

WHEN IS MORE UNCERTAINTY BETTER?

A MODEL OF UNCERTAINTY REGULATION AND EFFECTIVENESS

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ABSTRACT

Across all fields of management research, uncertainty is largely considered an aversive state that people and organizations cope with unwillingly and generally aim to avoid. However, theories based on principles of uncertainty reduction overlook opportunities arising from uncertainty creation. Building on recent research in management, cognition and neuroscience, we expand current conceptualizations of uncertainty by introducing a model of uncertainty regulation where individuals employ opening and closing behaviors to achieve alignment between preferred and experienced levels of uncertainty and with exogenous requirements for effectiveness. We derive propositions for uncertainty regulation and work performance which extend existing concepts of adaptation in uncertain environments to include deliberate uncertainty creation and expansive agency. We discuss implications for dynamic models of agentic goal striving, organizational support for individuals' uncertainty regulation, and extensions to team- and organization-level phenomena.

Keywords: Uncertainty creation, opening behavior, closing behavior, agency, work performance

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The concept of uncertainty is ubiquitous, describing a pervasive feature of the environment in which people and organizations must adapt to survive (Cyert & March, 1963; Thompson, 1967). Equally pervasive are the assumptions that uncertainty is aversive, and actors are primarily motivated to reduce the uncertainty. The aversive nature of uncertainty is expressed across fields of management research from strategy (e.g., Jauch & Kraft, 1986; Miller, 1992) to operations (e.g., Frishammar, Florén, & Wincent, 2010; Loch & Terwiesch, 1998) to organizational behavior and psychology (e.g., Cooper & Thatcher, 2010; Hogg, 2007). Even in research on entrepreneurship, innovation, and creativity, where embracing uncertainty is key, uncertainty reduction is considered an important driver of behavior (Mueller, Melwani, & Goncalo, 2012; Shepherd, McMullen, & Jennings, 2007).

It is timely to cultivate a fuller appreciation of both threats and opportunities embedded in the concept of uncertainty (McMullen & Shepherd, 2006; Shen, Fishbach, & Hsee, 2015; Smith & Lewis, 2011). We propose to move beyond “uncertainty management” with its focus on uncertainty reduction, toward “uncertainty regulation” that includes a positive role for uncertainty creation. We argue that individuals not only seek to reduce uncertainty, but at times actively create uncertainty that is functional and adaptive for themselves and others. We develop our model of uncertainty regulation in relation to individuals working in organizations and aim to better understand how individuals perceive and respond to uncertainty. Findings from recent behavioral, psychological, and brain studies point to a more agentic role for individuals as they learn and explore the environment (Beesley, Nguyen, Pearson, & Le Pelley, 2015; Geana, Wilson, Daw, & Cohen, 2016; Gottlieb & Oudeyer, 2018; Sansone & Thoman, 2005; Schulz &

Gershman, 2019). We integrate this research with long-standing research in work settings on performance and work design (Slocum Jr & Sims Jr, 1980; Van de Ven, 1976; Van de Ven, Ganco, & Hinings, 2013; Wall, Cordery, & Clegg, 2002) and research on proactivity at work (Griffin, Neal, & Parker, 2007; Parker, Wang, & Liao, 2019).

Our model describes how individuals both reduce and proactively generate uncertainty in a dynamic process of uncertainty regulation. It is likely that equivalent processes are relevant for organizations as actors as well, and we elaborate on this assumption in the discussion. To build a bridge towards an organizational level understanding of uncertainty regulation, we draw on examples from the entrepreneurship literature throughout the manuscript, because this research tends to emphasize individual actors, such as founders, while at the same time accounting for implications well beyond the individual. A case in point is the entrepreneurial journey of Marc Randolph and Reed Hastings at Netflix (Keating, 2012; Packard, Clark, & Klein, 2017). While Blockbuster reverted to strategies that had worked in the past, Netflix expanded services and explored new markets, with its founders moving between opening and closing the range of action options and outcomes they considered valid for Netflix' success. In 2010 Blockbuster filed for bankruptcy and Netflix is currently the 9th largest internet company in the world. Our theorizing suggests that the deliberate creation of uncertainty by the Netflix founders was important for this success.

Our proposed model outlines a dynamic process through which individuals regulate their experience of uncertainty in relation to individual preferences for uncertainty and in relation to the effectiveness of their behavior. Regulation involves alignment of uncertainty through two processes. In the first process, individuals align endogenous uncertainty—that is, the uncertainty they experience in their work environment and over which they have immediate control—with a

preferred level of uncertainty based on their personal attitudes and abilities. This alignment determines whether individuals engage in behaviors that increase or decrease uncertainty. We draw on literature concerning the exploration-exploitation dilemma in reinforcement learning (Gershman, 2018b; Gottlieb & Oudeyer, 2018; Kaelbling, Littman, & Moore, 1996; Walker, Luque, Le Pelley, & Beesley, 2019) to distinguish opening behaviors that generate further uncertainty and opportunities for learning from closing behaviors that reduce uncertainty and rely on existing knowledge. This literature provides detailed accounts of the psychological processes that determine whether an individual exploits existing knowledge to obtain immediate rewards or explores uncertain options for possible long-term gains (Schulz & Gershman, 2019; Wilson, Geana, White, Ludvig, & Cohen, 2014). In the second process, individuals align their regulation of endogenous uncertainty with the demands generated by exogenous uncertainty, that is, uncertainty in the broader environment over which they have little direct control. This alignment determines the effectiveness of individuals' behavior given the external requirements for routine versus emergent actions, which largely depend on the level of exogenous uncertainty individuals are expected to cope with (Carpini, Parker, & Griffin, 2017).

Our theorizing about the regulation of uncertainty in terms of both reduction and creation of uncertainty contributes to management research in several important ways. First and most fundamentally, we offer a new understanding of agency in uncertainty regulation. Rather than conceptualizing individuals as merely responding to the requirements of external exigencies, we stress their agency in creating conditions that match their preferred state. Moreover, we argue that these preferred states are not necessarily characterized by lower uncertainty but can also be states that exceed the uncertainty individuals experience in their environment.

Second, we show how effectiveness of work performance results from an alignment between exogenous uncertainty and an individual's uncertainty regulation towards a preferred level of endogenous uncertainty. We thereby extend current research which has emphasized necessary contingencies between exogenous uncertainty and individual flexibility and adaptation but has not specified the mechanisms through which these contingencies are enacted. We propose that effectiveness hinges on individuals' efforts to maintain a preferred level of endogenous uncertainty through balancing opening and closing behaviors.

Third, by outlining the dynamics involved in uncertainty regulation and effectiveness we provide the ground for developing and testing more comprehensive models of self-regulation and proactive adaptation in uncertain environments. We suggest that computational modelling may be the way forward to incorporate this fuller understanding of uncertainty regulation into the fundamental relationship between actors and the contexts in which they strive to achieve goals. The insights garnered should benefit a wide range of inquiries in management research, from individual and organizational learning to innovation, entrepreneurship, and strategy.

Our model aims to capture the true nature of human agency as both creating and responding to uncertainty (Bandura, 2001). This fundamental shift in perspective can substantially enrich current management thinking by highlighting uncertainty not as a condition to be endured and coped with, but to be actively constructed. However, this will also require a new understanding of the responsibility that comes with this more agentic role. Thereby, it will be possible to devise the prerequisites for individuals and organizations to prudently take advantage of uncertainty in their pursuit of valued goals.

EXOGENOUS AND ENDOGENOUS UNCERTAINTY

From the abundant literature on uncertainty and related concepts such as risk and ambiguity, we apply concepts of exogenous and endogenous uncertainty to develop our theorizing on uncertainty regulation. In the most general sense, we define uncertainty as any departure from absolute determinism (Walker et al., 2003), pointing to unpredictability as the core of uncertainty. For any individual, uncertainty is represented as a lack of information or ambiguous information in relation to a task they wish to accomplish (Galbraith, 1973; Grote, 2009; Lipshitz & Strauss, 1997). We ask how individuals handle a general state of "not knowing for sure", as it arises with insufficient knowledge on any component of a given work task. Exogenous and endogenous uncertainty delineate the location of uncertainty vis-à-vis the individual as well as the degree to which uncertainty can be controlled by the individual, which is central to our model of uncertainty regulation.

Exogenous uncertainty

Exogenous uncertainty exists in the environment outside an individuals' general sphere of influence (Powell, 1992) and, therefore, is often called environmental or external uncertainty (Downey, Hellriegel, & Slocum Jr, 1975; Jauch & Kraft, 1986). As exogenous uncertainty exists independent of the individual, it is sometimes also referred to as objective (Downey & Slocum Jr, 1975) or even "true" uncertainty (Knight, 1921) . We use the term "exogenous context" to describe the external environment in which uncertainty arises and which is largely uncontrollable by individuals. For individuals at work, the exogenous context includes elements outside their immediate sphere of influence within the organization and in the organization's environment.

There is a long-standing debate on whether exogenous uncertainty is in principle fully mitigable if sufficient effort is spent on knowledge acquisition or whether there will always be

pockets of the unknowable due to stochastic processes, such as Schumpeterian shocks (Schumpeter, 1943), and the impact of others' "free will" (Packard & Clark, 2019). We do not resolve this debate as we focus on everyday processes of uncertainty regulation in what has been called "large worlds" (Kozyreva & Hertwig, 2019) where the effort required to know all potentially knowable information far exceeds the individual's resources.

We view exogenous uncertainty as an ontological fact of being in a world where some features are fundamentally unknown. However, individuals can be embedded in different exogenous contexts that vary with respect to the amount of uncertainty they confront individuals with. Emergency departments in hospitals or start-ups engaged in drug discovery are examples for very high levels of exogenous uncertainty where events in the exogenous context place unpredictable and highly variable demands on individuals' immediate work contexts. Exogenous contexts with lower levels of uncertainty might include a manufacturing firm with a simple product line and a secure market.

Endogenous uncertainty

Endogenous uncertainty denotes an epistemological condition in which there is a lack of knowledge and information about the world (O'Donnell, 2013). However, the domain of endogenous uncertainty is amenable to discovery and knowledge expansion and can be directly influenced by the individual. Endogenous uncertainty is influenced but not fully caused by exogenous uncertainty, as individual sensemaking as well as changes in the individual's immediate surroundings—which we term the “endogenous context”—modify what is known and can be known (Lipshitz & Strauss, 1997; Maitlis & Christianson, 2014). Not least, endogenous uncertainty is influenced by individuals themselves as they seek to either reduce the experience

of uncertainty or, as we argue in this paper, to create uncertainty as part of uncertainty regulation.

The terms “exogenous” and “endogenous” allow a separation of uncertainty concepts that are conflated in concepts such as perceived uncertainty (Downey & Slocum Jr, 1975) or internal uncertainty (Jauch & Kraft, 1986), which define and measure exogenous uncertainty in terms of subjective representations of that uncertainty (Downey & Slocum Jr, 1975; Milliken, 1987). We aim to show that the experience of uncertainty is much more varied and malleable than being a mere reflection of exogenous uncertainty. We next develop our model of how individuals appraise and act on endogenous uncertainty within a broader context of exogenous uncertainty and how through this uncertainty regulation they also engage with the requirements posed by the exogenous context to bring about effectiveness.

A MODEL OF UNCERTAINTY REGULATION

Building on the principles of psychological self-regulation (Carver & Scheier, 1998; Diefendorff & Lord, 2008; Kanfer, 2005), our proposed model of uncertainty regulation depicted in Figure 1 contains four core elements: (1) attending to exogenous uncertainty which creates the experience of endogenous uncertainty; (2) appraising endogenous uncertainty in relation to a preferred level of uncertainty; (3) choosing between exploring new opportunities through opening behaviors that increase uncertainty and exploiting predictable outcomes and rewards through closing behaviors that reduce uncertainty; (4) performing effectively through proficiency, adaptivity, proactivity, or expansive agency contingent on the requisite demands of exogenous uncertainty. In the development of the model we focus on psychological mechanisms and explanations at the micro-level to provide the most coherent and stringent account of the proposed processes. However, similar processes are likely to occur at the organizational level,

which we will come back to in the discussion. As our model addresses uncertainty regulation in work contexts, we emphasize uncertainty related to work tasks. The proposed processes may also apply to other kinds of uncertainty, such as uncertainty about the self or social uncertainty (Brown & Zeigler-Hill, 2017; FeldmanHall & Shenhav, 2019; Hogg, 2007) but we concentrate on the task context in which an individual is working toward organizational goals.

Insert Figure 1 about here

A simple example illustrates the core elements of the model: An employee in the marketing department of a snowboard manufacturer has been asked to identify new customer segments for their next advertising campaign. This assignment focuses her *attention* on novelty and ensuing uncertainty. She is excited about this opportunity to show what she has learned in a recent marketing course to her colleagues and her boss. Accordingly, her *appraisal* of the endogenous uncertainty is positive and affords opportunity to explore which leads to her *choice* to increase uncertainty through opening behaviors. She decides on her own to enlarge her task by not only exploring new customer segments but also new advertising techniques using influencers on social media, which the company has never done before. During her first presentation of results to her department, she meets with resistance to the idea of using social influencers, but she is able to convince her boss that new customer segments should be investigated in tandem with new advertising techniques, leading to an officially endorsed expansion of her project brief. This alignment of her own interests and the project requirements resulted in *effective performance* that contributed positively to the overall goals of the company.

In the following sections we outline the four elements involved in the regulation of uncertainty: attention, appraisal, choice of behaviors, and effective performance. These elements unfold dynamically such that the elements are constantly updated with reference to previous states of each element. The recursive nature of self-regulation makes it somewhat arbitrary to identify a discrete starting point for the process, but we begin with the role of attention.

Attending to uncertainty

Uncertainty has long been proposed as a stimulus for active investigation of the environment (Hebb, 1955), although the motivation to reduce uncertainty has been the key theoretical explanation (Kagan, 1972). Detection of uncertainty has typically been thought of as awareness of threat (Jonas et al., 2014; Kagan, 1972), but we propose that individuals initially attend to uncertainty without assigning either a positive or negative valence. At this stage, attention to uncertainty simply means an individual is aware of unexplained variability in the work environment that might be important. Evaluating the experience of uncertainty and its significance is thought to depend on distinct cognitive processing that occurs subsequent to this attention (Anderson, Carleton, Diefenbach, & Han, 2019).

Recent studies in neuroscience and cognition highlight some interesting implications of the initial attention given to uncertainty. Randles, Benjamin, Martens, and Heine (2018) found evidence that working memory capacity increased when people encountered uncertainty. They suggested that uncertainty creates a heightened vigilance for new information that is grounded in fundamental neural processing. Walker et al. (2019) reported that people widen their attention span when they are uncertain about a reward, paying attention to a greater number of cues in their environment. Attention directs cognitive resources towards uncertainty and initiates an evaluation of whether there is an opportunity to learn and expand knowledge or to protect and

take advantage of existing knowledge (Beesley et al., 2015). For instance, entrepreneurs are known for their readiness to engage with the opportunities arising from uncertainty (Alvarez, Young, & Woolley, 2015; Edelman & Yli-Renko, 2010). The engagement with exogenous uncertainty prepares an individual for deeper processing of information in a subsequent step of assessing and acting upon the experienced endogenous uncertainty. This process has also been described as enactment (Weick, 1979: 130): “Enactment is the only process where the organism directly engages an external environment.” We capture this fundamental linkage between exogenous and endogenous uncertainty in the following first proposition.

Proposition 1. Individuals experience endogenous uncertainty as they attend to and engage with exogenous uncertainty as both a potential source of interest and learning and as a potential threat.

Appraising uncertainty in relation to uncertainty preferences

Attention directed toward uncertainty is followed by an appraisal process that evaluates and gives meaning to the experience of uncertainty. This appraisal involves more complex and directed cognitive and emotional control (Laureiro-Martinez, 2014; Laureiro-Martínez, Brusoni, Canessa, & Zollo, 2015) to inform ongoing decisions about how to act. We adopt a reward-learning approach that identifies the cognitive processes through which individuals continually make and update uncertainty-related appraisals (Anderson, 2016; Gottlieb & Oudeyer, 2018; Schulz, Wu, Ruggeri, & Meder, 2019; Stojic, Orquin, Dayan, Dolan, & Speekenbrink, 2020). From this perspective, information itself is rewarding. Uncertainty signals the possibility of acquiring new information and knowledge about the world. Evaluation, therefore, revolves around the potential rewards that might be achieved by engaging with uncertainty.

By proposing that uncertainty can signal potential rewards, our approach challenges the assumption that uncertainty is fundamentally aversive (e.g., Carleton, 2016). Indeed, there is evidence that uncertainty can generate positive emotions under certain circumstances. Wilson, Centerbar, Kermer, and Gilbert (2005: 5) described a “pleasure paradox” to highlight that uncertainty can produce positive feelings, especially when the uncertainty is connected to a generally positive event such as receiving a gift. Positive experiences also seem to be intensified with more uncertainty (Kurtz, Wilson, & Gilbert, 2007). For instance, women were found to be more attracted to men when they were left unclear about these men's positive feelings towards them (Bar-Anan, Wilson, & Gilbert, 2009). In other words, positive appraisal of uncertainty is not necessarily an inverse function of the amount of uncertainty experienced.

A fundamental form of appraisal is whether uncertainty is interesting (Sansone & Thoman, 2005). Silvia (2008) described interest as a somewhat neglected emotional appraisal that motivates exploration and learning. The adaptive role of interest is well recognized in child development studies, which show increased interest by children in situations with higher uncertainty (Kidd & Hayden, 2015) and also indicate that children both create and select experiences that are associated with more uncertainty. Oudeyer and Smith (2016) emphasized that “learning experiences do not passively ‘happen’ to infants. Rather, infants' own activities create and select these experiences”. Curiosity is a closely related appraisal that underpins many exploratory behaviors through which people interact with their environment and learn adaptive responses (Hagtvedt, Dossinger, Harrison, & Huang, 2019). Loewenstein (1994) reviewed the history of curiosity research and highlighted the adaptive importance of curiosity. Sansone and Smith (2000) argued that interest and curiosity are often overlooked as explanations of purposeful behavior (Sansone, 1986). Our model juxtaposes the common assumption that

uncertainty generates fear and anxiety with the alternative possibility that uncertainty is an important source of generating interest and curiosity.

To explain how different appraisals are made, self-regulation theories typically incorporate appraisal in relation to some referent or standard (Carver & Scheier, 1998; Diefendorff & Lord, 2008; Kanfer, 2005). We introduce an uncertainty preference to represent the input of multiple individual factors into the appraisal. Generally, we expect to observe an inverted U-shaped function between an individual's experience of uncertainty and the level of uncertainty preferred in a particular situation, such as fulfilling a specific work task. At low levels of experienced uncertainty, individuals are motivated to increase uncertainty. Conversely, at high levels of experienced uncertainty, reduction of uncertainty is the more likely choice. This inverted U shape differs from the shape derived via standard uncertainty reduction assumptions, which would be represented by a monotonically decreasing line. The inverted U is unlikely to be symmetrical or similarly shaped for all individuals and may change over time for a given individual. In reviewing the prevalence of the inverted U in psychology, Grant and Schwartz (2011: 62) noted "there is no such thing as an unmitigated good". We add the converse—for uncertainty, there is no such thing as an unmitigated bad, thereby suggesting a more complex process of uncertainty regulation.

Uncertainty preference will partly result from relatively stable individual differences with respect to evaluating and addressing uncertainty, such as tolerance for ambiguity (Norton, 1975), uncertainty orientation (Sorrentino, Short, & Raynor, 1984), intolerance of uncertainty (Carleton, Norton, & Asmundson, 2007), learning versus performance goal orientation (Brett & VandeWalle, 1999), or openness to experience (LePine, Colquitt, & Erez, 2000). Moreover, uncertainty preferences and ensuing appraisals will be influenced by an individual's perceived

self-efficacy and abilities in relation to the experienced uncertainty (Bandura, 1982). For instance, Fang He, Sirén, Singh, Solomon, and von Krogh (2018) found that entrepreneurs' learning from failure was influenced both by the rate of failure and their perceived ability to regulate their emotions. This perceived ability presumably helped the entrepreneurs to reappraise uncertainty stemming from failure in a positive way that promoted learning as a key requirement for exploring entrepreneurial opportunities. Also, entrepreneurship training seems to be most effective in terms of leading to actual business ownership when participants show intermediate levels of self-efficacy and also variations in their perceived self-efficacy, which hints at the importance of perceived ability, but also a readiness to question own abilities in the pursuit of an uncertain venture (Gielnik, Bledow, & Stark, 2019). We expect that individuals develop preferences regarding uncertainty over time and change their preference levels adaptively, in response to both personal and situational factors included in our model of uncertainty regulation.

Proposition 2. Individuals appraise endogenous uncertainty with reference to a preferred level of uncertainty, which varies between and within individuals due to trait and state uncertainty-related attitudes and abilities.

Choosing between exploration and exploitation through opening and closing behaviors

Uncertainty appraisals inform an individual's ongoing choice of whether to engage with the opportunities inherent in uncertainty or to enact behaviors that reduce uncertainty and lead to more predictable outcomes. Across a range of literatures, this decision has been framed as a choice between exploration and exploitation. Management researchers have long considered the tradeoffs involved in this choice (Berger-Tal, Nathan, Meron, & Saltz, 2014; March, 1991; O'Reilly III & Tushman, 2013), and a growing body of research in computer science and neuroscience investigates exploration/exploitation as a fundamental dilemma in human decision

making and learning (Belkaid & Krichmar, 2020; Schulz & Gershman, 2019; Wilson et al., 2014).

Exploitation involves the direction of attentional resources to pursue known rewards and more certain outcomes. This process is well understood and amenable to computational, experimental, and real-world investigation (Vancouver, Wang, & Li, 2020). The choice to explore, on the other hand, forgoes known rewards and orients an individual's activities toward cues in the environment that signal highly uncertain possibilities for long-term gain (Beesley et al., 2015). Despite increasing research devoted to exploration, the underlying cognitive processes remain an "open question" Gershman (2018a: 34). Moreover, findings from controlled and rather simple experiments, such as multi-arm bandit games, are difficult to generalize to real world settings. Some initial attempts have been made to study more realistic behaviors, such as choices between known and new restaurants in online food delivery services, which suggest similar cognitive processes as those found in multi-arm bandit experiments (Schulz et al., 2019). Overall, neurological studies provide sufficient support for a distinction between choices to explore and exploit information (Kidd & Hayden, 2015) to give credence to this central feature of our model of uncertainty regulation.

Additional support comes from theories of learning which propose that individuals can favor learning goals "to understand or master something new" or performance goals "to gain favorable judgments of their competence or avoid negative judgments of their competence" (Dweck, 1986: 1040). These goal orientations have been described as both more stable personal dispositions and as state conditions which are influenced by the individual's context (Vandewalle, Nerstad, & Dysvik, 2019). Especially in educational research, but also in organizational learning, an orientation towards mastery or even expansion into completely new

realms of knowledge and competence has been given particular attention as the preferred, though difficult to achieve orientation. Engeström (2001: 137) coined the term “expansive learning” for processes of reconceptualizing objectives and motives of an activity "to embrace a radically wider horizon of possibilities than in the previous mode of the activity", which describes an exceptionally far-reaching form of exploration.

We propose that individuals who experience endogenous uncertainty below a preferred level are motivated to engage in exploration and harness the opportunities for discovery that are an intrinsic feature of uncertainty. If, on the other hand, individuals experience endogenous uncertainty above a preferred level of uncertainty, they will opt for exploitation of existing knowledge. The choice between exploration and exploitation leads to distinct behaviors with different implications for the level of endogenous uncertainty as well as task-related outcomes. We distinguish two types of behavior that reflect this choice. "Closing behaviors" (Rosing, Frese, & Bausch, 2011: 966) involve known routines and application of existing knowledge that narrows the range of possible outcomes (Greco, Charlier, & Brown, 2019). Examples of closing behaviors in work contexts include convergent thinking during decision-making processes, following detailed rules, seeking positive feedback, or closely monitoring others' performance. In contrast, "opening behaviors" (Rosing et al., 2011: 966) involve non-routine and emergent patterns of action that open up new possibilities for learning and action. Investigations of curiosity-based learning highlight the active generation of new experiences that follow from curiosity (Oudeyer & Smith, 2016). In work contexts, opening behaviors might include actions such as: voicing doubts about an ongoing course of action, divergent thinking in decision-making, improvising oneself and encouraging others to improvise, or environmental scanning for new business opportunities. Due to its experimental nature, opening behavior is more difficult to

self-regulate and outcomes are more uncertain. Ott, Eisenhardt, and Bingham (2017) describe how entrepreneurs manage this difficulty by combining doing and thinking in strategy formation, where, for example, feedback acts as a support to specify what knowledge gaps exist and which knowledge domains are the most promising for learning and innovation.

Proposition 3a. If endogenous uncertainty is appraised as below a preferred level of uncertainty, individuals will engage in exploration through opening behaviors that create uncertainty.

Proposition 3b. If endogenous uncertainty is appraised as above a preferred level of uncertainty, individuals will engage in exploitation through closing behaviors that reduce uncertainty.

Aligning endogenous and exogenous uncertainty for effectiveness

We next consider the effectiveness of individuals' opening and closing behaviors in relation to the exogenous context. Effectiveness concerns the degree to which an individual's behavior successfully leads to valued outcomes in the broader work environment (Borman, 1991; Campbell, 1990). The assumption that effectiveness arises when individuals align their behavior with the exogenous context is a central assumption of various contingency theories. For example, teams operating in conditions of high uncertainty require more explicit coordination compared to more certain contexts where implicit coordination is sufficient (Rico, Sánchez-Manzanares, Gil, & Gibson, 2008). In organizations, the basic principle that more exogenous uncertainty requires more flexible forms of behavior has remained consistent through the evolution of contingency theories (Burns & Stalker, 1961; Lawrence & Lorsch, 1967; Trist & Bamforth, 1951) to theories of dynamic capability (Teece, Pisano, & Shuen, 1997), ambidexterity (Tushman & O'Reilly III, 1996), and effectuation (Sarasvathy, 2001). We extend this reasoning by proposing that

effectiveness results when individuals align the level of endogenous uncertainty with the requirements of the exogenous context. Thereby, the chosen opening and closing behaviors will not only be adequate for achieving a preferred level of endogenous uncertainty, but they will also contribute to work performance.

To understand the requirements for effectiveness under conditions of different levels of uncertainty, we draw on the performance model of Griffin et al. (2007). These authors distinguish three dimensions work role performance—proficiency, adaptivity, and proactivity—to describe patterns of behavior that are assumed to be effective under increasing levels of uncertainty. Proficiency, for example through following rules and timelines, is effective with low levels of uncertainty; adaptivity encompasses reactions to slightly higher levels of uncertainty, for instance through learning new skills for a changed work role; proactivity involves active engagement with high levels of uncertainty, for instance by making suggestions for changes in the way work is done to increase internal flexibility. The notion of effective performance enables us to link the actions that increase or decrease endogenous uncertainty (opening and closing behaviors respectively) to the actions that constitute adequate responses to conditions of exogenous uncertainty (proficiency, adaptivity, and proactivity). We propose that opening and closing behaviors are the building blocks not only for endogenous uncertainty regulation, but also for effective performance that is achieved when endogenous uncertainty regulation concurrently matches the requirements of the exogenous context.

Before describing in more detail how opening and closing behaviors are linked to effective performance, we note that Griffin et al. (2007) defined uncertainty as unpredictability in the general (exogenous) context and did not differentiate endogenous from exogenous uncertainty. They also did not consider how individuals might actively generate uncertainty through their

behavior. These limitations reflect that, to date, even proactivity as the most uncertainty-embracing behavior pattern has been seen as an adaptive response to highly uncertain environments that is motivated by the aim to reduce that uncertainty (Grant & Ashford, 2008; Parker et al., 2019). However, there is growing evidence that this perspective on proactivity is too narrow. For example, feedback seeking was originally conceptualized as a behavior aimed at reducing task uncertainty (Ashford, 1986). More recent findings suggest that individuals may benefit from ambivalent responses to their feedback seeking which increase uncertainty and support creativity (Harrison & Dossinger, 2017).

To incorporate the more agentic approach to uncertainty regulation proposed in our model, we extend the categories of effective behavior patterns proposed by Griffin et al. (2007) to include the concept of expansive agency, which entails that individuals deliberately increase uncertainty beyond the immediate requirements for work performance. Expansive agency helps to introduce completely new options for effectively engaging with uncertainty, for instance by redefining the scope of tasks or even the superordinate goals to be reached. This concept draws on Engeström's (2001, 2016) theory of expansive learning which details how individuals achieve to fundamentally transform existing activity systems. In these cases, individuals not only respond to exogenous uncertainty, but create exogenous uncertainty in order to initiate such transformations. For example, Engeström (2001) described the transformation from critical pathways to care agreements as the main coordinating mechanism across pediatric care institutions, which was eventually made possible by openly confronting processes of scape-goating and thereby questioning basic relationships between the institutions. The notion of expansive agency also aligns with a model of entrepreneurial decision-making outlined by Packard et al. (2017). At any point in their decision-making on new ventures, investments or

products, entrepreneurs may choose to completely reopen the set of options and outcomes to be considered in response to a changed landscape of opportunities. Processes of redefining the scope of tasks have also been described as an integral part of the interaction between founders and venture capitalists (Kazanjian & Drazin, 1990).

Successful alignment. We argue that effectiveness is achieved when opening and closing behaviors aimed at regulating endogenous uncertainty are aligned with the demands generated by exogenous uncertainty. If individuals increase uncertainty because their preferred level of endogenous uncertainty is higher than the experienced level, the resulting opening behaviors will be particularly effective under conditions of high exogenous uncertainty in alignment with the demands for proactivity or expansive agency. For example, individuals may ask their supervisor for feedback as a way to show their interest in more challenging tasks, which can initiate a successful process of work redesign if there is a need for taking on more responsibility to better manage changing customer demands (De Stobbeleir, De Boeck, & Dries, 2016).

If, on the other hand, individuals reduce uncertainty because their preferred level of endogenous uncertainty is lower than the experienced level, the resulting closing behaviors will be particularly effective under conditions of low exogenous uncertainty in alignment with the demands for proficiency or adaptivity. Again, using feedback seeking as an example, personally insecure individuals might search mostly positive feedback which will be effective especially with routine tasks where good performance is likely.

Our reasoning implies that at any point in time exogenous and endogenous uncertainty may deviate from each other due to the processes involved in regulating endogenous uncertainty that we have described above. Once more, research on feedback provides an interesting example to illustrate this point. Anseel, Strauss, and Lievens (2017: 299) described a "feedback paradox"

where individuals search for feedback least when they need it most. In the terms of our model, this can entail situations where individuals reduce endogenous uncertainty, for instance in order to satisfy their need for self-verification, by only asking for positive feedback, while at the same time their performance deteriorates. Through the resulting negative outcomes, acknowledgement of the higher levels of exogenous uncertainty may be triggered, which starts a new cycle of uncertainty regulation aimed at increasing endogenous uncertainty, for instance by seeking feedback from particularly discerning colleagues.

In summary, we argue that effectiveness is achieved when opening and closing behaviors are balanced in a way that permits both uncertainty regulation towards a preferred level of endogenous uncertainty and an appropriate level of engagement with exogenous uncertainty. A special case for the alignment of endogenous and exogenous uncertainty is the deliberate creation of uncertainty by the individuals themselves. As outlined earlier, such expansive agency will be effective if a situation requires a completely new framing in order to achieve superordinate goals. Creativity and innovation are research domains that should provide prime examples of such processes. However, to date even these fields of study have been imbued with the dominant view of uncertainty reduction (Anderson, Potočnik, & Zhou, 2014; West, 2002). Examples of a fuller understanding of uncertainty creation in innovation are predominantly found once more in the entrepreneurship literature. Alvarez, Young, and Woolley (2018) used the founding and growth of Wakefield Seafoods to show how an entrepreneur can create and later exploit a business opportunity through a broad range of technological innovations, marketing activities, relationship building, and even policymaking.

Proposition 4a. If an individual's opening (closing) behaviors regulate endogenous uncertainty to a preferred level that aligns with the requirements of

exogenous uncertainty in terms of proactivity or expansive agency (proficiency or adaptivity), effectiveness is achieved.

Misalignment. Effectiveness will be hampered when actions aimed at regulating endogenous uncertainty are not aligned with the demands generated by exogenous uncertainty. If individuals increase uncertainty because their preferred level of endogenous uncertainty is higher than the experienced level, we assume that the resulting opening behaviors will be ineffective under conditions of low exogenous uncertainty. This situation has received little attention in the literature, presumably due to the pervasive assumption that organizations and their employees have to face ever more uncertainty, requiring high levels of proactivity (Aragón-Correa, 1998; Crant, 2000; Parker & Bindl, 2017). There are only a few tentative suggestions that there might also be a "dark side" to proactivity (Belschak, Den Hartog, & Fay, 2010; Bolino & Grant, 2016). We suggest that negative effects of proactivity related to an increase in uncertainty by expanding one's job role have been rarely found because top-down work design tends to err on the side of oversimplifying jobs (Parker, Van den Broeck, & Holman, 2017). Proactivity in such cases helps to compensate for poor work design and leads to more effective outcomes. However, this possibility does not preclude the occurrence of misalignment due to too much uncertainty creation. The recent turbulences at Tesla may provide some anecdotal evidence: Rather than focusing on the requirements for producing cars reliably, Elon Musk seems to have been driven to increase uncertainty by pushing for ever new developments. In the period leading to the resignation of Tesla's Chief of Vehicle Engineering, Doug Field, in the summer of 2018, Elon Musk, Tesla's declared Chief Engineer, tweeted: "About a year ago, I asked Doug to manage both engineering & production. He agreed that Tesla needed eng & prod better aligned, so we

don't design cars that are crazy hard to build. Right now, tho, better to divide & conquer, so I'm back to sleeping at factory. Car biz is hell."

If, on the other hand, individuals reduce uncertainty because their preferred level of endogenous uncertainty is lower than the experienced level, we assume that the resulting closing behaviors will be ineffective under conditions of high exogenous uncertainty. For example, employees who are new in their job have been found to approach supportive supervisors (Nifadkar, Tsui, & Ashforth, 2012) and ask primarily for positive feedback (Gong, Wang, Huang, & Cheung, 2017). Our model suggests that such closing behaviors are misaligned with the demands of the environment in cases where further exploration and engagement with uncertainty are required, which might explain the mixed results regarding the presumed positive relationship between feedback seeking and performance (Anseel, Beatty, Shen, Lievens, & Sackett, 2015). Another example is provided by Gibson and Dibble (2013) in their analysis of external activities of film-making teams where they found that teams sometimes compromised their original ideas and overall effectiveness in order to reduce uncertainty and secure their film projects in view of (inappropriate) external demands, for instance by marketing agents.

Proposition 4b. If an individual's opening (closing) behaviors regulate endogenous uncertainty to a preferred level that is higher (lower) than is required by exogenous uncertainty and therefore does not align with proactivity or expansive agency (proficiency or adaptivity), effectiveness is reduced.

THE DYNAMICS OF UNCERTAINTY REGULATION

We have described two interrelated and dynamic processes of alignment that unfold during uncertainty regulation as individuals choose between exploration and exploitation. In the first process, individuals strive to align uncertainty in the endogenous context with their preferred

level of uncertainty. In the second process, individuals align endogenous uncertainty regulation with the requirements of the exogenous context. As these processes evolve over time, individuals must attend both to their experience of endogenous uncertainty and to the effectiveness of their actions. Appraisal of this information triggers new cycles of choices between exploration and exploitation through which individuals can capture the inherent informational value of uncertainty by choosing actions that create uncertainty and enhance knowledge gain.

There are a number of research streams which substantiate the assumed dynamics of uncertainty regulation. Continuously balancing a mix of uncertainty creation and reduction is evident in studies of learning, creativity, and entrepreneurial activity. For instance, research on curiosity attests to humans' interest in novelty, but also indicates that a basic motivation for seeking novelty is to gain knowledge and later reduce uncertainty (Kidd & Hayden, 2015). Greco et al. (2019) proposed that individuals who alternate between exploration and exploitation mindsets would achieve overall higher levels of learning and performance. In a similar vein, Raisch, Hargrave, and van de Ven (2018) have suggested a learning spiral of convergence and divergence for effectively handling paradoxical tensions in organizations. In an empirical study on successful entrepreneurship, Andries, Debackere, and Van Looy (2013: 289) described how uncertainty creation and reduction were intertwined when new business ventures experimented with different business models to facilitate “long-term survival by enacting variety”. Feedback from the environment during experimentation enabled learning, after which the chosen business models were exploited. Similarly, Berends, Jelinek, Reymen, and Stultiëns (2014) found that entrepreneurs tended to move from an effectuation logic, where they focused on using and recombining available means to reach highly uncertain outcomes, towards a causation logic, where they followed a preplanned path for achieving predictable outcomes. The reverse

transitions from exploitation to exploration can be seen when organizations set stretch goals and have sufficient slack resources to pursue experimentation (Sitkin, See, Miller, Lawless, & Carton, 2011). These processes not only concern a one-sided adaptation of behavior to external conditions, but a complex reciprocal interaction between actors and their environments as described in psychology (Bandura, 1982) and in sociology (Heugens & Lander, 2009).

Counter to much of management research with its emphasis on uncertainty reduction, Geana et al. (2016: 1754) speculated that individuals escape boredom by engaging in exploration and information seeking due to an “endogenous bias toward exploration, acquired over the course of evolution and/or development”. As we have argued throughout, the notion that individuals might seek stimulation in this way is intuitive, yet not well-integrated into management theories. Rather, one finds an abundance of studies that seem to speak to the opposite bias towards exploitation and protection of known certainties (e.g., Grant & Ashford, 2008; Greco et al., 2019; Hogg, van Knippenberg, & Rast, 2012). We suggest that inconsistencies in defining and incorporating exogenous and endogenous uncertainty, especially the tendency to use individuals' perception of uncertainty as a measure of exogenous uncertainty, is one reason that uncertainty creation inherent in learning through trial and error (Bingham & Davis, 2012), improvisation (Miner, Bassof, & Moorman, 2001), or bricolage (Baker & Nelson, 2005) has been obscured in organizational research.

Beyond the dynamics involved in regulating endogenous uncertainty toward a preferred level of uncertainty, we assume continuous processes of adjusting misalignments with exogenous uncertainty to improve effectiveness. Realignment can be effected by changing the level of preferred endogenous uncertainty and/or the level of exogenous uncertainty. The work design literature provides possible mechanisms for such realignments. Early on, Slocum Jr and Sims Jr

(1980) argued that in order to create meaningful and motivating jobs, uncertainty often needs to be injected into the work situation so that employees obtain opportunities for exercising discretion and for learning. More recently, the concept of job crafting has been introduced to describe how employees proactively change their jobs to better align them with personal preferences (Wrzesniewski & Dutton, 2001). Job crafting can be used to reduce or increase job demands but might also involve changes in work relationships and in the way one thinks about one's job and gives meaning to it. The kind of job crafting individuals engage in also depends on personal characteristics, for instance need for autonomy, competence, and relatedness and promotion versus prevention-oriented regulatory focus (Bindl, Unsworth, Gibson, & Stride, 2019). Meta-analytic evidence suggests that increasing challenging job demands is related to good work performance and that proactive personality is the strongest predictor for this type of job crafting (Rudolph, Katz, Lavigne, & Zacher, 2017). This research usually does not consider uncertainty directly, nor does it capture dynamic processes of mis- and realignment. Thus, only cautiously can these findings be taken as evidence for processes of uncertainty creation by individuals with higher levels of preferred uncertainty. One recent study provides a more differentiated picture of the effects of job crafting, where medium levels of job crafting were found to be related to worse performance (Dierdorff & Jensen, 2018). The authors' reasoning for this effect resembles our model of uncertainty regulation. They maintained that job crafting is motivated by individuals' preferences rather than by performance requirements. Only at high levels of crafting will an alignment with performance requirements be achieved as peers begin to pay attention to the job crafting activities and offer constructive feedback to adjust them.

Proactivity at work is generally exhibited more by employees with certain personality characteristics, such as proactive personality, learning goal orientation, and conscientiousness

(Parker & Collins, 2010). At the same time, research on the relationship between personality and work design provides evidence that people can develop more proactive personalities through the experience of appropriate levels of job demands and job control (Li, Fay, Frese, Harms, & Gao, 2014). In relation to realignment of uncertainty regulation and effectiveness, this reciprocal relationship between individuals' predispositions and preferences and their work environment suggests an ongoing adaptation which leaves neither the person nor the exogenous context unchanged.

Our dynamic model is consistent with recent models of self-regulation that propose a set of feedback loops operating at different levels of analysis (Ballard, Palada, Griffin, & Neal). For example, Neal, Ballard, and Vancouver (2017) outlined a general model for self-regulation in which actions at one time influence the environment which, in turn, leads to modification of subsequent goals and choices. They proposed that, over time, behaviors enacted to align multiple processes lead to change in both the person (e.g., goals, effort levels) and the environment (e.g., reward opportunities). The dynamics arising from even simple feedback loops operating together can be complex, and Neal et al. (2017) suggested that computational models were best suited for testing models with multiple choices or processes. We return to this possibility in the discussion.

We capture the described dynamics with our final proposition.

Proposition 5. Realignment of endogenous uncertainty regulation with exogenous uncertainty is achieved by continuous processes of adaptation which change both an individual's preferred level of uncertainty and their exposure to exogenous uncertainty.

DISCUSSION

We have presented a theoretical model that specifies the role of uncertainty reduction and creation in a dynamic process of uncertainty regulation. Although it is well recognized that humans seek out uncertain and novel events (Clark, 2017), most theoretical approaches give a central role to uncertainty reduction. This emphasis on uncertainty reduction is not surprising for two main reasons: First, the experience of uncertainty is often aversive and threatening, evoking efforts to mitigate the negative experience; second, the source of uncertainty is often exogenous and not under the direct control of individuals, evoking efforts to cope and survive. Our model contrasts these observations with their conceptual counterpoints. The aversive nature of uncertainty is countered by its signal of opportunity and the potential to learn. The non-determinism of exogenous uncertainty is countered by individual agency that regulates uncertainty in the endogenous context and which, ultimately, can shape the exogenous context. In the following sections, we first explore theoretical implications for human agency as a positive source of uncertainty. We then explore management implications of the model in terms of the organizational practices or interventions that might support effective uncertainty regulation. Lastly, we consider how our model can be extended to incorporate multiple actors and multiple levels of analysis, thereby demonstrating its relevance for meso- and macro-level research in management.

Human agency as a positive source of uncertainty

Our model generates new insights into the link between human agency and uncertainty. While research in neuroscience and cognition has articulated how individuals generate uncertainty, this process is under-represented in organizational theories involving uncertainty. We believe a key reason for this under-representation is that the challenge of integrating

exogenous and endogenous uncertainty with individual agency has obscured the adaptive value of creating uncertainty. The exogenous context is typically viewed as a source of aleatory uncertainty that creates situations that are not fully knowable nor controllable (Knight, 1921). On the other hand, closed endogenous systems are potentially knowable but are also non-deterministic in the presence of human will (see Packard & Clark, 2019 for more complete discussion of free will). The intersection of exogenous uncertainty and human free will creates two fundamentally different approaches to uncertainty in management research as Jauch and Kraft (1986) have illustrated. They contrasted the approach of March and Simon (1958) which focused on internal management of uncertainty with the approach of Cyert and March (1963), which proposed actively influencing the environment to control uncertainty.

Our model bridges these approaches by specifying how individuals directly engage with uncertainty in the endogenous context and, through this process, engage indirectly with exogenous uncertainty. The model readily represents the process of uncertainty reduction that is typically studied in organizational research. More importantly, our model provides a process through which individual expansive agency in the endogenous context might influence the exogenous context over time. We have coined the term expansive agency as a form of proactive behavior that not only embraces uncertainty in a self-starting, future-oriented, and change-focused manner (Parker, Williams, & Turner, 2006), but functions to increase endogenous uncertainty and create opportunities for setting entirely new goals and learn about the means to achieve those goals. Similar to Alvarez, Barney, and Anderson (2013) in their discussion of entrepreneurial behavior, we argue that exploration through expansive agency not only discovers existing opportunities, but also builds new landscapes for action within which emergent behaviors create uncertainties for individuals themselves and for others.

We suggest expanding models of work performance (Carpini et al., 2017) to include situations where individual behavior not only aligns with different levels of exogenous uncertainty, but where opening behaviors can also increase exogenous uncertainty in order to fundamentally reshape tasks and work settings. Our line of reasoning echoes the concerns raised by Poulis and Poulis (2016) regarding a too narrow understanding of the law of requisite variety where actors build sufficient endogenous complexity to match the complexity of their environment. The authors make the case for actors' motivation to increase internal complexity beyond environmental complexity to be able to create disruption in their environment in the hope of "superior rewards in a transformed context" (Poulis & Poulis, 2016: 512).

Organizational practices for supporting effective uncertainty regulation

Individuals who effectively manage exploitation and exploration tradeoffs are more likely to contribute to organizational capabilities such as ambidexterity (Greco et al., 2019). In contrast to structural ambidexterity based on separate units for exploration and exploitation (Gupta, Smith, & Shalley, 2006), Gibson and Birkinshaw (2004) proposed that contextual ambidexterity can be achieved by building social processes that support integrative individual judgments in the face of conflicting demands. Our model suggests avenues through which organizations might influence information processing and behaviors in order to build these capabilities. The distinct elements of the uncertainty regulation process highlight the factors that are most important to consider.

Beginning with the role of attention to uncertainty, we have emphasized the adaptive value in noticing variability and unexpected events in the environment (Kozyreva & Hertwig, 2019). Yet many organizational factors can deter or minimize attention to uncertainties and subsequently reduce opportunities for learning. Individual limitations such as bounded rationality

and organizational routines that discourage proactive scanning (Sitkin et al., 2011) have long been recognized as factors that constrain the attention of decision makers (Ocasio, 1997). To counter these attention limiting factors, organizations must support means for individuals to allocate attentional resources to uncertainties that might signal opportunities for exploration. Reason (1997) introduced the concept of chronic unease to describe an organizational culture that motivates constant attention to risk. Similarly, a culture can be established that values continuous scanning for new opportunities not only by top executives, as discussed in the organizational literature (Hambrick, 1982), but by everyone in the organization.

The second possibility for organizational support of uncertainty regulation concerns individuals' appraisal of uncertainty as an opportunity for learning rather than a threat to be diminished. We have outlined the role of an uncertainty preference in shaping uncertainty appraisals. The determinants of uncertainty preference will be diverse and are likely to include historical factors unique to individuals, such as in building an orientation toward learning versus performance goals (Brett & VandeWalle, 1999). In addition, the uncertainty preference can also vary in different situations, for example, when organizations adopt stretch goals as discussed earlier (Sitkin et al., 2011) or when entrepreneurs' readiness to learn from failure changes as a function of the rate of failure (Fang He et al., 2018). Organizations can support more approach-oriented appraisals by framing uncertainty as a learning opportunity. The "f***-up nights" currently popular in the start-up scene are an example for this more positive approach to uncertainty. Greco et al. (2019) proposed that a reduced organizational emphasis on performance monitoring and a focus on longer term goals would encourage a culture that motivates more exploratory choices.

If attention and appraisal can be directed more effectively towards the positive aspects of uncertainty, choices between exploration and exploitation will become more balanced and the readiness to employ both opening and closing behaviors will increase. One possible mechanism to foster such a reorientation is psychological safety (Edmondson, 1999), which has long been discussed as an important influence on individuals' willingness to create uncertainty for themselves and others by voicing new ideas, concerns and criticism. Also, a broader use of the techniques subsumed under the concept of design thinking can be beneficial to push a more uncertainty-friendly work redesign where employees are inspired to not only co-create their own work processes, but to live the spirit of playful creativity and collaboration in their daily work (Gruber, De Leon, George, & Thompson, 2015).

Extending uncertainty regulation beyond the individual

Our model of uncertainty regulation was developed around individuals in their immediate work environment. We now consider how the model might be extended beyond the individual in two ways. First, we consider extension to an endogenous group context in which individuals generate uncertainty not only for themselves but also for others. This extension requires the introduction of more complex dynamics to account for the multiple sources of uncertainty with which an individual interacts. Second, we consider extension to the organization, which itself is an information-processing agent acting in an endogenous context and embedded within a wider exogenous context of economic, social, and environmental conditions.

Uncertainty creation or reduction by one actor will likely affect endogenous uncertainty of others. Feedback seeking and giving provides an example of uncertainty regulation across actors at the individual level (Harrison & Rouse, 2015). In the team and leadership literatures, many processes such as adaptive coordination (Grote, Kolbe, & Waller, 2018), ambidextrous

leadership (Rosing et al., 2011) and managing diverse teams (Hmieleski & Ensley, 2007), suggest a complex interplay between leaders' and team members' opening and closing behaviors. For example, Salvato (2009) showed how exploratory experiments conducted by individuals increased heterogeneity within designer firms, which was then shaped by managers into more homogenous capabilities for each firm. At the organizational level, de Vasconcelos Gomes, Salerno, Phaal, and Probert (2018) analyzed how new venture success depended on participatory management of uncertainties across firm boundaries, for instance by conducting collective learning experiments with technology suppliers.

Systematically capturing such processes within a framework of multi-actor uncertainty regulation will provide a more complete picture of the relationship between endogenous and exogenous uncertainty in work performance. A basic assumption would be that multiple actors will generally mean higher levels of uncertainty in the endogenous context and weaker impact of opening and closing behaviors by each individual actor. To explore this assumption, one should consider how one actor's opening and closing behaviors provide triggers for others' choices of exploration and exploitation and how this impacts effectiveness in achieving individual and collective goals. Building on such research, the next question to study would be whether actors influence each other's uncertainty regulation to a point where collective uncertainty preferences emerge which drive joint opening and closing behaviors. We suggest that computational modelling is well-suited to examine these intertwined processes of uncertainty regulation. This approach was implemented in the original research by March (1991) on exploration and exploitation in organizations and recently used to replicate his results (Chanda & Miller, 2018). Computational modelling has also been employed successfully for research into self-regulatory processes at the individual level (Vancouver et al., 2020) and is increasingly adopted for research

at the team (Kozlowski, 2015) and organizational level (Mauer, Wuebker, Schlüter, & Brettel, 2018) as well as multilevel systems (Cronin & Vancouver, 2019).

The second extension we consider is how the model might be applied to organization-level entities as they regulate uncertainty. The exploitation/exploration dilemma is a fundamental challenge for all adaptive systems so there is likely value in considering whether isomorphic processes might be specified at more aggregate levels of analysis. We suggest that entrepreneurship is an appropriate domain to begin to test our propositions at the organizational level, especially in light of the debate about the discovery and creation of entrepreneurial opportunities (Alvarez & Barney, 2007), which includes uncertainty at its core. Opportunity discovery triggers uncertainty reduction by collecting information about different options for realizing the opportunity. In the case of opportunity creation, the opportunity itself evolves and changes over time, whereby uncertainty is created and maintained. However, uncertainty creation has not been explicitly addressed in this debate to date. Applying our uncertainty regulation model to opportunity discovery and creation has thus the potential to both advance entrepreneurship research and provide a testbed for our model.

A related, and arguably the most obvious, field to apply our uncertainty regulation model to is innovation research. Benner and Tushman (2003: 249) noted, somewhat enigmatically, that “because of the shifting nature of innovation requirements embedded in technology cycles, organizations must develop capabilities to move with, if not shape, these cycles”. Disruptive innovation creates uncertainty for competitors and requires the innovating firm to retain sufficient internal capabilities to cope with the uncertainty generated (Christensen, Raynor, & McDonald, 2015). In a similar vein, Sitkin et al. (2011) have argued that implementing stretch goals, which most likely requires major innovation, is likely to be successful only if a firm has

sufficient slack to address the higher demands on managing uncertainty. Despite these considerations, most empirical innovation research has been mute on questions of uncertainty creation (Anderson et al., 2014). Even in science itself, where uncertainty creation should be daily business, research indicates a bias against novelty and the uncertainties it brings (Wang, Veugelers, & Stephan, 2017). A better understanding of the tensions between uncertainty creation and reduction can propel innovation research towards a new and more complete vision of what fruitful innovation entails. By integrating the motivation to achieve a preferred level of uncertainty into concepts of structural and contextual ambidexterity (Gibson & Birkinshaw, 2004; Gupta et al., 2006) and into paradox-inspired approaches to creativity (Miron-Spektor & Erez, 2017), specific mechanisms can be explored that lead to concurrent exploration and exploitation, and to successful generation and implementation of novel and useful ideas.

CONCLUSION

By proposing our model of uncertainty regulation, grounded in the alignment between endogenous uncertainty, individual uncertainty preferences, and effectiveness, we have extended current approaches that emphasize uncertainty reduction as a dominant motivational force. Our more balanced view, which incorporates recent advances in cognition and neuroscience research, includes the deliberate creation of endogenous uncertainty as a source of effective performance. This view holds promise for reconciling inconsistent findings and integrating evidence across different domains in management research to gain a fuller understanding of the dynamics involved in agentic goal striving. Uncertainty is often a threatening condition in organizations that should not be taken lightly. However, giving due consideration to its upsides and downsides not only enriches our theoretical understanding of organizational processes, but also opens new avenues for supporting creativity and learning in organizations. By emphasizing agency rather

than more reactive adaptation in uncertainty regulation, we also accentuate the responsibility that individual and organizational actors have to create contexts in which they can take advantage of uncertainty.

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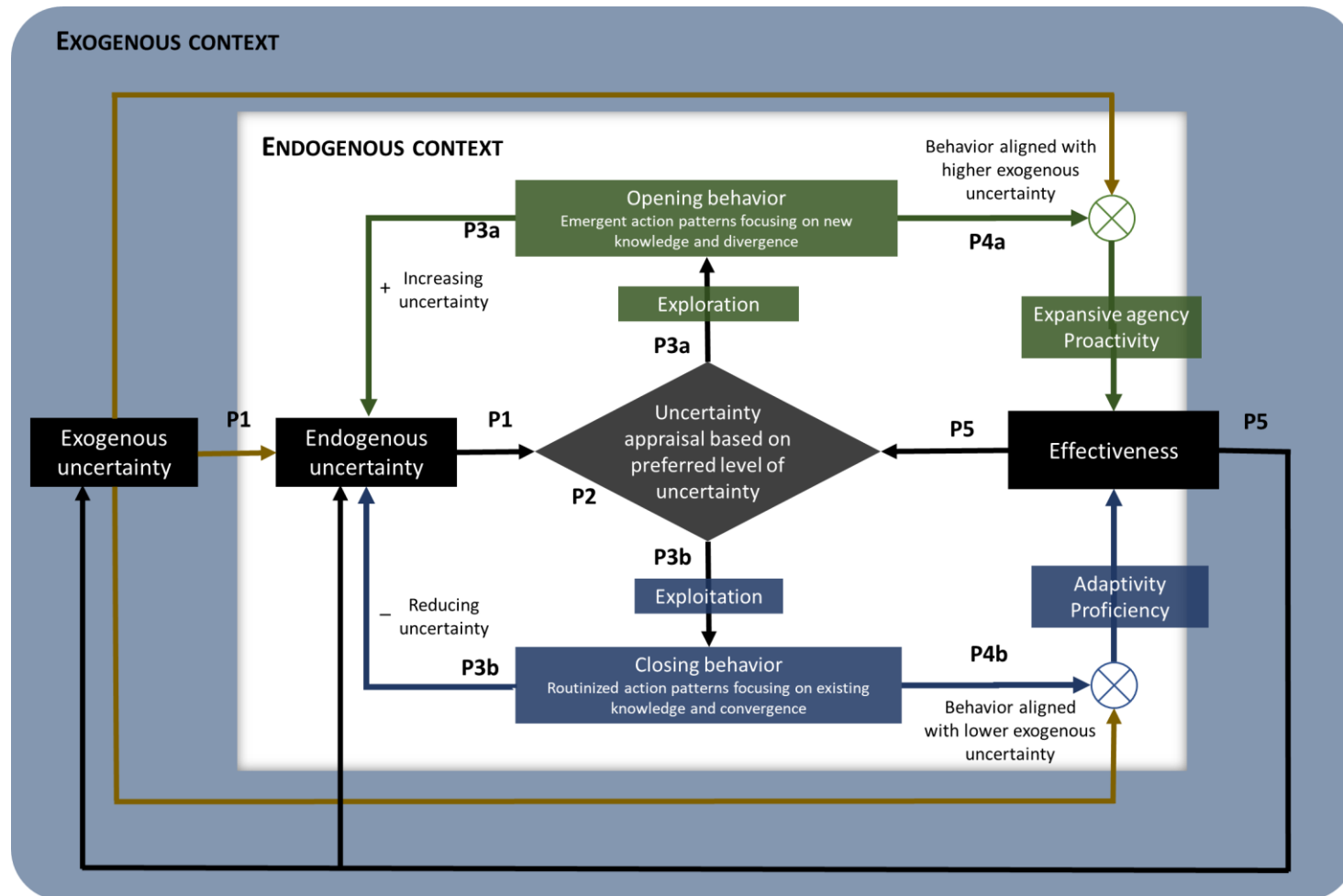
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FIGURE 1
Model of uncertainty regulation



Biographical sketches

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