jouini & Midler, 2020; Menold et al., 2017; Thomke, 1998). Establishing repeated prototyping as a regular practice concerning products and business models allows to generate knowledge to counteract the inherent uncertainty of turbulent markets (Athuahene-Gima & Wei, 2011), react to changing conditions, and test varying aspects of potential business models related to the new product or service (BenMahmoud-Jouini & Midler, 2020), thus reducing equivocality.

In sum, with increased turbulence in the market, the relevance of timely and validated information for success increases. Consequently, securing such information through RVT is even more beneficial for innovation projects of organizations operating in turbulent environments. In contrast, stable markets entail less complex and dynamic situations with less uncertainty, leading to a reduced imperative for early and repeated information search (Atuahene-Gima & Wei, 2011; Palmer & Wiseman, 1999) and testing of market-related assumptions (Morgan et al., 2019).

Hypothesis 2 *The positive relationship between the use intensity of an RVT approach at the front end of innovation processes and innovation program performance will be stronger (weaker) with increasing (decreasing) market turbulence.*

Second, the performance relevance of RVT will also be dependent upon technology turbulence. Organizations differ in "the rate of change associated with new […] technologies" (Calantone et al., 2010, p. 1072) which they are confronted with. The emergence of new technologies often implies a constant search for information on technological changes and adjusting concepts to these changes in order to maintain competitive advantage (von Hippel & Tyre, 1995). For innovation projects, the risk of concept obsolescence increases with the frequency of technological developments (Calantone et al., 2003). In addition to this risk of obsolescence on the market side, dynamic technological environments can render existing knowledge structures obsolete (Tushman & Anderson, 1986). Gaining more robust technological knowledge through fast iterations and validation of prototypes as fundamental elements of RVT should become more valuable for innovation projects of organizations operating in contexts of technological turbulence. In order to react quickly to the described double risk of obsolescence, and to increase the speed-to-market, RVT allows for the development of multiple and overlapping design iterations in an innovation project. This increases the probability of incorporating state-of-the-art technology (Eisenhardt & Tabrizi, 1995; Moorman & Miner, 1998). Constantly revisiting technology-related assumptions and their early validation becomes increasingly relevant when technological conditions change frequently (Morgan et al., 2019; Song & Montoya-Weiss, 2001). Thus, we suggest that with increased technological turbulence, the ability to rapidly test and validate technological assumptions of concepts becomes more relevant for project success, and following the RVT approach will be even more beneficial for innovation programs of organizations in such environments.

Hypothesis 3 *The positive relationship between the use intensity of an RVT approach at the front end of innovation processes and innovation program performance will be stronger (weaker) with increasing (decreasing) technology turbulence.*

2.3.2 | Internal environment

Organizations vary with respect to their risk propensity. While some organizations seek risky business opportunities, others have developed a "play-it-safe" mentality with a strong proclivity for low-risk innovation activity (Antoncic & Hisrich, 2001; Das & Joshi, 2007; Shane, 1995). Innovation activities, and FEI activities, in particular, are inherently uncertain and thus, attitudes toward risk become a relevant facet of organizational culture (Elsbach & Stigliani, 2018; Khazanchi et al., 2007; Khurana & Rosenthal, 1998). One of the main sources of risk is the fear of making costly, suboptimal decisions (Mohan et al., 2017). The information collected in innovation projects through early experimentation and validation of concepts through prototyping allows for aligned, informed decision-making, contributing to the establishment of experimentation and repeated validity tests as legitimate practices under risk-averse conditions. Furthermore, the information made available through RVT will contribute to alleviate the uncertainty related to innovation projects. Following contingency theory (Emery & Trist, 1965; Scott, 1981), such an adequate fit between a risk-averse cultural setting and RVT as an approach to the front-end of innovation processes should result in improved innovation performance. In addition, RVT allows employees under risk-averse organizational cultures to seek more innovation activities: Early testing, creating visibility and ability to communicate about the innovation facets, and developing alternative business models at an early innovation stage, makes innovation opportunities more tangible and creates an experience of better-controlled risks (Bogers & Horst, 2014; Mu et al., 2009; Sarooghi et al., 2015). As risk-averse organizations have a higher need for information in order to reduce uncertainty than risk-affine organizations (Antoncic & Hisrich, 2001), RVT will allow even risk-averse organizations to explore and realize more innovative opportunities (Elsbach & Stigliani, 2018; Mu et al., 2009), thus making the performance relevance of RVT for innovation projects likely to be greater for such risk-averse organizations as opposed to their risk-affine peers.

Hypothesis 4 *The positive relationship between the use intensity of an RVT approach at the front end of innovation processes and innovation program performance will be stronger (weaker) with increasing (decreasing) levels of organizational risk avoidance.*

Temporal orientation constitutes a further relevant facet of organizational culture (Ofori-Dankwa & Julian, 2001; Tang et al., 2020). It refers to the attitudes of the organization toward time and the belief of the members of an organization of being able to influence, through their actions, the long-term future of the organization (Ruvio et al., 2014; Tang et al., 2020). Recognizing time pressure or the lack thereof may be shaped by different factors such as stock market listing and resulting demands for quarterly reports, product life-cycle dynamics, or investment horizons (Doyle & Hooley, 1992; Laverty, 1996; Lin et al., 2019). Hence, organizational culture varies with respect to its time perspectives and how diligently organizations assess long-term consequences before taking decisions (Ruvio et al., 2014; Tang et al., 2020).

Long-term orientation as a specific configuration of temporal orientation builds on the beliefs on the plasticity of the distant future through concrete actions of the firm (Ruvio et al., 2014). Consequently, high value is attributed to developing and adhering to thorough plans, with the intention of impact on distant future rather than short-term performance (Laverty, 1996; Lin et al., 2019). In contrast, RVT aims for the early and constant generation of information over thorough deliberation and assessment of all potential options. Quick and short-term learning in projects might not fit well with a conservative organizational culture valuing long-term perspectives (Chandy & Tellis, 1998). Repeated experimentation within each project based on incomplete information or rough prototypes contrasts with the preference for meticulous planning, comprehensive search, and thorough deliberation of long-term consequences. Equivocal sources of information stemming from experimenting with different prototypes or overlapping business models in projects are at odds with the equivocality-avoidant long-term orientation (Laverty, 1996; Yadav et al., 2007). Furthermore, the nature of RVT's iterative, experimental activities can be perceived as disturbing routines and thus leading to delays in activities, which may be in conflict with productivity norms (Elsbach & Stigliani, 2018). Such a misfit of culture and RVT is likely to result in limited acceptance of such an approach for innovation projects. Even if employed, the approach may be executed with limited enthusiasm, or its results will lack legitimacy and are barely used for subsequent decisions, significantly reducing its value for innovation (Elsbach & Stigliani, 2018; Rauth et al., 2014). Hence, long-term time orientation as an organizational culture facet is suggested to weaken the performance relevance of RVT.

Hypothesis 5 *The positive relationship between the use intensity of an RVT approach at the front-end of innovation development and innovation program performance will be weaker (stronger) in a more (less) long-term-oriented organizational culture.*

3 | METHODS

3.1 | Data collection and sample

To test the proposed hypotheses, depicted in Figure 1, we collected data from a cross-sectional sample of firms located in Germany and Austria in 2016 and 2017 over a period of 18 months. Executives and senior managers were contacted by email and phone to inform them about the purpose of the study, which covered different areas of innovation management. The managers expressing their commitment to participate in the study with their organizations nominated a set of employees responsible for innovation tasks. A separate subsection of the survey, pertaining to the firm's innovation program performance, was sent to a manager at the executive level, a priori identified as possessing a competent perspective on the innovation portfolio of the corresponding firm. All nominated employees independently received an invitation to an electronic survey and a reminder after 2 weeks in case they had not completed the survey so far. In total, our final sample included responses from 1022 informants in 129 organizations (on average 7.92 informants per organization). We summarize the sample characteristics in Table 2 on firm

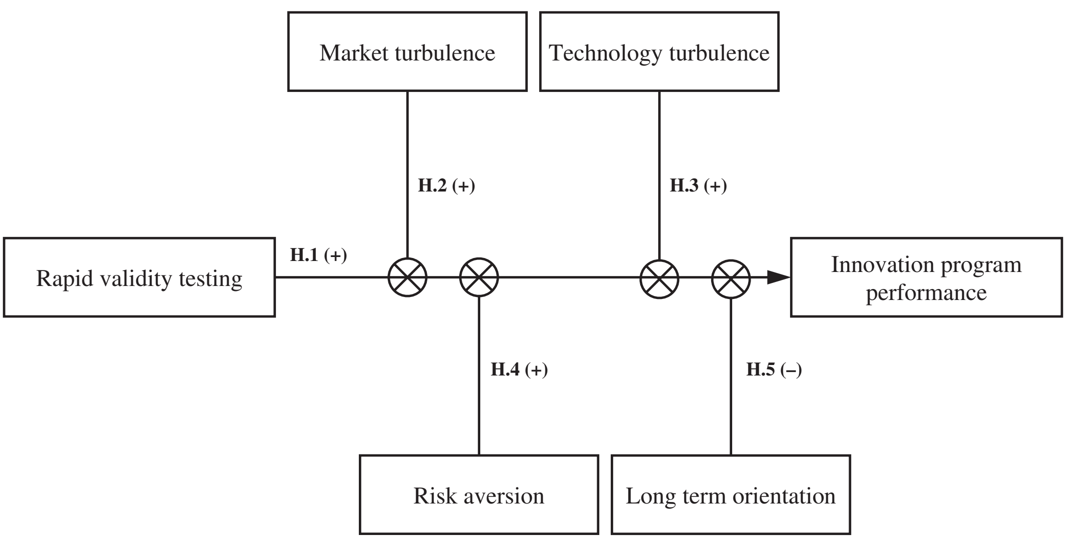

FIGURE 1 Main model

TABLE 2 Sample characteristics

Firm size (FTE)	No.	Percentage	Firm size (revenue; EUR)	No.	Percentage
Less than 100 FTE	31	24.0%	Less than 50 Mio.	35	27.1%
101–250	35	27.1%	51–250 Mio.	38	29.5%
251–500	21	16.3%	251–500 Mio.	13	10.1%
More than 500 FTE	42	32.6%	more than 500 Mio.	26	20.2%
n.a.	0	0.0%	n.a.	17	13.2%
Industry				**No.**	**Percentage**
Manufacturing goods	(chemicals, food, plastics, glass, etc.)			52	40.3%
Industrial engineering	(machine construction, plant engineering, etc.)			18	14.0%
Utilities	(energy, water, recycling)			42	32.6%
Others	(information technology, industrial research)			17	13.2%
No. informants	**No.**	**Percentage**	**Job areas (informants)**	**No.**	**Percentage**
2–3 informants	21	16.3%	R&D/Innovation management	219	21.4%
4–5	18	14.0%	Marketing/Sales	158	15.5%
6–7	37	28.7%	Leadership/Strategy	146	14.3%
8–9	22	17.1%	Production	86	8.4%
more than 10 informants	31	24.0%	Product management	79	7.7%
			Project management	44	4.3%
Hierarchical position (informants)	**No.**	**Percentage**	Quality management	20	2.0%
Upper management	162	15.9%	Purchasing	20	2.0%
Middle management	220	21.5%	IT	17	1.7%
Lower management/team leader	340	33.3%	Controlling/accounting	16	1.6%
Employee	256	25.0%	Human resources	11	1.1%
n.a.	44	4.3%	others	101	9.9%
			n.a.	105	10.3%
Total number of informants		1022			
Total number of firms		129	Average no. informants by the firm		7,92

and informant levels. In order to assess nonresponse bias, we compare early (first quantile) and late respondents (last quantile) (Armstrong & Overton, 1977). None of the *t*-tests performed for the main model variables result in a significant difference between the two groups, which suggests that non-response bias is unlikely to be an issue.

3.2 | Measures and scale properties

We use multi-item measures and five-point Likert-type scales to capture all main constructs. Where possible, we apply established indicators applied in prior research, and the development of new scales closely follows the corresponding literature. In order to ensure content validity, the items were pretested with representatives from 20 organizations in two consecutive rounds, resulting in minor wording adaptions based on their feedback.

Innovation program performance is assessed with three items adapted from Gemünden et al. (2007) that capture the innovation execution success at the portfolio level within the previous 3 years following the traditional triple constraints: achieving the intended quality objectives, being completed on time, and being within their budget restrictions.

RVT is captured with seven items encompassing the full conceptual domain of RVT. We draw on the conceptual work of Verganti (1999) and the corresponding literature on particular practices described in design thinking, lean innovation, pretotyping, and prototyping for the development of the items. Our operationalization of RVT allows us to assess the intensity of use of such an approach of planned flexibility to cope with uncertainty and ambiguity. Elements, items, and the supporting literature are summarized in Table 3.

Market turbulence and technology turbulence are assessed with five and four items correspondingly, adapted from

TABLE 3 Rapid validity testing scale elements and supporting research

RVT items	RVT labels	Supporting literature (selected)
When carrying out innovation activities, we form central assumptions at an early stage, which we then test and refine.	Problem framing	Riess (2011); Carlgren et al. (2016); Cui and Wu (2017); Savoia (2019)
We continuously experiment during the product/service development phase in order to test our assumptions thoroughly.	Prototyping as test	Riess (2011); Bogers and Horst (2014); Carlgren et al. (2016); Cui and Wu (2017); Savoia (2019)
We already begin to develop prototypes during an early development phase in order to visualize, communicate, and assess our concepts.	Prototyping as communication	Riess (2011); Bogers and Horst (2014); Carlgren et al. (2016); Cui and Wu (2017); Savoia (2019)
We carry out systematic prototype tests, for example, systematic customer survey and customer observation.	User integration	Riess (2011); Bogers and Horst (2014); Carlgren et al. (2016); Cui and Wu (2017); Savoia (2019)
Over the course of developing the product/service, we produce several prototypes from mock-ups through to functional models.	Product iteration	Carlgren et al. (2016); Cui and Wu (2017); Savoia (2019); Bogers and Horst (2014)
Using prototypes, we already attempt to estimate market potential as well as the production costs and pricing scope of our new products/services.	Commercial learning	Verganti (1997, 1999)
We experiment with different business models, for example, developing alternative business cases.	Business model iteration	Ries (2011)

Venkatraman (1989) and Calantone et al. (2003) that capture whether the organizational environment is characterized by rapidly changing customer requirements, fast shifts in the competitive landscape, and frequent technological breakthroughs.

Risk aversion of the organization is assessed with three items following Jaworski and Kohli (1993) that capture the organization's tendency to adopt a play-it-safe and "wait-and-see" posture when it comes to innovation activities and decisions.

Long-term orientation captured with three items adopted from Ruvio et al. (2014) the organization's tendency to take a long-term perspective as opposed to only considering short-term profits in decision-making about innovation activities.

The survey includes several control variables. Literature provides strong evidence for the success of innovation activities to be dependent upon the level of formal control (Cooper, 1990; Schultz et al., 2013). Therefore, we include innovation process formality (the degree to which all innovation activities of the firm follow clearly defined stages and decision points) with four items from Schultz et al. (2019) and project management control (the degree to which all projects have clear goals that are closely monitored) with four items from Schultz et al. (2013). Dummy variables represent industry differences (goods manufacturer, industrial engineering, utilities, and a residual group of other industries) as innovation practices and their effectiveness might vary by industry (Morgan et al., 2019). Furthermore, the number of employees is used as a proxy for organization size, as it may influence the levels of formalization (Atuahene-Gima et al., 2005; Damanpour, 1996; Hall et al., 1967; Schultz et al., 2019). By recoding the absolute size variable into six categories, we avoid biases caused by extreme outliers.

Common method variance issues are addressed by following recent recommendations (Chang et al., 2010; Kline et al., 2000; Podsakoff et al., 2003). Respondents were informed about the confidentiality of their responses and asked to answer honestly. Fact-based items reduce biases caused by social desirability and anchor effects. Furthermore, respondents were asked about aspects of innovation management not related to the investigated concepts and rated a set of other innovation outcomes, which helps covering the actual focus of this study. This makes it unlikely that respondents bias the results with their theories-in-use. Ex post, Harman's single factor test including all items of the eight main model variables is applied. Eight factors with eigenvalues >1 are extracted, which together explained 80.4% of the variance, whereas the largest factor accounts for only 20.9%. Thus, common method bias is unlikely to be present in the used data set.

With the phenomenon and constructs investigated in this research being located at the organizational level of analysis, the variables, which were assessed by several informants within each organization, are aggregated on the organizational level by calculating the mean across the individual responses. Therefore, we apply the referent-shift consensus composition model (Chan, 1998). The items are phrased in such a way that informants did not assess their activities and perceptions but those of their organization as a whole by shifting the referent of the content in the items from the self to the organization. Specifying the organization as the referent rather than the individual is crucial, as the referent shift ensures that the practices in the entire organization are assessed, even if the individual does not apply the investigated practices as opposed to most others in the organization.

Within-group consensus is used to justify the aggregation of the individuals' collective perceptions to represent the construct score of the higher organizational level. Statistically, this is assessed with the intraclass correlation coefficient ICC (1, *k*) informing about the interrater reliability and agreement (LeBreton & Senter, 2008; Shrout & Fleiss, 1979). The values ranged between 0.69 and 0.92 and indicate high interrater agreement for all constructs. The value for long-term orientation (0.51) also indicates sufficient, but lower within-group consensus compared with the other constructs. This culture facet appears in some cases to be perceived with some variation. However, the aggregation is still valid as the overall score indicates the diffusion of the long-term orientation in the organization.

To test the scale properties, we conduct further tests to assess their validity and reliability. Cronbach's alpha coefficients are all >0.77 for all multi-item measures, supporting their internal consistency (Hair et al., 2006). Principal component analysis (varimax rotation) extracts only one factor with an eigenvalue >1 for each construct and loadings >0.72 for all items, which demonstrates unidimensionality (Ahire & Devaraj, 2001). Confirmatory factor analysis including all multi-item measures is applied to assess convergent validity. All factor loadings were >0.50 and significant ($p < 0.001$). The average variance extracted of all variables is >0.54, and the composite reliability values are >0.70. Discriminant validity is demonstrated by the square root of the average variance extracted of all variables being larger than their correlations with any other construct (Fornell & Larcker, 1981). The global fit indices are also within the recommended boundaries (Hair et al., 2006). For the model including all predictor variables, the comparative fit index is 0.913, the root mean square error of approximation is 0.082, and the χ^2/d.f. ratio is 1.854. When adding the dependent variable, the model also shows acceptable fit: the comparative fit index was 0.893, the root mean square error of approximation is 0.085, and the χ^2/d.f. ratio is 1.916. Means, standard deviations, correlations, Cronbach's alpha, ICC (1, *k*), and average variance extracted are summarized in Table 4. The scales are reported in the Appendix Table A1.

4 | RESULTS

The hypotheses are tested using ordinary least-square regression analysis. The results are summarized in Table 5. The baseline model with the covariates (Model 1) shows that risk aversion ($\beta = -0.20$, $p < 0.05$) has a negative impact on innovation program performance and project management control positively affects performance ($\beta = 0.39$, $p < 0.01$).

When adding RVT (Model 2), the additional predictor has a significant positive effect on innovation program performance ($\beta = 0.28$, $p < 0.05$), in support of Hypothesis 1. In total, the predictors explain 17% of the variance in innovation program performance, which constitutes an increase of 3% compared to the baseline model.

To test the remaining moderation hypotheses, we mean-center the moderator and independent variables to facilitate the interpretation of coefficients (Aiken & West, 1991). Table 5 shows the unstandardized coefficients of the stepwise regression, with innovation program performance as the dependent variable and one moderation effect per model. The results of Model 3 show that market turbulence does not moderate the relationship between RVT and innovation program performance ($\beta = 0.01$, p = n.s.). This leads us to reject Hypothesis 2. Model 4 assesses the moderating effect of the technological turbulence of the organization's environment. The positive performance impact of RVT is strengthened when technological turbulence increased ($\beta = 0.24$, $p < 0.01$), which lends support to Hypothesis 3. The model including the moderator increases the variance explained by 5% compared with the main model (Model 2). In Model 5, an increase in the organization's risk-aversion also strengthens the positive performance impact of RVT ($\beta = 0.21$, $p < 0.05$), in support of Hypothesis 4. The explained variance in the dependent variable increases by 4% when the moderation term is added to the model. Model 6 shows that a stronger long-term orientation hampers the positive performance impact of RVT ($\beta = -0.31$, $p < 0.001$), supporting Hypothesis 5. The moderated model explains 8% of additional variance in the dependent variable compared with the main model.

The plots of simple slope analyses are depicted in Figure 2 and illustrate the strength of RVT's effect on innovation program performance for low (mean minus one standard deviation) and high (mean plus one standard deviation) levels of all investigated moderators. In addition, we assess the significance of each simple slope (Aiken & West, 1991). With respect to the moderator market turbulence, the gradient for low (0.20, $t = 1.12$; $p = 0.27$) and for high (0.23, $t = 1.39$; $p = 0.17$) levels of market turbulence is not significant. For technology turbulence, the gradient is only significant for high levels (0.53, $t = 3.36$; $p = 0.001$) but not for low levels (–0.06, $t = -0.39$; $p = 0.70$). Similarly, the gradient for high levels of risk aversion is significant (0.48, $t = 3.06$; $p = 0.003$) but not for low levels (0.09, $t = 0.77$; $p = 0.45$). The gradient for low levels of long-term orientation is significant (0.87, $t = 3.99$; $p < 0.001$) but not for high levels (–0.22, $t = -1.35$; $p = 0.18$).

5 | DISCUSSION

For organizations to cope with the uncertainties and equivocality in the FEI, scholars have suggested iterative learning and development in form of approaches like design thinking, lean innovation, pretotyping, and prototyping. Despite their popularity in practice, these approaches subsume different

TABLE 4 Mean, standard deviations, and correlation matrix[a]

	Mean	SD	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	ICC (1, *k*)	AVE
1. Industry dummy (utility)	(—)	(—)	(—)												(—)	(—)
2. Industry dummy (manufacturing)	(—)	(—)	(—)	(—)											(—)	(—)
3. Industry dummy (engineering)	(—)	(—)	(—)	(—)	(—)										(—)	(—)
4. Firm size (FTE)	3.88	1.42	–0.08	0.20*	–0.04	(—)									(—)	(—)
5. Market turbulence	3.01	0.49	0.55***	–0.41***	–0.27**	–0.04	*(0.79)*								0.69	0.54
6. Technology turbulence	2.72	0.57	–0.02	–0.23**	0.04	0.09	0.45***	*(0.88)*							0.76	0.65
7. Risk aversion	3.14	0.66	0.30***	–0.12	–0.07	0.18*	0.11	–0.19*	*(0.91)*						0.74	0.77
8. Long-term orientation	3.60	0.46	0.31***	–0.15	–0.16	–0.10	0.14	–0.07	–0.14	*(0.77)*					0.51	0.56
9. Innovation process formality	2.64	1.27	–0.63***	0.60***	0.09	0.39***	–0.43***	–0.11	0.00	–0.13	*(0.98)*				0.92	0.94
10. Project management control	2.66	0.75	–0.44***	0.46***	0.09	0.34***	–0.40***	–0.14	–0.08	–0.01	0.76***	*(0.94)*			0.79	0.87
11. Rapid validity testing	2.88	0.72	–0.58***	0.48***	0.19*	0.26**	–0.32***	0.20*	–0.31***	–0.16	0.64***	0.62***	*(0.93)*		0.79	0.70
12. Innovation program performance	3.12	0.56	–0.01	0.05	0.00	–0.05	–0.12	–0.15	–0.20*	0.14	0.04	0.22*	0.18*	*(0.81)*	0.64	0.87

Note: $n = 129$.

[a]S.D., standard deviation. Cronbach's alpha was reported along the diagonal (in italics). ICC (1, *k*) intra-class correlation coefficient. AVE average variance extracted.

$^{*}p < 0.05$,; $^{**}p < 0.01$,; $^{***}p < 0.001$ (two-tailed).

(—) is meant to reflect that there were no mean standard deviations and cronbach's alpha scores to report, due to the fact that these were binary values and single item constructs.

TABLE 5 Effects on innovation program performance[a]

Dependent variable: Innovation program performance	Model 1				Model 2				Model 3				Model 4				Model 5				Model 6			
Variables	β	B	S.E.	p	β	B	S.E.	p	β	B	S.E.	p	β	B	S.E.	p	β	B	S.E.	p	β	B	S.E.	p
Intercept	(—)***	3.42	0.73	0.000	(—)***	3.08	0.74	0.000	(—)***	3.10	0.77	0.000	(—)***	2.94	0.72	0.000	(—)***	2.80	0.74	0.000	(—)***	2.68	0.72	0.000
Industry dummy (utility)	0.07	0.09	0.20	0.660	0.06	0.07	0.19	0.714	0.07	0.08	0.20	0.700	0.15	0.17	0.19	0.364	0.14	0.17	0.19	0.393	0.05	0.06	0.18	0.732
Industry dummy (manufacturing)	–0.02	–0.02	0.18	0.904	–0.11	–0.12	0.18	0.503	–0.11	–0.12	0.18	0.503	–0.09	–0.10	0.18	0.581	–0.04	–0.05	0.18	0.780	–0.07	–0.08	0.17	0.658
Industry dummy (engineering)	0.00	–0.01	0.20	0.972	–0.06	–0.10	0.20	0.610	–0.06	–0.10	0.20	0.614	–0.07	–0.11	0.19	0.568	–0.03	–0.05	0.20	0.815	–0.08	–0.12	0.19	0.517
Firm size (FTE)	–0.04	–0.02	0.04	0.675	–0.05	–0.02	0.04	0.635	–0.05	–0.02	0.04	0.633	–0.06	–0.03	0.04	0.503	–0.04	–0.01	0.04	0.698	–0.05	–0.02	0.04	0.591
Market turbulence	–0.02	–0.02	0.15	0.900	.000	0.00	0.15	0.991	–0.01	–0.01	0.16	0.957	–0.11	–0.12	0.15	0.415	–0.04	–0.04	0.14	0.775	0.00	0.00	0.14	0.973
Technology turbulence	–0.14	–0.14	0.11	0.203	–0.23	–0.23	0.12	0.055	–0.23	–0.23	0.12	0.058	–0.16	–0.16	0.12	0.179	–0.18	–0.18	0.12	0.138	–0.21	–0.21	0.11	0.071
Risk aversion	–0.20*	–0.17	0.09	0.048	–0.15	–0.13	0.09	0.149	–0.15	–0.13	0.09	0.149	–0.08	–0.07	0.09	0.420	–0.11	–0.09	0.09	0.285	–0.12	–0.10	0.08	0.212
Long-term orientation	0.05	0.06	0.12	0.626	0.06	0.08	0.11	0.511	0.06	0.07	0.12	0.522	0.07	0.09	0.11	0.436	0.06	0.08	0.11	0.495	0.13	0.16	0.11	0.151
Innovation process formality	–0.19	–0.09	0.08	0.256	–0.26	–0.11	0.08	0.136	–0.25	–0.11	0.08	0.138	–0.20	–0.09	0.07	0.234	–0.33	–0.15	0.08	0.055	–0.08	–0.04	0.08	0.637
Project management control	0.38**	0.28	0.10	0.007	0.29*	0.22	0.11	0.041	0.29*	0.22	0.11	0.041	0.26	0.19	0.10	0.067	0.28*	0.21	0.100	0.043	0.14	0.11	0.11	0.314
Rapid validity testing					0.28*	0.22	0.11	.049	0.28	0.22	0.11	.052	0.31*	0.24	0.11	0.028	0.37*	0.28	0.11	0.012	0.29*	0.22	0.10	0.034
Market turbulence × Rapid validity testing									0.01	0.02	0.13	0.902												
Technology turbulence × Rapid validity testing													0.24**	0.29	0.11	0.008								
Risk aversion × Rapid validity testing																	0.21*	0.19	0.08	0.023				
Long-term orientation × Rapid validity testing																					–0.31***	–0.45	0.13	0.001
R^2	0.14				0.17				0.17				0.22				0.21				0.25			
Adj. R^2	0.07				0.10				0.09				0.14				0.13				0.17			
ΔR^2	0.14				0.03				0.00				0.05				0.04				0.08			
F	2.00*				2.22*				2.02*				2.75**				2.55**				3.22***			
ΔF	2.00*				3.94*				0.02				7.23**				5.28*				11.89***			

Note: $n = 129$.

[a] β, standardized beta coefficient; B, unstandardized beta coefficient; S.E., standard error; p, level of significance; (Adj.) R^2, (adjusted) explained variance.

*$p < 0.05$,; **$p < 0.01$,; ***$p < 0.001$ (two-tailed).

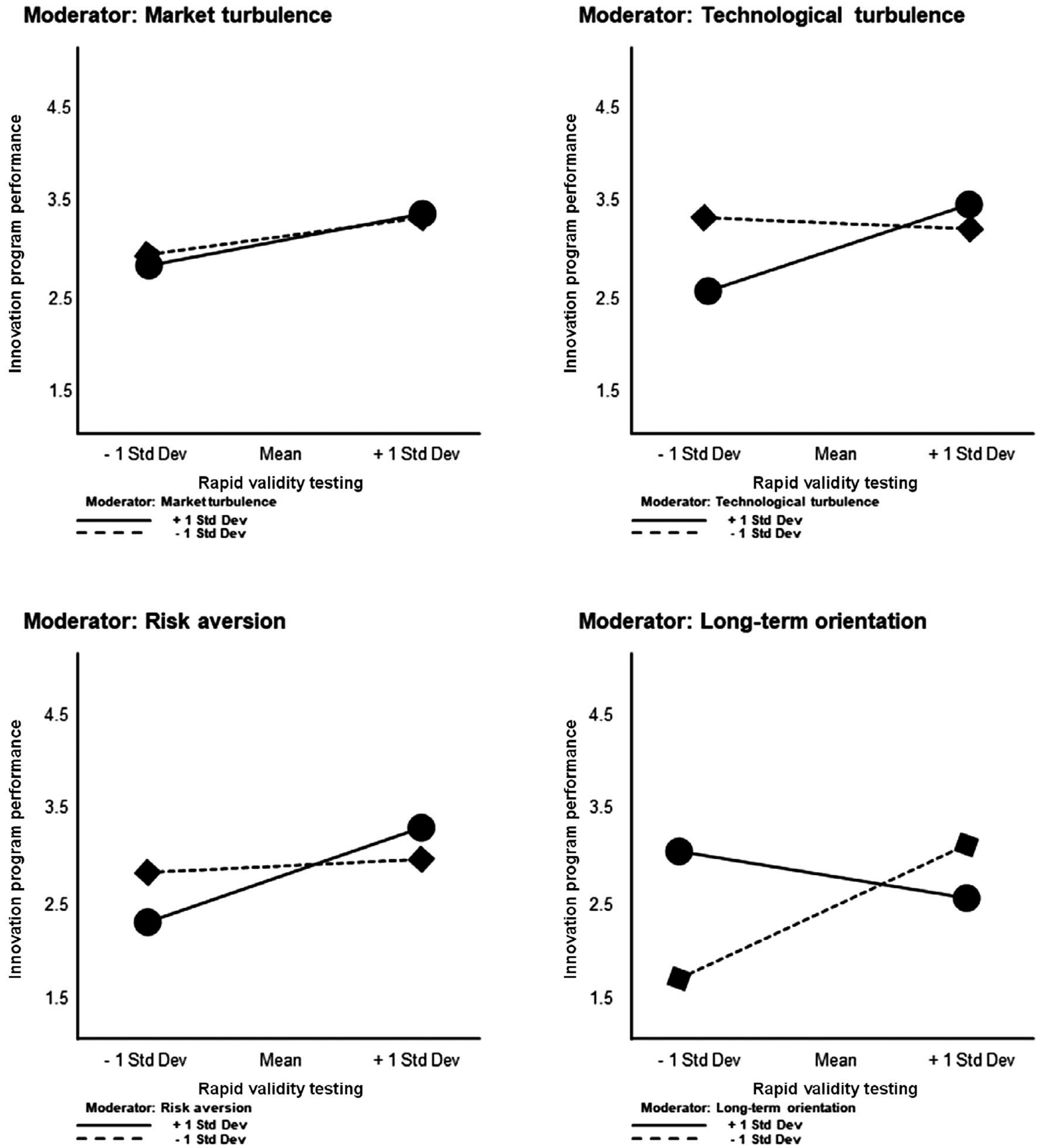

FIGURE 2 Plots of moderation effects

activities under their umbrella terms and might lack certain elements necessary to enact planned flexibility in the FEI. Furthermore, there is still a lack of empirical evidence about the performance relevance of these integrated approaches, mostly relying on normative assumptions or anecdotal evidence (Elsbach & Stigliani, 2018; Liedtka, 2015; Razzouk & Shute, 2012). Together, this makes it difficult to determine which activities enable planned flexibility in the FEI and if investing in building this capability actually pays off. With this research, we aim to contribute to this stream of the innovation literature by conceptualizing and thereby building a better understanding of what elements constitute a comprehensive approach enabling planned flexibility and by providing empirical evidence of its relevance for innovation performance.

Motivated by this initial situation, we set out in this study to conceptualize an approach referred to as RVT based on considerations of Verganti's (1999) concept of planned flexibility. Its comprehensive set of seven defining elements aggregate what is proposed by the practice-oriented approaches mentioned above and extends it by introducing commercial learning, that is, the early evaluation of market potential, pricing, and evaluation costs as a further activity at the FEI. We thereby contribute to the FEI literature by providing a comprehensive set of activities to balance anticipation and reaction capabilities and thus enable planned flexibility. We introduce a concept that includes and goes beyond what has been part of existing approaches. As such, the RVT concept shows, which elements, enabling rapid learning and development in the FEI, are currently not present in popular approaches and thereby highlights areas for improvement for future revisions of these approaches. Building on the framework of planned flexibility to determine its relevant elements, RVT also offers a conceptual fundament, as opposed to the normative argumentation often observed in prior approaches such as in the heralded "pretotyping manifestos" (Savoia, 2019), design thinking (Brown, 2008), and lean innovation (Blank, 2013).

We further hypothesize that organizations implementing RVT will achieve higher innovation program performance, that is, that their innovation projects are more likely to achieve their goals on time within budget. The elements of RVT facilitate iterative gathering and the use of information collected from multiple stakeholders to arrive at clear and high-quality concept definitions, alignment between departments to reduce delays, and anticipate potential challenges to avoid costly changes later in the innovation process or product life cycle. Drawing on multirespondent data collected from a cross-sectional sample of 129 organizations, we find support for this proposed positive relationship. This finding is an important extension of the FEI literature: With few exceptions, for example (Roth et al., 2020), prior empirical evidence of the effectiveness of popular approaches such as design thinking, pretotyping, and lean innovation stems from anecdotes or case-study data. Using a quantitative study design, this research shows that organizations implementing RVT as an overarching concept including the aspects covered by prior approaches, also report higher levels of performance across their innovation program. Thus, we provide stronger empirical evidence of the performance relevance of approaches facilitating planned flexibility in the FEI.

Following prior recommendations to take contingency factors into consideration when studying such approaches to learn more about the generalizability of their effectiveness (Nakata & Hwang, 2020), we also investigated the role of relevant environmental factors so far neglected. The results are encouraging and suggest future research on the contingent effectiveness of different FEI approaches enabling planned flexibility. Considering the role of the external environment as an important driver of uncertainty and equivocality in the FEI, we examined the role of technological and market turbulence. A fast-changing technology landscape implies the emergence of different options for technologies involved in the development and use of new products or service concepts. In these situations, quick testing of assumed opportunities becomes more relevant, to sort out the most promising alternatives (Thomke, 1998). Hence, RVT allows to reduce ambiguity and to select technologies, which receive better response from the market (Calantone et al., 2003). The data supported our assumption that organizations confronted with higher technological turbulence benefit more from RVT. Thereby, the concept of RVT relates to the literature about technological breakthroughs that highlighted the threats of detrimental technology path dependencies of organizations (Vergne & Durand, 2010) and the increased uncertainties coming along with highly innovative technologies that can cause organizations to ignore opportunities despite their upside potentials (Jalonen, 2012). Scholars suggest organizations to develop abilities to engage in iterative learning cycles (Buganza et al., 2009), to probe early user reaction to radical innovation (Lynn et al., 1996), and deliberately setting out to test alternative and new business models (Hu, 2014). RVT integrates and complements these proposed abilities and can be seen as a comprehensive approach that increases the chances to cope with uncertainties inherent to technological dynamics and to leverage the innovation upsides of such dynamics to a better degree.

We assumed RVT to be more relevant for firms in turbulent markets, as it facilitates the reduction of uncertainty regarding customer needs, needs-solution fit, competitive advantage, and optimal business model. Contrary to expectations, the data did not support the supposed moderation effect. Rather, RVT seems to be positively related to performance independent of market turbulence levels. One reason could lie in the assumption that the positive effect of implementation of RVT is independent of market turbulence and thus organizations in stable market environments can equally profit from it. A further explanation for the lack of support for this hypothesis can stem from the applied performance measure captures the internal aspect of performance, and that the moderation effect might only become visible with respect to market-related performance aspects such as customer satisfaction, revenue growth, and competitive advantage. It might be that organizations in highly turbulent markets have no higher immanent benefit from clearer concept definitions and adhering to time and budget constraints as opposed to their peers in less turbulent market environments. However, they could obtain more benefit from RVT in later stages when the product or service launches by providing solutions and business models that fit better with customer needs and the competitive landscape at this very moment in the rapidly changing market.

With respect to internal factors, we find support that organizations with a rather risk-averse posture benefit more from RVT than their risk-affine peers. Thus, organizations characterized by a culture, which tries to avoid risk as much as possible, could overcome their risk of inertia by engaging in RVT. In line with the values of these organizations, RVT offers a path to reduce risks and uncertainty to an acceptable level by introducing a planned approach to experimentation at the FEI. Without quick systematic tests of assumptions, seeking early market input, and exploring alternative business models offered by RVT, risk-averse organizations will unlikely perform well in innovation because no approach reduces uncertainty inherent in innovation that fits their play-it-safe mentality (Rodríguez et al., 2008).

Furthermore, we hypothesize that RVT with its constant information flows and iterations does not fit well organizations with a long-term orientation, which emphasizes meticulous planning ahead for longer periods and adhering to those plans. The data support this assumption, and it seems that RVT outputs lack legitimacy in such cultural settings and thereby fail to produce the intended performance impact. Whereas prior research has neglected such internal contingency factors when investigating the relevance of different approaches to master the challenges of the FEI, this study demonstrates that cultural aspects play an important role.

6 | MANAGERIAL IMPLICATIONS

This research provides several implications for practitioners. First, we provide evidence that organizations benefit from the broad implementation of RVT in their FEI activities. Particularly, organizations in industries characterized by high technological turbulence, in which technologies change constantly and are characterized by frequent technological breakthroughs that even challenge established business models in the industry, investments into building RVT capabilities seem promising to ensure that innovation activities deliver as promised on time within budget. Anticipating customer's needs and expectations through early integration and the use of prototypes and other interaction techniques helps ensure need-solution fit and reduces implementation time by rapidly procuring information to examine and validate concepts, potentially preventing costly changes further along the implementation process. Reacting to changing and/or unexpected customer feedback by rapidly iterating prototypes support in reducing ambiguity around the features of the concept, contributing to increased concept quality. Problems can be anticipated through experimentation and prototyping, which can contribute to avoiding delays in execution time. Keeping within project time frames is also supported by results of experiments and prototypes, inasmuch that they can be used to generate a common understanding of the concept under development, ensuring alignment among internal stakeholders. RVT activities also involve business modeling and commercial learning, which prior popular approaches have barely, or not at all, considered. Managers are recommended to include the architecture of value creation, delivery, and capture as well as the early evaluation of market potential, pricing, and implementation costs early on in the FEI popular in practice offers a significant further activity. Integrating this enriches the understanding of feasibility and potential returns of the ideas developed and provides a further argument for managers to consider in FEI implementation decisions.

In organizations that have not applied any rapid learning and development principles before, introducing popular methods such as lean innovation or design thinking is certainly a good starting point. Therefore, managers can make use of the popularity of said approaches to get investing decision-makers and applying employees to buy in. However, since the defining elements included in popular practices are broader than those of RVT, managers need to ensure that they complement them with further practices. This also applies to organizations in which one of the discussed approaches is already established. For instance, design thinking should be complemented by practices that support the early evaluation of market potential and implementation costs, assess technological aspects, and iterate on business model designs. Otherwise, FEI activities remain limited to ensuring the customer needs-solution fit through customer integration, experimentation, and prototyping but neglect the technical, economic, and commercial aspects of rapid concept generation and validation. Rather than focusing on particular popular approaches, managers are recommended to implement practices that together cover all RVT elements when designing the FEI to achieve maximum performance impact.

RVT practices are of particular value for organizations with a stronger posture toward risk avoidance. Especially managers in large established organizations often find themselves in a context which tends to rely more on well-known routines and technologies rather than entrepreneurial opportunity seeking and new technology exploration, and thereby struggle to realize innovation and renewal (Ganco & Agarwal, 2009; O'Connor & DeMartino, 2006; Sandberg & Aarikka-Stenroos, 2014). This should speak especially to managers in risk-averse sectors like utilities (Kearney et al., 2009; Tremml, 2019), including firms in the electricity, water, sewage service, and natural gas business. RVT can be seen and should be framed as an approach in the FEI to identify and actually overcome such problems: Applying RVT as a concept to reflect on the firm's position toward risk offers a valuable opportunity to assess which of its elements can be strategically deployed to reduce uncertainty and thus address risk-avoidant attitudes in innovation programs. RVT, as a planned and controllable approach to innovation that focuses on the rapid reduction of uncertainty and risk inherent in innovation initiatives, can contribute to alleviate constraints like tighter controls for resource utilization faced by managers in risk-averse industries (Kearney et al., 2009). The iterative process with multiple prototypes in search of the optimal technological approach together with the integration of customers to test usability and acceptance ensure that stable, validated concepts are available once the decision for further investments into downstream activities is made, thus providing managers with validated evidence on the feasibility of the newly developed concepts for further implementation. The early consideration and validation of commercial as well as business model aspects allow for better-informed decisions about whether to pursue FEI outcomes further. Thus, RVT particularly fits the cultural mindset of risk-averse organizations. Furthermore, adopting and deploying RVT might provide an avenue for risk-averse organizations to establish an innovation-friendly culture by legitimating flexibility-related practices through their application and validation (Elsbach & Stigliani, 2018). This potential of RVT to support cultural changes is particularly relevant for contexts in which risk-aversity seems to impede exploiting the competence of organizations in the core businesses (Tremml, 2019).

However, managers need to be aware that if their organization is characterized by a strong long-term orientation, RVT might not be as effective. The idea of RVT to collect data and act on it on a continuous basis goes against the preference of long-term planning and sequential rather than overlapping and experimental approaches. Managers in such organizations need to be aware that if they implement RVT in their organizations, this approach, as well as its outcomes, might find less acceptance among employees and decision-makers. This might require them to tighten their monitoring efforts and management support for innovation activities to create the commitment and motivation among employees to follow RVT principles. Furthermore, the investment into establishing RVT in the FEI as well as getting further funding to pursue outcomes of RVT-driven FEI activities might also require managers to engage in more issue selling and promotion activities to convince organizational decision-makers of the merits of the approach and its outcomes.

7 | LIMITATIONS AND FUTURE RESEARCH

This study has some limitations, which should be noted and can inform future research. With respect to the selected performance metric, we used a project portfolio-based performance measure that captured the extent to which the projects of the innovation program meet their quality, time, and budget objectives. Thereby, we followed prior recommendations to take the project life cycle into account when selecting appropriate performance metrics (Shenhar et al., 2001) and selected this internal performance indicator as opposed to financial or market success-related performance metrics. A similar approach has been performed in one of the rare quantitative studies on the effectiveness of design thinking (Roth et al., 2020) in which project performance metrics like budget, time, and quality are seen as being closely linked to the activities conducted at the FEI (Tatikonda & Rosenthal, 2000). The internal success of projects as an immanent outcome relates more closely to the concept of RVT in the FEI than a market or financial performance. The latter performance dimensions can also be impacted by the proficiency of downstream activities such as launch and sales activities or postlaunch moves of competitors. That being said, project success metrics are neither fully decoupled from market characteristics nor overall innovation program performance (Kock & Gemünden, 2019). Faster changing customer needs can trigger to change project requirements and thereby affect the time and budget necessary to adapt to the changed requirements. The same applies to moves of competitors or changes in value chain partners (Brettel et al., 2012; Hauser et al., 2006). Managerial measures that improve internal performance are likely to also affect economic- and market-related performance. This is also supported by the findings like internal project performance metrics being positively associated with performance indicators such as customer satisfaction, commercial success, and profitability (e.g., Cooper & Kleinschmidt, 1995; Shenhar et al., 2001). Nevertheless, future research might investigate the economic performance relevance of RVT at the market level and thereby provide clear evidence to this still unanswered question.

Furthermore, our intention was to conceptualize and assess the effectiveness of RVT as a comprehensive approach drawing on the principles of planned flexibility (Verganti, 1997, 1999) and aggregating the different elements proposed by popular FEI practices design thinking, lean innovation, pretotyping, and prototyping. We find support for our proposition that an organizational implementation of RVT is associated with innovation program performance. Future research, however, might further investigate the relative importance of each defining element of RVT for success. However, this might require changing the level of analysis to the individual project to appropriately consider project characteristics that are likely to make some elements of RVT to matter more than others for project performance. For instance, there is reason to believe that the relative performance relevance of experimentation and prototyping is higher for projects with higher degrees of innovativeness as past research on radical innovation projects has suggested (e.g., Mascitelli, 2000). Furthermore, explicit user integration might be of higher relative performance relevance in product innovation projects as opposed to service innovation projects. Services are created in close interaction together with the customer (e.g., Storey et al., 2016) and thereby user integration is an integral part of service development, whereas product development can more easily omit close user integration. Thereby, product innovation projects might benefit relatively more from user integration as it is less naturally embedded in the development process. Another interesting extension from this research would be the analysis of the relative importance of RVT elements in product versus process innovation. The RVT concept can also be applied to process innovations, and it would be interesting to see if elements such as (internal) user integration, commercial learning, or prototyping differ between product and process project contexts with respect to their relative performance relevance.

Finally, the exploration of further contingency factors might be of high value. We provide support for our initial assumption that the effectiveness of RVT depends upon various environmental factors. In this study, we focused on external factors that are causing more or less uncertainty and equivocality in the FEI in form of market and technological turbulence that RVT actually aims to reduce. Future research might inquire further into this industry perspective. One promising approach would be to investigate whether the application of RVT differs between firms operating in manufacturing or the service business. For instance, and due to the involvement of customers, employees, and network partners, frontline employees often responsible for service innovation, and the higher customization of services to customer needs, service innovation is more complex (Gallouj & Weinstein, 1997; Storey et al., 2016) and requires a higher proficiency in managing internal and external information flows (Kang & Kang, 2014). Past research finds that firms with a stronger emphasis on the provision of services benefit even more from better market knowledge, which depends upon the proficiency of managing information flows (Kroh et al., 2018). RVT might thereby be even more effective in firms with a stronger service focus as its elements are directed toward facilitating knowledge gathering and diffusion between internal and external stakeholders.

Internally, we focused on contingency factors that aimed to compensate for the tendency of past practices such as design thinking or lean innovation to the origin and having been investigated in entrepreneurial and small business contexts when investigating the generalizability of the performance relevance of RVT. However, further factors of the internal environment might be of relevance. One relevant area is the fit between the experimental, iterative approach of RVT and the level of formal control of projects and innovation activities. With the data at hand, we performed an additional assessment, not reported explicitly in the results section, and included interaction terms of RVT with innovation process formality and project management control. Both interaction terms (project management control × RVT: $\beta = 0.061$, $B = 0.055$, S.E. = 0.096; innovation process formalization × RVT: $\beta = 0.098$, $B = 0.146$, S.E. = 0.068), indicating that RVT does not conflict with the formal controls an organization applies to manage its innovation activities. This leads us to the suggestion to rather focus on further aspects of organizational culture and orientation that might make RVT more or less effective. For instance, the level by which an organization is offensive versus defensive in its response to external threats prefers a rather analytical versus improvised approach to information generation and knowledge building, or has a proactive versus reactive stand for opportunity-seeking (Morgan & Strong, 2003; Talke, 2007). Following contingency theory, the fit of RVT might vary according to these organizational mindsets and thereby also differ in their effectiveness in these different internal environments.

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CONFLICT OF INTEREST

The authors have read and agreed to the Committee on Publication Ethics (COPE) international standards for authors.

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APPENDIX

TABLE A1 Measures

Construct/Source	Items
Innovation program performance	*(1 = strongly disagree, 5 = strongly agree)*
	The quality of results met our expectations
Source: Gemünden et al. (2007)	The planned development times were achieved.
	The planned development budgets were kept.
Rapid validity testing	*(1 = strongly disagree, 5 = strongly agree)*
Conceptually rooted in Verganti (1999), see Table 3 for details.	When carrying out innovation activities, we form central assumptions at an early stage which we then test and refine.
	We continuously experiment during the product/service development phase in order to test our assumptions thoroughly.
	We already begin to develop prototypes during an early development phase in order to visualize, communicate, and assess our concepts.
	We carry out systematic prototype tests, for example, systematic customer surveys and customer observation.
	Over the course of developing the product/service, we produce several prototypes, from mock-ups through to functional models.
	Using prototypes, we already attempt to estimate market potential as well as the production costs and pricing scope of our new products/services.
	We experiment with different business models, for example, developing alternative business cases.
Market turbulence	*(1 = strongly disagree, 5 = strongly agree)*
Adapted from Calantone et al. (2003) and Venkatraman (1989)	Many new competitors are active in the market.
	The competitive conditions in the market are unpredictable.
	Customers' needs in our industry are changing rapidly.
	Many new value chain partners (suppliers, service partners) are active in the market.
	Business models often change in the market.
Technology turbulence	*(1 = strongly disagree, 5 = strongly agree)*
Adapted from Calantone et al. (2003) and Venkatraman (1989)	Our industry often experiences technological breakthroughs.
	The technologies applied in our industry are constantly changing.
	Technologies from different technological fields are often combined in our industry.
	New technologies in our industry often trigger business model changes.
Risk aversion	*(1 = strongly disagree, 5 = strongly agree)*
Adapted from Jaworski and Kohli (1993)	Our company is characterized by an "always play-it-safe" mentality.
	With respect to innovation, we have a wait-and-see posture.
	We have a strong proclivity for low-risk innovation activity.
Long-term orientation	*(1 = strongly disagree, 5 = strongly agree)*
Adapted from Ruvio et al. (2014)	Our innovation decisions explicitly take long-term and future developments into consideration.
	When taking decisions, we also always consider the future consequences for our company.
	We value long-term success over short-term profits.
Innovation process formality	*(1 = strongly disagree, 5 = strongly agree)*

TABLE A1 Continued

Construct/Source	Items
Source: Schultz et al. (2019)	Our company uses a formal innovation process, for example, a standardized set of stages and go/no-go decisions that guide all innovation activities from the idea through to market launch.
	Our standardized innovation process lists and defines specific activities for each phase of the process (e.g., the validation stage contains activities such as prototype and customer tests).
	Our standardized innovation process includes clearly defined go/no-go decision points for each stage of the process.
	Our standardized innovation process defines "gate keepers," whose task is, for example, to review the activities at each stage of the process as well as decide on whether to continue or abort the project.
Project management control	*(1 = strongly disagree, 5 = strongly agree)*
Source: Schultz et al. (2013)	Our company has clear, written, and measurable goals for its innovation projects.
	Specific financial goals are defined for our innovation projects.
	The progress of our innovation projects and the achievement of innovation goals are regularly evaluated.
	We have defined procedures for evaluating our innovation projects.
	All innovation projects, even unsuccessful projects, are regularly evaluated in order to learn from experience.
	We monitor the performance of our innovation projects at a defined time after market introduction.