Inside-out, outside-in, or all-in-one?

The role of network sequencing in the elaboration of ideas

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ABSTRACT

The structure of advice and support networks within organizations has a profound impact on the elaboration of novel ideas. We explore how the sequence in which individuals expose ideas to their network contacts affects their innovation performance. We argue that, during idea elaboration, inside-out network sequencing – that is, mobilizing input and support from inner-circle ties before outer-circle ones – yields an innovation performance advantage over outside-in network sequencing and all-in-one mobilization of network contacts. Inside-out network sequencing generates valuable early feedback and support from inner-circle ties that actively engage with ill-defined, ill-structured and uncertain ideas, and delays exposure to outer-circle ties until ideas can better withstand criticism from beyond the social circle where they emerged. We further contend that the benefits of inside-out network sequencing are amplified in environments that lack support for innovation. Using an analysis of survey data and archival innovation performance records for 301 R&D scientists and engineers in a large multinational firm, we find support for our predictions.

INTRODUCTION

The creative minds of individuals are an essential breeding ground for novel ideas and a critical driver of bottom-up innovation in organizations (Burgelman, 1983; Cheng & van de Ven, 1996; Perry-Smith & Mannucci, 2017). However, individuals pursuing novel ideas are rarely able to transform the original gist of an idea into a more compelling, elaborated proposition without the feedback and support of others inside their organization (De Stobbeleir, Ashford, & Buyens, 2011; Harrison & Rouse, 2015; Rouse, 2020). Drawing on colleagues to gain feedback and support in the elaboration of one's ideas can be a difficult process. Due to the ill-defined, ill-structured, and uncertain nature of early-stage ideas (Blair & Mumford, 2007; March, 2006), individuals face a dual risk in that they may see their high-potential ideas dismissed for the wrong reasons if they expose them to the wrong people at the wrong time, but also risk pursuing dead ends if they do not access colleagues' feedback and support in a timely fashion (Criscuolo, Salter, & Ter Wal, 2014; Kim & Kim, 2020; Mannucci & Perry-Smith, 2021; Mueller, Melwani, & Goncalo, 2012).

Extant research at the interface of networks and innovation has shed ample light on how the structure of intra-organizational networks facilitates the creative and innovative process (Burt, 2004; Perry-Smith, 2006; Tortoriello & Krackhardt, 2010). Yet, notable exceptions aside (Mannucci & Perry-Smith, 2021; Perry-Smith & Mannucci, 2017), it does not consider how individuals seeking to elaborate their ideas might “square the circle” of mitigating the risks of exposing early-stage ideas to colleagues while also leveraging the benefits of doing so. Following recent studies of network timing effects in the pursuit of creativity and innovation (e.g. Mannucci & Perry-Smith, 2021; Quintane & Carnabuci, 2016; Soda, Mannucci, & Burt, 2021), this study explores the question of how the sequence in which individuals expose their novel ideas to colleagues matters for their innovation performance.

We introduce the concept of “inside-out” network sequencing as the practice by which individuals elaborating novel ideas mobilize feedback and support from their inner-circle ties before their outer-circle ones. We argue that such an approach will help individuals outperform those who sequence their networks from the “outside-in” or those who go “all-in-one” by reaching out to all their contacts at the same stage of idea elaboration. Building on research on social circles (Dunbar, 1998; Kadushin, 1968), social cohesion around relationships (Reagans and McEvily 2003; Tortoriello & Krackhardt, 2010; Tortoriello, Reagans, & McEvily, 2012), and innovation in mature organizations (Battilana & Casciaro, 2013; Criscuolo et al., 2014; Dougherty, 1992), we contend that the nature of the feedback and support an individual receives from any given colleague – and hence the best timing of first exposure of an idea to them – depends on the extent to which that colleague is embedded in the individual’s inner or outer circle of network contacts. For this purpose, we conceptualize inner-circle ties as those network contacts with whom an idea creator shares more third-party connections – in that the idea creator and network contact draw from an overlapping pool of advice ties – and outer-circle ties as those contacts with few or no shared third-party connections – that is, contacts that operate in circles separate from the cohesive web of relations in the idea creator's inner circle. Inside-out network sequencing allows individuals to leverage the benefits of early feedback from inner-circle ties who are more likely to commit to spending time digesting ill-defined, ill-structured, and uncertain ideas, and to whose feedback the idea creator is receptive. At the same time, it allows individuals to shield early-stage ideas from outer-circle ties until they can better withstand the cold scrutiny of relative outsiders. Outer-circle ties are less likely to have the commitment and contextual knowledge to appreciate ideas at their earliest stages of elaboration, but their outsider perspective makes them ideally suited to offer complementary expertise and to externally validate ideas once they are more developed.

We examine the sequencing effects in individuals' network mobilization in an interview- and survey-based study of R&D scientists and engineers in a Fortune-500 corporation we call Neptune for reasons of confidentiality. Based on a survey of 301 R&D scientists and engineers and archival records of their innovation performance, we find that individuals that adopt an inside-out network sequencing approach are more likely to attain high innovation performance ratings than those who adopt outside-in or all-in-one approaches. We also find that the performance benefits of inside-out network sequencing are amplified in less supportive innovation contexts.

Our study contributes to theories of networks and innovation in three main ways. First, we demonstrate that, in addition to network structure and position (Burt, 2004; Perry-Smith, 2006; Tortoriello & Krackhardt, 2010), the sequencing effects of networks also matter. In so doing, we connect to a growing body of research that considers patterns of network mobilization to be an important behavioral aspect of networks (Burt & Merluzzi, 2016; Mannucci & Perry-

Smith, 2021; Smith, Menon, & Thompson, 2012). Second, our research brings into focus the strategic nature of networking in relation to the pursuit of novel ideas in established organizations. Adding to a growing body of research on strategic networking behaviors (Bensaou, Galunic, & Jonczyk-Sédès, 2013; Casciaro, Gino, & Kouchaki, 2014; Hallen & Eisenhardt, 2012; Ter Wal, Criscuolo, McEvily, & Salter, 2020; Vissa, 2012), we demonstrate that individuals elaborating creative ideas can outperform colleagues not only through the strategic pursuit of beneficial positions, but also by making savvy choices of who to involve when. Finally, building on prior work on how feedback and support can help individuals navigate hurdles in the elaboration of ideas (Battilana & Casciaro, 2013; Harrison & Rouse, 2015; Madjar, Oldham, & Pratt, 2002; Perry-Smith & Mannucci, 2017; Taylor & Greve, 2006), our study demonstrates that network mechanisms such as feedback depend on timing and embeddedness, and may backfire if mobilized at the wrong time.

THEORY AND HYPOTHESES

Idea elaboration in organizations

It is widely established that social networks play a critical role in the generation of novel ideas in organizations (Gómez Solórzano, Tortoriello, & Soda, 2019; Perry-Smith, 2006). Specifically, individuals who by virtue of the structure and composition of their networks are exposed to a more diverse set of inputs are at a “vision” advantage when it comes to seeing opportunities for recombinatorial novelty (Burt, 2004). Accordingly, it has been shown that having weak ties beyond one’s immediate social circle can be conducive to the generation of novel ideas (Mannucci & Perry-Smith, 2021).

In this study, we focus on how the mobilization of networks matters after ideas are first generated, that is, when idea creators seek to elaborate their ideas. Idea elaboration typically involves transforming an initial vague concept into a more detailed proposition (Perry-Smith & Mannucci, 2017). Idea creators typically turn a basic idea into a first proof of concept through an iterative process, switching between gathering initial evidence regarding an idea's technological feasibility and market potential and making improvements and adjustments to the initial idea (Van de Ven, 1999). Subsequently, idea elaboration also typically involves validation, whereby idea creators broaden the evidence base of an idea's potential through activities such as prototyping, lab testing, and initial market research.

When elaborating novel ideas, individuals have significant discretion to decide when to expose them to others (De Stobbeleir et al., 2011). Even those whose input has contributed to the generation of a novel idea will often be unaware of whether and how their input has been used and may not know about the idea unless its creator circles back to them (Obstfeld, 2005). Given the discretion thus afforded to individuals, we ask how those elaborating novel ideas should decide when to expose early-stage ideas and to whom. Two of the most fundamental properties of early-stage ideas, discussed below, mean that how individuals can best take advantage of their network contacts is not self-evident.

First, early-stage ideas tend to be ill-defined and ill-structured (March, 2006; Reid & de Brentani, 2004), which makes feedback necessary but difficult to acquire (Perry-Smith, 2014). On the one hand, to turn an ill-defined and ill-structured idea into a valuable innovation for the organization, individuals need to mobilize feedback and support from a wide range of colleagues. The notion of the "lone genius" who builds an innovation from basic idea through to proof of concept and validation without direct or indirect input from others is inconsistent with the observation that most innovations materialize through social interaction (Rouse, 2020; Simonton, 1999; Singh & Fleming, 2010; Sosa, 2011). Feedback is critical in helping to identify inconsistencies in logic and feasibility (Cronin & Weingart, 2007; Perry-Smith and Mannucci, 2017). On the other hand, when ideas are not yet fully formed in individuals' own minds (Csikszentmihalyi, 1997), it is not straightforward to obtain meaningful feedback. Because early-stage ideas are unlikely to fit existing organizational categories or frames (Blair & Mumford, 2007), it often takes time and cognitive effort for those hearing about an idea and its possible merits to envisage and understand it, which limits their ability to provide helpful feedback.

Second, early-stage ideas tend to be inherently uncertain (Berg, 2016; Dougherty, 1992; Perry-Smith & Mannucci, 2017). This uncertainty may be with respect to the size and nature of the business opportunity, the technical challenges to be faced, or indeed both. It is difficult to determine "whether a new idea is truly creative or dumb —brilliant or just plain foolish; […] the most creative and the stupidest idea often look the same at the early stages" (Katz, 2005: 23). Individuals need support and positive encouragement from colleagues to build compelling narratives, and evidence to persuade decision makers that their ideas will deliver significant benefits for the wider organization (Battilana & Casciaro, 2013; Sosa, 2011; Zhou, 1998). However, colleagues can recoil when they encounter ideas that do not fit existing organizational categories, routines, and goals (Criscuolo, Dahlander, Grohsjean, & Salter, 2017; Knudsen & Levinthal, 2007). Thus, exposing novel ideas to colleagues at an early stage carries a substantial risk of receiving negative or even dismissive reactions that may be demoralizing (Berg, 2016; Criscuolo et al., 2014; Kim & Kim, 2020; Lu, Bartol, Venkataramani, Zheng, & Liu, 2019; Mueller et al., 2012).

Taken together, these properties present individuals with a catch-22 situation when mobilizing networks in the elaboration of novel ideas: the ideas need input from others to advance and develop, but mobilization at the wrong time can undermine the creative process.

Some individuals might be politically savvy (Ferris et al., 2007), first exposing their early-stage ideas to those most committed to help, most tolerant of seeing immature ideas, and to whose input they are most receptive, while holding off from engaging those likely to be initially dismissive and impatient. Others may be less deliberate in trying to control awareness and perception of their ideas; for example, due to enthusiasm to broadcast their ideas widely from the outset (Amabile, 2000) or, conversely, to overly guard their ideas for fear of embarrassment or ridicule (Edmondson, 1999; Mueller et al., 2012).

As we will argue in more detail below, the nature of the feedback and support received from colleagues and, by extension, its usefulness in helping individuals elaborate their ideas into innovations depends on the degree to which a network contact belongs to the idea creator's inner or outer circle. Extant research characterizes inner and outer social circles (cf. Dunbar, 1998; Kadushin, 1968) either in structural terms – that is, in terms of the extent to which shared third-party connections mean there is substantial network overlap between a focal individual and a given network contact (e.g. Reagans & McEvily, 2003; Tortoriello et al., 2012) – or in relational terms, that is in terms of tie strength or emotional intensity (e.g. Mannucci & Perry-Smith, 2021). Although structural and relational properties of ties tend to be correlated (Reagans & McEvily, 2003), for the purpose of our study we conceptualize the distinction between inner- and outer-circle ties in terms of shared third parties. Inner-circle ties are those network contacts who draw from a shared pool of advice ties with the idea creator; thus, the greater the proportion of shared third-party connections, the greater the likelihood a network contact belongs to an individual's inner circle. In contrast, outer-circle ties tend to operate in separate "social worlds" with little to no overlapping connections with the idea creator; thus, the lower the number of common third parties, the higher the chances a network contact belongs to an idea creator's outer circle.

As we will explain in the next section, the extent of shared third parties that distinguishes inner- and outer-circle ties is at heart of our reasoning why individuals benefit from mobilizing their network contacts in a given sequence when seeking feedback and support for idea elaboration. Specifically, in building our arguments, we focus on two key differences between inner-circle and outer-circle ties that fundamentally alter the nature of feedback and support: the greater commitment of inner-circle ties, induced by the shared third parties that surround inner-circle relations (Reagans & McEvily, 2003; Tortoriello & Krackhardt, 2010; Tortoriello et al., 2012), and the greater information redundancy and contextual knowledge arising from the greater network overlap with inner-circle ties (Aral & Van Alstyne, 2011; Granovetter, 1973).

The benefits of inside-out network sequencing for innovation performance

We introduce the concept of *inside-out network sequencing* to capture how individuals mobilize inner- and outer-circle ties during different stages of idea elaboration. As depicted in Figure 1, we present inside-out network sequencing as a continuum. At the high end of the spectrum, individuals who expose their ideas gradually from their inner circle to their outer circle show high levels of inside-out network sequencing. At the low end of the scale, individuals either adopt an *outside-in* approach by mobilizing outer-circle ties before inner-circle ones, or an *all-in-one* mobilization approach that enlists all contacts at the same stage of idea elaboration. Our core premise is that inside-out network sequencing helps individuals elaborating novel ideas to achieve better innovation performance relative to outside-in sequencing or all-in-one network mobilization.

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Our justifications for this premise are as follows. First, individuals benefit from exposing their ideas to their inner-circle ties early. The additional commitment of inner-circle colleagues increases the patience needed to digest what might be, at least at first, ill-defined and ill-structured ideas (Gómez Solórzano et al., 2019; Reagans & McEvily, 2003). As such, this creates ideal conditions for candid, constructive feedback (Rouse, 2020). The willingness of inner-circle contacts to engage with and build on premature ideas can provide useful input and material support (De Stobbeleir et al., 2011; Mannucci & Perry-Smith, 2021; Ryan, 1982), for example, helping to reformulate the idea to make it more attractive to others in the organization (Deichmann & Jensen, 2018). Individuals may also be more receptive to feedback from those who are more committed (Levin & Cross, 2004) so that, for example, they spend more time rethinking an idea when inner-circle ties offer an alternative framing of the idea and its underlying assumptions (Perry-Smith, 2014). People are generally less hostile and defensive in response to feedback that is not based merely on immediate reactions but on deep engagement with the idea itself (Baer & Brown, 2012; Ilgen, Fisher, & Taylor, 1979), which is particularly beneficial given the vulnerability of "half-baked" ideas.

The ability of inner-circle ties to provide valuable feedback, despite the often ill-defined and ill-structured nature of early-stage ideas, is further boosted by the greater information redundancy that characterizes inner circles. Overlaps in knowledge allow inner-circle ties to better interpret partial and "noisy" bits of information in relation to early-stage ideas (Gavetti & Warglien, 2015; Shannon & Weaver, 1948) and, in their attempts to piece these bits together, they are more likely to identify logical inconsistencies (Cronin & Weingart, 2007; Hargadon & Bechky, 2006) and mistaken assumptions (Cross & Sproull, 2004). If not identified early, such issues may haunt the idea later, as individuals grow increasingly wedded to a chosen course and reluctant to deviate from it (Dane, 2010; Fuchs, Sting, Schlickel, & Alexy, 2019; Laureiro-Martínez & Brusoni, 2018). Thus, the principal value of engaging with inner-circle ties lies in their ability to offer alternative frames as opposed to providing diverse information (Perry-Smith, 2014) that might prove distracting when ideas are not fully formed (Csikszentmihalyi, 1997). At the same time, the greater access of inner-circle ties to contextual information about a novel idea helps to reduce perceived uncertainty and increases openness to new directions. Because ideas tend to be "sticky" to the context in which they are developed (Von Hippel, 1994), inner-circle colleagues will better understand the rationale and motivations behind a novel idea and thus be likely to see more of its potential and less of its "foolishness". They may also signal to the individual that these ideas are worthy of further pursuit, which may fuel the individual's passion to continue (Amabile, 2000; Zhou, 1998) in the face of the setbacks that individuals working on early-stage ideas inevitably face when attempting to turn their conception into reality (Perry-Smith & Mannucci, 2017; Van de Ven, 1999).

Our second justification is that individuals benefit from guarding their early-stage ideas from outer-circle ties at first, for reasons that mirror the benefits of involving inner-circle ties early. A relative lack of commitment means that outer-circle contacts lack the patience to properly digest ill-defined and ill-structured ideas, which undermines their ability to provide meaningful feedback (Kim & Kim, 2020). Similarly, a lack of information redundancy constrains the ability of outer-circle ties to see and evaluate how idea elements fit together (Burgelman, 1983; Reid & de Brentani, 2004). A lack of understanding of the context from which an idea originates (Von Hippel, 1994) means that outer circles may fail to appreciate the "adventurous" divergent stage of the creative process (Berg, 2016; Criscuolo et al., 2017; Mueller et al., 2012), and be much more uncertain of an idea's merits at this early stage. Because uncertainty fuels skepticism (Knudsen & Levinthal, 2007; Zhou, Wang, Bavato, Tasselli, & Wu, 2019), which is often rooted in fear that deviation from the status quo might disrupt established job roles and organizational operations (Ford, Ford, & D'Amelio, 2008), individuals risk their early idea-elaboration efforts being fatally undermined by engagement with relative outsiders who may be less tolerant of the ambiguities associated with a novel idea and less willing to take the idea creator's idea as a valid starting point to build on (Mannucci & Perry-Smith, 2021). Concerns over practical matters, frequently rife among those who lack context of where an idea comes from, can be a source of frustration and exasperation (Mueller, Melwani, Loewenstein, & Deal, 2018; Mueller et al., 2012), potentially leading individuals to abandon promising ideas, and thus increasing the incidence of "false negatives" in idea development (Mannucci & Perry-Smith, 2021).

Finally, while individuals will be better off if they hold outer-circle ties at bay to start with, the feedback and support of such ties will be valuable once ideas are more developed. Non-redundancy in informational terms may make it difficult for outer-circle ties to contribute meaningfully at first, but further down the line knowledge from outside an individual's immediate circle might help to sharpen, refine, and hone an idea, and address perceived weaknesses (Hansen, Mors, & Løvås, 2005; Harvey, 2014; Taylor & Greve, 2006). Ideas may not have been ready for the cold scrutiny of outer circles early on, but once ideas are more developed, individuals can benefit from assessment and/or validation by those with some distance from the idea (Koch & Leitner, 2008) who how may better appreciate if and how an idea or innovation might fit in the wider architecture of an organization's markets, technologies, or systems (Henderson & Clark, 1990). Idea creators may also be more receptive to incorporating non-redundant information from outer-circles once they have worked out their idea in a greater level of detail; individuals will be particularly open to diverse input, because that is what they expect to receive from such ties (Perry-Smith, 2014). Thus, early exposure to outer circles risks the abandonment of unripe yet promising ideas, whereas later involvement of such ties increases the chances that ideas are dismissed for the right and not the wrong reasons, effectively reducing the risk of "false positives" in idea development (Mannucci & Perry-Smith, 2021). When they are more developed, ideas have become stronger and can better withstand unwarranted outsider criticism. In addition, at this point, outer-circle ties need less commitment and less information overlap to appreciate the ideas. Indeed, at later stages, it is helpful and, perhaps, even necessary to enlist feedback and support from outer circles to advance idea elaboration (Mueller et al., 2018; Podolny & Baron, 1997), and it may be possible to leverage any criticism to one's advantage by demonstrating that the idea can withstand such "external" scrutiny (Battilana & Casciaro, 2013; Brennecke, 2020; Mueller et al., 2012).

Taken together, a high degree of *inside-out* network sequencing best enables individuals to turn ideas into innovations for their organization. It helps them overcome flaws early on, while balancing the prevention of premature criticism with helpful outsider input once ideas are more advanced. By having inner-circle interactions precede outer-circle ones, individuals can mitigate the risks of dropping good ideas or continuing to work on bad ones. In contrast, an *outside-in* approach undermines innovation performance because individuals miss out on the benefits of high-quality inner-circle feedback while also failing to mitigate the risks of early exposure to outer circles. Similarly, *all-in-one* network mobilization implies that individuals forgo the opportunity to receive either valuable early or valuable late feedback. Thus, we hypothesize:

> *Hypothesis 1 (H1). Inside-out network sequencing in idea elaboration is positively associated with individual innovation performance.*

The contingent effect of unsafe spaces for innovation

The benefits of inside-out network sequencing for individual innovation performance are rooted in contrasting reactions to novel ideas between an individual's inner and outer circles. This contrast is likely to be more pronounced in work contexts that are more hostile to innovation, and less pronounced in “safe spaces” where innovation is celebrated and encouraged (Rouse, 2020; Scott & Bruce, 1994). We delineate four work environment characteristics that restrict the support that individuals receive – or perceive that they receive – for their innovation efforts.

First, in certain work contexts managers overseeing innovation place greater emphasis on accountability than autonomy (Bailyn, 1985; Kanter, 2000). Under such conditions, individuals may feel less supported in their freedom to explore novel directions, and risk their creativity being curtailed by excessive oversight and premature concerns about the feasibility and viability of ideas that need time to be proven (Criscuolo et al., 2014; Gambardella, Panico, & Valentini, 2015). Second, leaders in the work environment, such as decision makers and opinion leaders, may fail to create a supportive climate for innovation (De Stobbeleir et al., 2011; Scott & Bruce, 1994); for example, by making individuals feel uncomfortable in proposing ideas that deviate from the status quo, or dismissing without serious consideration requests for additional resources, however reasonable they might be (Edmondson, 1999). Third, work contexts may be less supportive if fewer slack resources are available for idea exploration (Levinthal & March, 1981; Voss, Sirdeshmukh, & Voss, 2008). Low-slack environments, having limited time and financial resources for experimentation and risk-taking outside formally budgeted projects, restrict individuals’ ability to be openly “playful” (Agrawal, Catalini, Goldfarb, & Luo, 2018; Miron-Spektor, Ingram, Keller, Smith, & Lewis, 2018). Finally, certain work environments may be hostile toward ideas that risk cannibalizing existing assets (Chandy & Tellis, 1998). Successful innovation often involves old technologies and products being superseded by new ones, thereby jeopardizing competencies that firms have often built over time and potentially undermining existing revenue streams and business models (Tripsas & Gavetti, 2000; Tushman

& Anderson, 1986). While it is recognized in some work contexts that replacing old with new is necessary to sustain competitive advantage, other contexts are characterized by deeply rooted fears of cannibalizing existing assets (Danneels, 2008).

Under conditions of limited support for innovation, it is even more important for individuals to mobilize inner-circle ties before they expose their ideas to a wider circle of contacts. In such environments, individuals have less room to maneuver when it comes to figuring out how ill-structured and ill-defined ideas might be adapted to fit the organization, so calling on the early help of committed inner-circle ties will be vital. Equally, it will also be even more important to delay exposure to outer-circle ties until the idea is better defined and the evidence base supporting it has become stronger, because in a less supportive environment such contacts may be exceedingly wary of committing time and energy to their colleagues' ideas when they appear messy or nebulous. Although exposure to outer-circle ties remains important and should not be avoided altogether, individuals who turn too early to such parties for help and support may find they are rebuffed, because their ideas may be seen as incongruent with a focus on delivering outcomes aligned to exigent goals and expectations (Ford et al., 2008). The lack of contextual information and of knowledge overlap that characterizes outer-circle ties will reinforce dismissive and skeptical reactions toward early-stage ideas in environments with a strong emphasis on accountability, where leadership lacks commitment to innovation, slack resources are limited, and/or existing assets are keenly protected (Knudsen & Levinthal, 2007). Under these circumstances, individuals benefit from calling on the help of committed inner-circle ties earlier whilst postponing exposure to until greater accumulated evidence means ideas can better withstand scrutiny. Thus, the greater contrast in unsupportive environments in terms of the type of feedback received from inner and outer circles increases the need for a more careful, gradual roll-out of early-stage ideas among committed, embedded parties before the ideas are revealed to the outer circles of an individual's network. As a result, the benefits of inside-out network sequencing over other approaches will be amplified in unsupportive work contexts:

> *Hypothesis 2 (H2). The association between inside-out network sequencing and innovation performance is stronger when individuals operate in less supportive work environments.*

METHOD AND CONTEXT

Research context

Our study is situated in a large technology-intensive multinational firm, which we call Neptune[1]. Neptune considers its R&D scientists and engineers as the primary engine for delivering on its ambition to offer the most scientifically advanced products in the broad range of markets in which it operates. Although innovative ideas will only be successfully launched if they are linked to market needs and Neptune's overall strategy, it is the expectation that scientists and engineers play a critical role in enabling innovation through bottom-up initiatives. Neptune's R&D scientists and engineers therefore represent an ideal population in which to study to whom individuals expose their novel ideas and when, and how such choices affect their innovation performance. Individuals have discretion to decide when to mobilize feedback and support from specific connections in their network, but the reality is that a broad range of colleagues will need to be involved at some stage or other to advance the elaboration of their ideas through the organization. The research study was sponsored by an internal Neptune taskforce, overseeing talent development in R&D. Specifically, our research was driven by the organization's desire to

[1] The present study is part of a larger stream of work with the same organization (see Criscuolo, Salter & Ter Wal, 2014; Salter, Ter Wal, Criscuolo & Alexy, 2015, Ter Wal, Criscuolo & Salter 2017), including one study that partly relies on overlapping data (Ter Wal, Criscuolo, McEvily & Salter 2020). We comment on overlaps wherever relevant.

understand how it could better support its R&D workforce in driving innovation, with leadership having voiced concerns that the exceptional technical skills of its scientists and engineers were not always leveraged to the best extent.

Insights from exploratory interviews

As a first, exploratory step we conducted interviews with both R&D scientists/engineers and R&D managers in Neptune, across sites in North America, Europe, and Asia, and across a broad range of product divisions. In total, we held one-hour interviews with 40 R&D scientists and engineers, and 30 R&D managers (see also, Ter Wal, Criscuolo, McEvily & Salter, 2020). The interviews revealed a significant tension among the scientists and engineers: although there was no doubt that the organization expected them to lead in the production of novel ideas, many indicated that, in reality, organizational skepticism toward novel ideas frustrated their attempts to push such ideas forward. Members of the task force that sponsored our study signaled that some scientists and engineers struggled to bring their ideas to fruition, suggesting that a lack of support could cause them to work on the wrong ideas or be preventing them from abandoning dead-end ideas sooner. One R&D manager we interviewed explained:

> It's always good to talk before doing too much. If you talk about it with a couple of people and you don't have a firm 'no' [you continue, but] if [you] see a killer issue, 'okay, stop it now, don't be too stubborn.'

With this tension in mind, the second objective of the interviews was to understand how R&D scientists and engineers sought to overcome such challenges. This led us to ask specific questions about who they tended to guard their ideas from, and who they would involve early on in the elaboration of their ideas. We were struck by the variety of approaches adopted by individuals in terms of when and from whom they sought feedback. One interviewee, about to be relocated from a secluded office to an open-plan desk, lamented no longer being able to control who would know about their early-stage experimentation:

> [There are] people who get their energy from being alone. They need their space, they need their downtime, they need the quiet. […] I don't expose things [to anyone] until I'm completely convinced.

In contrast, another interviewee said they had no reservations in talking to very senior colleagues from the very outset when exploring a novel idea:

> So I talked to the director in process right from the beginning.

The interviews also brought to light a range of considerations that motivated scientists and engineers to confide early-stage ideas in some colleagues while guarding them from others. They emphasized, for example, that it can be challenging to articulate ideas at the earliest stages, making it difficult to get meaningful feedback. One R&D scientist reported:

> When I get an idea, it's messy. I don't know quite how to relate it and how to describe it in words that my managers or the budget holders may, necessarily, understand.

This was echoed by a scientist who said early-stage ideas are often not ready for feedback:

> Because if you engage too early with others and you still do not know what is going to be the key point of difference you get a lot of feedback, but it's not useful.

Despite the risks and difficulties of early exposure, many R&D scientists and engineers stressed the importance of early-stage feedback from trusted parties. One of them explained:

> The old friends network, shall we say, is always a very effective one [to consult early] because they are the people [with] whom you can have some fairly frank and open discussions about the technology. […] So they will be honest enough to say where they think there could be some significant flaw in either the work, the logic or the ideas you're bringing forward. […] So, I think, the way I work is probably start with the internal, more local network of people and then, thereafter, […] build the case and get […] broader understanding, look on a broader basis.

Another R&D scientist explained that they would involve different people at different stages. They would enroll their inner-circle ties early on, reaching out to outer-circle ties later. In our terminology, they adopt an inside-out network sequencing approach:

> There would be two filters or two layers of support I would talk to. […] The first step is assessing the opportunity with people I trust just to get a feel of their passion meter, whether they feel the same excitement about the idea. Maybe not experts in the area but just people I trust. That can be my mentors, friends, my partner even. And the second step is trying to determine the feasibility by talking to internal or external experts.

Meanwhile, many interviewees emphasized the importance of guarding their ideas to avoid premature evaluation. One R&D engineer said:

> You're going to keep the idea confidential until you know it works and then maybe you go and get funding. If you do this too early you kill the idea even before it has hatched.

One significant challenge in the early stages are questions in relation to concerns that will take time to resolve:

> You need to have the data, because the moment you come people say, 'Oh, it's expensive. Oh, it's difficult. Oh, we need to test it. Oh, can we make patents?' So you actually need to have the answers to at least some of them already so that you can attract […] resources to make it a proper project.

Another R&D scientist made a similar point, also emphasizing the need to obtain input and support from colleagues outside one's immediate social circle in later stages:

> As soon as we scope out the work, as we define what this is and if we have some ideas where this may go, we need a sponsor to help us to create the connections on the scale needed to make it happen. [… At that stage] I may have done some prototyping, so I can top this with […] some data, limited data, so then it will be easier for the sponsor to enroll and help us.

Interviewees mentioned that building an evidence base of an idea's potential and feasibility was critical, and that withholding the idea from most people until then was imperative:

> What I would try to do is to get some sort of proof of concept, so until I had some sort of data in my […] hand, or some sort of device that showed that it worked, I probably wouldn't tell that many people about it.

Taken together, our interviews paint a rich and varied picture of how and why R&D scientists and engineers enlist the support of different colleagues at different stages when elaborating novel ideas. This encouraged the research question motivating this study: How does the sequence in which R&D scientists and engineers mobilize feedback and support from colleagues for the elaboration of novel ideas affect their innovation performance?

Survey design and empirical setup

To answer this question and test our hypotheses, we developed three slightly different, online surveys that were sent to all 622 senior R&D scientists and engineers, 969 R&D managers and 80 R&D directors in Neptune (see also, Ter Wal, Criscuolo, McEvily & Salter, 2020). We developed these surveys in close collaboration with the project sponsors in Neptune, using feedback from focus groups. After an initial invitation from Neptune's CTO and two reminders from its head of Human Resources, we achieved a response rate of 61% (N = 370) from its R&D scientists/engineers, 43% from its R&D managers, and 46% from its R&D directors. Although the bulk of our variables are constructed using responses from the scientists and engineers, our moderator variables are derived from data collected from the other two surveys.

After eliminating surveys with incomplete data in relation to the variables used in our study, we were left with 301 responses from R&D scientists/engineers, representing 48% of the original population. We tested the representativeness of this final sample to the full population and found no significant differences in terms of tenure, seniority, gender, or business division; however, individuals with higher innovation performance ratings were overrepresented in our sample. Provided that higher-rated individuals are less inclined to adopt careful inside-out networking, any bias their overrepresentation might introduce would lead to more conservative coefficient estimates of its effect on innovation performance. We include population weights in our regression analyses to counter any bias arising because of this overrepresentation; our results are robust to model specifications without weights. Neptune provided access to archival data, including basic HR information used to coordinate survey invitations, such as seniority, business division, tenure, gender, and career progression, as well as individual innovation performance ratings. We linked this data to the survey responses using a matching algorithm that converted respondent email addresses to anonymous ID numbers, used for both survey and archival data[2].

Dependent and independent variables

Innovation performance. We measure the innovation performance of R&D scientists and engineers by leveraging Neptune's annual performance review system (Criscuolo, Salter, & Ter Wal, 2014; Ter Wal, Criscuolo, McEvily, & Salter, 2020; Ter Wal, Criscuolo, & Salter, 2017), which allocates individuals to three bands based on an elaborate assessment of their contributions to innovations that generate revenue or reduce costs for the organization, or – for those working on upstream projects – offer significant promise of achieving such outcomes further down the line. Thus, the rating system is intended primarily to assess an individual's ability to develop "good ideas" (Burt, 2004).

To enable the rating process, each individual is required to complete a performance review document with detailed and verifiable evidence of their contributions to five main projects on their work plan, agreed with their line manager at the beginning of the year. Additional work outside these formal work plans can also be documented. Completed review documents are then compared across pools of scientists/engineers of the same rank by a committee of line managers who allocate individuals to one of three performance rating bands

[2] Our efforts to collect interview, survey and archival data from Neptune were part of a broader research program. Specifically, Ter Wal, Criscuolo, McEvily and Salter (2020) also drew from these data. As that study uses a different unit of analysis (manager-technologist partnerships instead of technologists) and focuses on different aspects of networks (regular equivalence as opposed to sequence effects), the present study makes an independent contribution. For reasons of consistency, and given the overlap in dependent variable, we use the same control variables where possible. Our results are robust to including the main variable in Ter Wal, Criscuolo, McEvily and Salter (2020) – namely, dual networking – in the analyses of the present paper.

following a forced distribution. By examining these documents collectively, the assessors seek to judge the validity of an individual's claims against those of others and to disentangle individual contributions made to collective endeavors.

The criteria for innovation performance focus on specific contributions such as new and improved products, processes, and technologies, as well as broader contributions such as capability development and the exploration of new technological directions. Given that different individuals pursue different types of contributions – for example, product versus process innovation, patented inventions versus those kept secret, capability development versus product development – we believe that, in our context, the aggregate innovation performance rating is more suitable as a dependent variable than counts of patents, products, or process innovations. Although performance ratings are inherently subjective, the committee-based evaluation process is akin to a multi-rater assessment that, at least in part, mitigates subjectivity biases. We obtained the annual ratings six months after undertaking the survey. Therefore, the ratings cover outcomes associated with the six months for which the survey gathered network mobilization patterns and six months after.

Inside-out sequencing. We collected network data in three steps. First, we included name generator and name interpreter questions (cf. Burt, 1992; Podolny & Baron, 1997) to map individuals' core network relations within the organization. Thus, we used four name generator questions (see Appendix A) to solicit up to 11 names or initials of colleagues the respondent had interacted with in the six months before the survey. A name interpreter question obtained rank, business division, and frequency of communication for each contact listed.

Second, we asked respondents to complete an alter–alter matrix to indicate any pairs of network contacts who they believed would seek information or advice from one another (see

Appendix A). We characterize inner- versus outer-circle ties in terms of the number of shared third-party ties (Reagans and McEvily 2003; Tortoriello & Krackhardt, 2010). The greater the fraction f_{ij} of ties held by individual *i* that are also held by *j*, that is, the more shared third-party ties *i* and *j* have, the greater the likelihood that *j* belongs to *i*'s inner circle (and vice versa for outer-circle ties). On average, respondents reported 2.3 shared third-party ties with their network contacts (SD = 1.63, Min = 0, Max = 9). Consistent with our theory, we find that inner-circle ties are more likely to be peers with overlapping knowledge.[3] We find substantial variation in whether individuals listed their line manager as part of their inner circle.[4]

In the third step, building on the name generator and interpreter approach, we developed a new scenario-based question to capture network mobilization. Specifically, we asked respondents to think of an innovative idea they had recently had and to indicate, for each contact in their network, when (at which stage of idea elaboration) they would first let that person know about the idea (see Appendix B).[5] The different stages of idea elaboration were inspired by NASA's levels of technological readiness, ranging from "Almost immediately after first getting the idea" (1) through "After formulating basic concept or application" (2) and "After first proof of concept" (3), to "After validation in a lab/trial environment" (4).[6] Our respondents were familiar with this terminology, our interviews having made us aware that a modified version of

[3] Specifically, inner-circle ties (i.e. with below-median f_{ij}) were more likely than outer-circle ties to be the same grade as the subject (ego) (49% vs 43%, prtest $z = -1.93$, $p = 0.053$). The level of expertise overlap, measured by respondents indicating their expertise on 50 strategic technology areas, was greater for inner-circle ties (mean = 2.77) than outer-circle ones (mean = 2.51, $t = -1.69$, $p = 0.09$).

[4] Among respondents who identified their line manager as part of their network, 53% included them in their inner circle and 47% in their outer circle.

[5] The timing of network mobilization is defined as the stage of idea elaboration in which an individual *first* exposes an idea to a network contact to obtain input or feedback. Once a contact is thus mobilized, they are "in the know" and may continue to contribute at later stages of idea elaboration, but empirically we observe only the stage of first exposure/mobilization.

[6] Individuals could also indicate if they would never disclose their idea to a given contact or to choose "Not applicable". In calculating our inside-out network sequencing variable, we excluded such ties (N = 91 out of a total of 2,021).

the NASA system was in use in Neptune. Scenario-based questions are well-suited to measurement of behavioral responses, particularly where actual past behaviors may be difficult to recall (Golden, 1992). Provided that respondents can relate to the scenario, a scenario-based approach should activate the same decision logic that would have driven past behaviors and thus provides reliable measurement of behavioral patterns (Aguinis & Bradley, 2014). However, the approach is not without limitations. As scenarios capture expected rather than actual behavior, it is not possible to observe whether and why individuals might deviate from their intent. Relatedly, in our setup it is difficult to establish to what extent the reported mobilization is representative of the approach taken for other ideas, which limits our ability to explore whether patterns of network mobilization might vary by the nature of the idea, its context, or its situation. In our robustness checks, we explore whether patterns of network mobilization differ between those individuals rated by their peers as more creative and those rated as less creative, and in our discussion, we comment on how resolving these questions offers valuable directions for future research.

On average, individuals activated 48.4% of their contacts immediately after coming up with an idea, 33.6% after formulating the idea's basic application, 12.6% post proof of concept, and the remainder (5.4%) after they had validated their idea. We note that, regardless of whether individuals worked in the front end of innovation or further downstream, they mobilized similar proportions of their ties in each of the four stages.[7] This suggests that respondents related to the stages of idea elaboration in similar ways regardless of their positioning in Neptune's innovation

[7] Our survey asked respondents to report the number of projects they worked on during the previous year that reached a critical implementation gate in the organization's stage-gate process. Because downstream R&D work is beyond this gate, we allowed respondents to respond with "Not applicable" and treated any who did so as downstream R&D workers. A χ^2 test confirms the distribution of network mobilization across stages does not differ between upstream and downstream workers.

process. This is consistent with our qualitative insight that all R&D scientists and engineers in Neptune are expected to come up with ideas for how to improve products, processes, technologies, and brands, and not just those working in the early stages of this innovation process.

Although in our context there was a tendency for individuals to be eager to disclose their ideas at early stages of elaboration, there is ample variance in how scientists and engineers distributed first exposure of their ideas among their network contacts. Few individuals mobilized all their contacts in a single stage: among the 301 individuals in our sample, only 14 enrolled all of their contacts in the first stage, and only 4 did so in the second stage. Instead, R&D scientists and engineers tended to spread network mobilization across stages: 125 (41%) of them mobilized their contacts across two stages, 116 (38%) across three stages, and 42 (13%) across all four stages. In terms of the timing of inner- versus outer-circle tie mobilization, we find that, on average, inner-circle ties were mobilized earlier than outer-circle ones: the average proportion of shared third-party ties with contacts approached immediately after idea generation (0.406) is significantly higher than the proportion sought after validation (0.346, *t*-test = -2.13, p = 0.033). However, mobilizing inner-circle ties before outer-circle ones is by no means the default; an outside-in approach is also prevalent: in 42% of all reported alter–alter pairs mobilized at different stages, the outer-circle tie is mobilized *before* the inner-circle one.

To capture the extent to which R&D scientists and engineers followed an inside-out network sequencing strategy, we derived an index with two components: the first captures the extent to which tie mobilization is spread across the different stages (Stirling, 2007); the second measures the consistency in timing in terms of mobilizing inner-circle ties before outer-circle ones. Thus, inside-out network sequencing (*IONS*) for individual *i* is defined as:

$$IONS_i = -1 \cdot \sum_{s=1}^{4} (C_{is} \cdot p_{is} \ln p_{is})$$

where p_{is} is the proportion of i's contacts in each of the four stages s in the timing of network mobilization, the term $p_{is} \ln p_{is}$ expresses the level of concentration/dispersion of tie mobilization across stages, the multiplication by –1 reverses the scale such that higher values indicate more dispersed mobilization in terms of timing, and C_{is} captures the consistency in the timing of network mobilization for each stage, in terms of mobilizing inner-circle before outer-circle ties, calculated as the average consistency C_{ijks} across all of i's alter–alter combinations jk where either j or k (or both) are mobilized in stage s. Consistency, ranging from 0 to 1, is high (low) if alters jk are mobilized at the same stage with a similar (different) fraction of shared third-party ties (f_{ij} vs f_{ik}). It is also high (low) for any pair of alters mobilized at different stages in which the tie mobilized earlier shares more (fewer) third-party ties with i than the tie mobilized later. Formally:

If $s_j = s_k$ $\qquad C_{ijks} = 1 - |f_{ij} - f_{ik}|$

If $s_j < s_k$ $\qquad C_{ijks} = \frac{(f_{ij} - f_{ik}) + 1}{2}$

If $s_j > s_k$ $\qquad C_{ijks} = \frac{(f_{ik} - f_{ij}) + 1}{2}$

Thus, an individual demonstrates a high value of *IONS* if they have a large spread of network mobilization across the idea elaboration stages, and they mobilize network contacts with whom they share more third-party ties before those with whom they share fewer such ties. *IONS* is low for individuals who concentrate their tie mobilization in fewer stages, either early or late, or who are "out of sync" in terms of their order of inner- and outer-circle tie mobilization. This is depicted in Figure 2, which illustrates how *IONS* is computed, given a network of seven alters (the average network size in our sample) and approximately average density. It shows how inside-out network sequencing varies when the dispersion across stages increases or decreases, and when ties are mobilized in a consistent or inconsistent order. The figure shows that inside-out network sequencing can vary independently of the network structure. Further, the distribution of inside-out network sequencing values for respondents with below- and above-median constraint does not differ significantly (p = 0.106),[8] providing additional corroboration of our contention that inside-out network sequencing and network structure can vary independently of one another.

-------- Insert Figure 2 about here --------

Moderator variables

Emphasis on accountability. Using responses from our survey of R&D managers, we measure how much emphasis managers at a given site and division place on accountability in managing the R&D scientists and engineers who report to them. Because we could not find any suitable preexisting measure, we developed a new six-item scale, intended to measure both the degree of autonomy granted to R&D scientists and engineers, and the degree of managerial accountability. The six items loaded on two factors, accounting for 54% of the variance using the principal component method. The first factor, measuring accountability, has four items (see Appendix C); the Cronbach's alpha (0.61) and inter-item correlations (between $r = 0.20$ and $r = 0.43$) are acceptable values for the internal reliability of a newly developed scale with less than ten items (Churchill Jr, 1979).[9] We used this factor to derive a measure of the accountability to managers that R&D scientists and engineers experience in their division and site, by averaging

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[8] This is the *p*-value of the goodness-of-fit test proposed by Goldman and Kaplan (2018) and implemented by the *distcomp* command in Stata, where the null hypothesis is that two cumulative distribution functions are identical.
[9] The second factor of two items, which measures emphasis-on-autonomy, had a low Cronbach's α of 0.44 and therefore could not be used in our main analysis. As a robustness test, we constructed a single-item scale for autonomy, retaining the item with the stronger factor loading ("I leave scientists/engineers a lot of freedom to decide what to work on and when") and obtained results consistent with those reported here using the emphasis-on-accountability scale.

the responses of the R&D managers.[10]

Lack of innovation support. To capture the extent to which leaders in a division are unsupportive of individuals' innovation efforts, we leveraged two questions. First, to identify relevant leaders in a division we exploited a question, included in the surveys of both the R&D scientists/engineers and R&D managers, that asked individuals to nominate up to four people involved in taking important project-related decisions and whose opinion was critical during project review and evaluation. The collective nominations from the surveys resulted in a list of influential managers for each division. Second, we exploited a question from the survey of R&D scientists/engineers about the perceived level of support received from the managers with whom they most closely collaborated. We used a six-item scale, adapted from a supervisory support scale developed by Greenhaus, Parasuraman, and Wormley (1990) (Cronbach's $\alpha = 0.92$; see Appendix C). To obtain a measure of the perceived *lack* of support for innovation from decision makers and opinion leaders in a division, we reverse-coded the items of this scale and averaged the responses in relation to each of the nominated managers in a division. On average, we had 16.7 evaluations of leaders' (lack of) support for innovation in a division.

Lack of organizational slack. To derive a measure of the level of slack resources available within a division, we used responses from the survey of R&D directors. Our interviews had made it clear that R&D directors were best placed to answer questions about slack resources, because they are responsible for managing the financial budgets of their units. We used a four-item scale developed by Danneels (2008) (Cronbach's $\alpha = 0.81$; see Appendix C), and reverse-

[10] Of the 94 division-site combinations in our sample, we could not derive an emphasis-on-accountability measure for 28, because of non-response from R&D managers in those divisions and locations. For these missing cases, we replaced the value of the variable with the division-level average. For the remaining 66 combinations, we had an average of five responses. However, we derived our variable based on a single response in 13 cases. A check with HR records confirmed that these were sites with a small number of managers working in those divisions and therefore our measure can still be considered representative of the level of accountability that scientists/engineers experience in those working environments.

coded the items relative to the original scale to measure the *lack* of slack resources. Where we received responses from multiple directors for the same division, we computed the average.

Reluctance to cannibalize. To capture the extent to which a division provided an unfavorable context to R&D scientists and engineers when developing ideas that challenged the status quo and could potentially make existing assets and investments obsolete, we used a five-item scale developed by Chandy and Tellis (1998) and adapted by Danneels (2008) (Cronbach's $\alpha = 0.70$; see Appendix C), incorporating it into our survey of R&D directors. We judged the latter as best suited to assessing the willingness of a division to cannibalize, because they are responsible for strategic decision-making at the divisional level. We reverse-coded the items relative to the original scale to obtain a measure of reluctance, as opposed to willingness, to cannibalize existing assets, and averaged scores whenever we received multiple responses from the same division.

Control variables

To exclude alternative explanations of innovation performance, we control for job characteristics, individual attributes, and social network variables.

Job characteristics. First, we control for *Relative speed to promotion*, coded as 1 if the focal individual had been promoted to their current rank faster than peers of the same level. To derive this measure, we leveraged HR records on rank, year of entry, and year of attainment of current rank for the full population of R&D scientists and engineers in Neptune. This variable is expected to account for unobserved heterogeneity in quality because most R&D scientists and engineers in Neptune are hired straight from university and promotion-from-within is the norm in Neptune. Second, we control for rank by including a dummy variable (*Junior*) coded as 1 for R&D scientists and engineers in the lowest of three ranks, and 0 for those in the higher two. We added a third job characteristic control variable to measure how long an individual has spent working in their current job role (*Job tenure*). Fourth, we account for the level of *Managerial support* that individuals receive in their work (Oldham & Cummings, 1996) by using the focal individual's response to the survey question concerning managerial support that we used for our associated moderator variable, *Lack of innovation support* (see above). Fifth, because it may be more difficult to recognize contributions that will have an impact on the market in the distant future, we control for whether the innovative activities of the focal individual are long- or short-term in nature: the variable *Research portfolio time horizon* is equal to the proportion of their projects that are expected to be commercialized more than two years down the line. To derive this variable, we used the answers to a question in our survey in which we asked respondents when their five most important projects were expected to reach the market (less than 1 year; 1 to 2 years; 2 to 5 years; more than 5 years). We also include five sectoral dummies to account for differences across similar divisions that are not captured by our moderator variables.

***Individual attributes*.** We control for gender (*Female*) to account for potential gender bias in the assessment of innovation performance. We also include a measure of *Intrinsic motivation*, which has been shown to affect creativity (Amabile, 1996), based on an eight-item scale adapted from Rynes, Gerhart, and Minette (2004); a factor analysis led to a two-factor solution, with four items corresponding to intrinsic motivation (Cronbach's $\alpha = 0.63$).

Social network variables. Our theory pertains to how network sequencing affects performance outcomes above and beyond the well-established influence of network structure. Therefore, we control for the level of *Network constraint*, calculated in relation to an individual's ego network and its reporting of alter–alter ties, using the formula proposed by Burt (1992; 1998). Network constraint has been used in past research to measure redundancy in sources of knowledge and a resultant lack of opportunity to recombine ideas, and has been found to be negatively associated with innovative performance and creativity (e.g. Burt, 2004; Perry-Smith, 2006; Soda et al., 2021; Zou & Ingram, 2013). Network constraint varies with a network's size, density, and hierarchy (Burt, 2004)[11]. For undirected, binary network data such as ours, network constraint is higher for smaller networks, those with a higher density of alter–alter ties, and those with lower centralization; that is, in ego networks with fewer structural holes (Everett & Borgatti, 2020). In addition, it was recently shown that people with more constrained networks may be more prone to temporal myopia (Opper & Burt, 2021), which may in turn negatively affect their innovation performance (Levinthal & March, 1993). Further, although innovation performance evaluations in Neptune are based on input from multiple managers and follow a standardized procedure, we recognize that they could still be affected by the visibility of an individual from the perspective of the managers involved in the rating process. Therefore, we also control for an individual's *Prominence* in the organization, calculated as the total number of nominations a focal individual received from all respondents to our survey as a provider of advice (Kilduff & Krackhardt, 1994).

Estimation approach

Given the categorical nature of the innovation performance rating and given that a Wald test rejected the parallel regression assumption ($\chi^2 = 35.92$, $p < 0.001$), we estimate our models using an ordered probit model. We cluster the standard errors by a focal individual's rank to account for innovation performance ratings following a forced distribution within the three seniority ranks, which could introduce autocorrelation in the error terms for individuals of the same rank.

[11] Average network size is 6.58, with a standard deviation of 1.95. As is conventional in network studies, network size is not included in our regression models because of its typically high negative correlation with network constraint (r = -0.71).

We also mean-centered the *IONS* and moderator variables to ease interpretation of the coefficient estimates.

-------- Insert Table and Table 2 about here --------

RESULTS

Table 1 provides the summary statistics and correlations for the variables included in our study. Given the ordinal nature of our dependent variable, pairwise Pearson correlation coefficients with continuous variables such as our inside-out network sequencing index cannot be interpreted as measures of co-variation. However, comparison of average levels of inside-out network sequencing across the three performance rating bands (top, middle and bottom) supports the presence of an association between inside-out network sequencing and innovation performance, albeit not a linear one: bottom-rated individuals show lower levels of inside-out network sequencing (0.461) than middle- and top-rated ones (0.489, t = 1.289, p-value = 0.099), but we find no statistically significant difference in levels of inside-out network sequencing between those bottom- and middle-rated (0.470) and those top-rated (0.485, p-value = 0.289).[12] The scatter plot in Figure 3 further illustrates the raw association between inside-out network sequencing and innovation performance rating, both for the sample as a whole and for individuals who operate in less supportive work contexts. For ease of interpretation, it aggregates observations by decile of inside-out network sequencing, plotted against the proportion of individuals in each decile that received a top or middle rating. The graph supports the notion that, on average, individuals with higher levels of inside-out network sequencing receive more

[12] Although these statistics suggest inside-out network sequencing differentiates between bottom performers vs the rest rather than top performers vs the rest, the Brant–Wald test, which tests whether the parallel regression assumption is violated for each variable in an ordered logit, confirms that the coefficient for the inside-out network sequencing is identical across the binary regressions (bottom rating vs middle and top ratings; bottom and middle ratings vs top rating) (χ^2 = 0.12, p-value = 0.73). The overall result of the Brant–Wald test suggests that the parallel regression assumption is violated (χ^2 = 35.92, p-value < 0.001), which justifies the use of the ordered probit model in our study.

positive innovation performance evaluations, and that this association tends to be stronger for individuals who operate in a work environment that is less supportive of innovation.

-------- Insert Figure 3 about here --------

Table 2 reports the ordered probit analysis regressing the individual innovation performance rating against the *IONS* index and the control variables. Model 1 shows our baseline model including only our control variables. As expected, R&D scientists and engineers who have been promoted to their current rank more rapidly than average receive higher innovation performance ratings, as do those who received greater support from their managers, and those of longer job tenure. We also find intrinsic motivation and prominence to be positively associated with innovation performance. We find a negative association between network constraint and individual performance, supporting the established argument that larger, less dense networks richer in structural holes are more conducive to innovation (e.g. Burt, 2004; Perry-Smith, 2006; Soda et al., 2021; Zou & Ingram, 2013).

Model 2 tests Hypothesis 1, which predicted a positive association between the degree of inside-out network sequencing and the innovation performance rating. In support of this hypothesis, we find a positive and significant coefficient for inside-out network sequencing (β = 0.63, $p < 0.01$). An increase from its mean to one standard deviation above its mean increases the probability that an individual receives the highest grade of innovation rating by 9.3 percent. This corresponds to an increase from the baseline probability of 0.47 of achieving the highest innovation rating to one of 0.51. The same increase in inside-out network sequencing reduces the likelihood of receiving the lowest innovation rating by 7.6 percent, from 0.28 to 0.24.

Models 3 to 6 each incorporate one of the four moderator variables to test hypothesis H2, which predicted that the effect of inside-out network sequencing will be amplified for individuals who work in less supportive innovation environments. In Model 3, we find a positive and significant interaction effect between inside-out network sequencing and *Emphasis on accountability* ($\beta = 1.83$, $p < 0.01$). Figure 4A shows that in work contexts with greater emphasis on accountability, R&D scientists and engineers are more likely to achieve a top innovation performance rating if inside-out network sequencing is high. Model 4 shows that the interaction term for leaders' *Lack of innovation support* is also positive and significant ($\beta = 0.42$, $p < 0.001$), with the caveat that, as shown in Figure 3B, the difference in the predicted probability of achieving a top innovation rating is significant only when levels of inside-out network sequencing are low (<0.35; 20% of our sample). This suggests that the performance penalty for not adopting an inside-out network sequencing approach is more pronounced in work contexts where leaders' support for innovation is weak, whereas the benefits of high levels of inside-out network sequencing are similar in both supportive and unsupportive work contexts. In Model 5, we find the interaction between inside-out network sequencing and *Lack of organizational slack* to also be positive and significant ($\beta = 1.01$, $p < 0.001$). Figure 3C shows that when R&D scientists and engineers work in divisions with limited availability of slack resources the positive effect of inside-out network sequencing on innovation performance is amplified. Lastly, we find a similar pattern when we consider the contingent effect of the *Reluctance to cannibalize* existing assets. In Model 6, the interaction effect with this variable is positive and significant ($\beta = 1.02$, $p < 0.001$). Figure 3D shows that the moderation of a division's reluctance to cannibalize is significant for R&D scientists and engineers with higher levels of inside-out network sequencing (>0.35; 80% of our sample).

Robustness checks

We performed a range of additional analyses to test the robustness of our results. First, we explored an alternative dependent variable to innovation performance rating. Although the rating process is designed to capture the value of novel ideas that carry promise but may not eventually be implemented, individuals working on such earlier-stage ideas may not always have their ideation efforts recognized in their performance rating. Therefore, we used a more direct measure of individual ideation performance as an alternative dependent variable, namely a self-reported measure of the number of projects, in the year preceding our survey, that reached the stage-gate that marks the start of the implementation stage (Mean = 1.12, S.D. = 1.11, Min = 0, Max = 6) (Salter, Ter Wal, Criscuolo & Alexy, 2015). Because not all R&D scientists and engineers work in the front end of the innovation process, this innovation performance variable is only available for a subset of our initial sample (N = 212). We estimated a Poisson model and found that inside-out network sequencing is positively associated with ideation performance (β = 0.36, p-value < 0.001). Holding other continuous variables at their means and setting significant dummy variables to 1, a one-standard-deviation increase of inside-out network sequencing from the mean increases the predicted number of projects reaching the implementation gate by 15.6%.

Second, because there are two components in our inside-out network sequencing index, that is, dispersion of tie mobilization across different stages and consistency in timing of inner- vs outer-circle tie mobilization, we wanted to assess whether our results are driven by one or both of these elements. We therefore re-estimated our main model, first replacing our inside-out network sequencing variable with the dispersion index ($-1 \cdot \sum_{s=1}^{4} p_s \ln p_s$), and then with the consistency in timing measure ($\sum_{s=1}^{4} C_s$), and found the coefficients for both variables to be positive and statistically significant (β = 0.33, p < 0.001, and β = 0.32, p = 0.002, respectively). Relatedly, our operationalization of the distinction between inner- and outer-circle ties is based on the extent of shared third-party ties; it does not consider the strength or communication frequency of the focal tie. Thus, to gauge the role of communication frequency, we recalculated our inside-out network sequencing index, weighting the fraction of shared third-party ties f_{ij} with communication frequency. The revised measure will be at its highest when individuals mobilize high-frequency ties with many shared third-party ties very early, and low-frequency ties with no shared third-party ties very late. We find that this revised measure correlates substantially with the original measure ($r = 0.70$). All our results, except those for the moderating effect of the work environment's reluctance to cannibalize existing assets, remain substantively unchanged when we substitute the original measure with this revised one.

Third, although we control for unobserved heterogeneity in individual performance by including the relative speed to promotion in our models, this variable might not account for more recent changes in individuals' innovation performance. We therefore re-estimated our model testing H1 and controlled for the self-reported innovation performance rating received for the year preceding our survey. Because not all respondents reported this information in our survey, our sample size dropped to 251 observations, but we still find support for our main hypothesis: the degree of inside-out network sequencing has a positive and significant effect on innovation performance ($\beta = 0.84$, $p < 0.001$).

Fourth, because of variations in size of division or location, individual work contexts may vary in the numbers of colleagues with relevant expertise who are readily available to provide feedback. For example, some R&D sites have high proportions of junior R&D staff and it is conceivable that they may be engaged relatively early in the idea elaboration process, skewing inside-out network sequencing values. To address this, we ran an ANOVA model to test whether inside-out network sequencing showed greater variance between divisions (and locations) than within them, but we did not find evidence of this (F-test = 1.12, $p = 0.314$, for divisions; F-test =

1.20, $p = 0.243$, for sites). We also computed inside-out network sequencing excluding junior R&D professionals and found continuing support for our Hypothesis 1 ($\beta = 0.83$, $p < 0.001$).

Finally, one assumption that we have made throughout our study is that the approach taken by individuals in disclosing their ideas to their contacts is not contingent on the type of idea involved. Although we observed that the timing of network mobilization does not significantly differ between those working in the front end of innovation and those working further downstream, basing our empirical approach on a scenario-type question prevents us from directly measuring idea characteristics. Thus, to further gauge how the radicalness of an idea may affect network mobilization timing, we leveraged a question in our survey of R&D managers that asked them to evaluate the creativity of up to two of the scientists/engineers with whom they worked most closely, using ten items from the 13-item creativity scale developed by George and Zhou (2001) (Cronbach's $\alpha = 0.87$).[13] If our assumption holds, we would expect to see no differences in inside-out network sequencing between individuals judged highly creative, with ideas that are more radical and path-breaking, and those rated as less creative and more likely to develop incremental ideas. Consistent with this expectation, the result of the *t*-test comparing the mean value of inside-out network sequencing between groups with creativity above and below the mean is not statistically significant (*t*-test = 0.14, *p*-value = 0.885). Although such information was not available for our full sample, it does provide some reassurance that network mobilization approach is not a function of the type of idea for which individuals are seeking feedback.

DISCUSSION

This study has introduced the notion of inside-out network sequencing, defined as the practice of

[13] Due to non-responses R&D managers rating R&D scientists' and engineers' creativity, we have creativity scores for 181 of the 301 individuals in our sample; if a subject received multiple assessments, we averaged the scores.

individuals elaborating novel ideas to mobilize feedback and support from their inner-circle ties before their outer-circle ties. We show that inside-out network sequencing is associated with an innovation performance advantage relative to either outside-in network sequencing or mobilizing all network contacts in a single stage. This performance effect is manifest over and above that of network constraint established in the existing literature (e.g. Burt, 2004; Perry-Smith, 2006; Soda et al., 2021; Zou & Ingram, 2013). We suggest that this effect derives from early candid, yet constructive feedback from committed inner-circle parties who are best placed to digest and contribute to ideas that are often ill-defined and ill-structured, while avoiding early exposure to outer-circle contacts who, because of a lack of contextual knowledge, may inappropriately dismiss promising yet immature ideas, but can subsequently be enrolled to help validate ideas when they can withstand scrutiny from beyond the immediate social circle in which they were developed.

Implications for theory

This paper offers three broad contributions to theories of networks and innovation. First, in introducing the concept of inside-out network sequencing and its counterfactuals – outside-in network sequencing and all-in-one network mobilization – we demonstrate the sequencing effects of networks. Network research has traditionally emphasized the role of network structure and position in explaining individual performance differences (Burt, 2004; Perry-Smith, 2006; Soda, Tortoriello, & Iorio, 2018; Tortoriello & Krackhardt, 2010). In emphasizing the effects of network sequencing, we connect to a growing stream of research that considers patterns of network mobilization an important behavioral aspect of networks (Burt & Merluzzi, 2016; Mannucci & Perry-Smith, 2021; Smith et al., 2012). Sequencing effects offer an additional layer of explanation of how networks, or rather networking, enable or constrain outcomes and complement predominant structural effects. In other words, while networks and their structure are critical "contexts for action" (Burt, 2004: 354) that shape the information and power advantages attainable by individuals by virtue of advantageous positions, we show that individuals' actions within these contexts translate into variation in who-involves-whom-when, which in turn explains differences in individual performance. Thus, when developing innovation in large mature organizations, individuals pursuing novel ideas need not only to know the right people; they need to call on them at the right time. Because early-stage ideas need time and effort to mature and develop, early feedback and support from committed insiders, typically with overlapping, "redundant" information, helps bring ideas up to a level at which they can withstand outsider scrutiny and at which they are ready to incorporate input and suggestions from those with "non-redundant" information. Thus, individuals can mitigate the dual risk of dropping good ideas or continuing to work on bad ones by having inner-circle interactions precede outer-circle ones.

A second, related contribution revolves around the strategic nature of networking in relation to early-stage ideas. Our research adds to a growing body of research on strategic networking behaviors (Bensaou et al., 2013; Casciaro et al., 2014; Hallen & Eisenhardt, 2012; Ter Wal et al., 2020; Vissa, 2012) by bringing into focus the day-to-day decisions of individuals in leveraging their network connections, and the performance implications of these in terms of creative work. Although serendipitous and/or planned opportunities to discuss bottom-up ideas will arise for everyone, some will be better able to leverage such opportunities than others. More savvy individuals carefully judge – in spontaneous and planned exchanges alike – which network contacts are best involved first. Our study demonstrates that individuals pursuing creative ideas can outperform their peers not only by exploiting better network positions, but also by making savvy choices about whom to involve when. Those who strategically withhold their early-stage ideas from some while deliberately seeking early input from others can give themselves a meaningful advantage over those more oblivious to the social context in which ideas can advance. Strategic deliberations about whose input and support will best help to advance ideas at different stages proves to be a critical political skill required to formulate high-quality novel ideas and achieve high innovation performance (cf. Ferris et al., 2007).

Such deliberations are particularly important in work contexts in which support for innovation is limited (De Stobbeleir et al., 2011; Scott & Bruce, 1994). In such contexts, rather than indiscriminately shielding their ideas from all of their colleagues, individuals can particularly benefit from leveraging the “safe spaces” (cf. Edmondson, 1999; Rouse, 2020) in their network in which early ideas can be nurtured ahead of exposure to the “cold” scrutiny of the wider organization. Hostility toward novel ideas might be more widespread than often assumed (Berg, 2016; Mueller et al., 2012). Neptune, the organization we studied, has innovation at its very heart, yet – as in many large organizations – early ideas that diverge from the status quo are often skeptically received by the wider organization, requiring idea creators to tread carefully when discussing early-stage ideas even in organizations where novelty is officially prized. Given our findings, we would expect the benefits of inside-out network sequencing to be even stronger in less supportive organizations. In such contexts, it will be even more important to call on the help of committed and trusted parties to reshape and reformulate ideas in ways outsiders will be more receptive to, as failure to do so – and exposing ideas to outsiders before then – is likely to lead to fierce opposition from those who resist any deviation from the status quo (cf. Battilana & Casciaro, 2013). It is less clear how idea creators might best operate in outright hostile settings. In such circumstances, it might be that even confiding early in inner-circle ties is strewn with pitfalls, as the commitment to engage with half-baked ideas may be lacking even among those contacts with whom the idea creator shared many overlapping connections. Conversely, in extremely supportive settings it is conceivable innovators might not need to tread quite so carefully in avoiding early exposure of their ideas beyond their inner circle. Future research may explore how network sequencing effects may play out in a range of contexts.

Third, our study demonstrates that important network mechanisms in the development of innovations, such as feedback and support, are time- and alter-dependent. The elaboration of innovative ideas is a journey full of potential hurdles (Perry-Smith & Mannucci, 2017); the need to strengthen early-stage ideas with help from colleagues while avoiding needlessly dismissive initial reactions presents creators with a catch-22 situation. Building on insights that established how complementary insights from colleagues and their feedback and support help individuals to successfully navigate such hurdles (Battilana & Casciaro, 2013; Harrison & Rouse, 2015; Madjar et al., 2002; Taylor & Greve, 2006), and that feedback can have both positive and negative effects on creative endeavor (De Stobbeleir et al., 2011; Harrison & Rouse, 2015; Kim & Kim, 2020), our study shows that feedback and support from certain colleagues can backfire if mobilized at the wrong time.

These findings corroborate as well as complement prior arguments and findings as to the role of networks in idea elaboration. Perry-Smith and Mannucci (2017) postulate that the informational non-redundancy of weak ties – and, by extension, outer circles – is critical for the *generation* of ideas, and that strong ties, or those in the idea creator's inner circle, are beneficial for the *elaboration* of ideas. Subsequently, they report experimental evidence that tie strength, albeit indirectly through mediators, does indeed aid the elaboration of ideas (Mannucci & Perry-

Smith, 2021). Our results corroborate the importance of "strong", inner-circle ties for idea elaboration in pursuit of creativity and innovation outcomes, while also adding new insights by unpacking the idea elaboration phase into multiple sub-stages and documenting how both strong and weak ties can aid innovation performance when mobilized at the right time. Although outsiders are likely to have contributed important insights that allowed creators to generate novel ideas in the first place (Burt, 2004; Perry-Smith & Mannucci, 2017), they will often be unaware of whether or how their input has been incorporated into novel ideas, leaving the idea creator the discretion as to whether and when to involve them for feedback and support in the elaboration stage (De Stobbeleir et al., 2011; Obstfeld, 2005). While prior research showed that outer-circle ties are critical for obtaining a diversity of inputs for the recombinatorial process of idea generation, our findings indicate that they should be kept out of the loop until ideas have been worked out to some level of detail, and that they should only actively contribute to an idea's further development at the later stages of idea elaboration. Taken together, outer-circle ties function as information channels that underpin idea creators' vision advantage at the idea generation stage, and act as providers of feedback and support for ideas that can withstand scrutiny from relative outsiders in the later stages of idea elaboration.

Managerial implications

With the realization that creativity has a strong social dimension, organizations have given more attention to supporting the networking approaches of their employees. Our study contributes to thinking about how to effectively encourage networking via managerial actions. First, because we demonstrate that network sequencing matters and yet many individuals appear to make poor choices with respect to network mobilization, it is important to inform and encourage individuals to give more consideration to how they go about gaining support and feedback for their ideas.

We found performance outcomes were compromised for those individuals who brought their innovative ideas to outer-circle ties immediately, with little regard to the reactions that ill-defined and ill-structured ideas would elicit from those lacking the commitment to digest them and/or an understanding of their context. Those pursuing innovation need to find safe spaces among inner-circle contacts in which to nurture and elaborate their ideas, preparing them to withstand subsequent evaluation and criticism from outer-circle ties. At the same time, however, we found that some individuals waited too long to engage outer-circle ties (or failed to do so entirely), cleaving too closely to their inner circle. Without the diversity of perspective of outer-circle ties, individuals risk their ideas lacking sufficient maturity and being inadequately templated to win the support of key organizational actors. The critical issue is to find the "sweet spot", drawing on insights from both inner and outer-circle contacts at the right times. Given that it is difficult for organizations to disentangle promising creative ideas from those that are "plain foolish" (Katz, 2005; March, 2006), we believe that network sequencing strategies should be taught to R&D scientists and engineers. Such training could yield gains for organizations in helping their R&D talent to discard dead-end ideas sooner, to correct flaws in promising ideas earlier, and to avoid demoralizing feedback that may lead them to mistakenly abandon valuable but unripe ideas.

Our study also speaks to the importance of organizational context in determining when considered inside-out network sequencing approaches are most necessary. We show that in units that lack support for innovation, engaging outer-circle ties too early can be very costly to idea elaboration. Careful management of slack resources, careful balancing of autonomy with accountability, careful consideration of how innovations may displace important existing assets and revenue streams, and leadership that unambiguously supports novelty and innovation can each help mitigate the risk of needlessly compromising the creative talent of R&D workers who might lack savviness in their day-to-day network mobilization decisions.

Limitations and future research

This paper has some notable limitations, which beget important future research questions. First, our study is based on a single organization, presenting a challenge for generalizability. Although the organization we studied operates in a diverse array of product markets and conducts R&D across a wide range of technologies at multiple international sites, its HR practices, such as promotion-from-within, are similar throughout. As a result, our findings may, in part, be reflective of the particular social networks within this specific organizational context, and it would be instructive to examine network sequencing in alternative organizational contexts. Relatedly, this study focuses on networks within organizations, as this was the common pattern among our respondents' networks. However, it would be useful to map network sequencing inside and outside an organization to understand how potential innovators seek to mobilize and integrate external resources when developing innovations within their organization.

Second, our use of scenario-based questions in the measurement of network mobilization timing has limitations too, capturing expected rather than actual behavior. People may not always do in practice what they said they would in theory. For example, individuals might intend to approach a given person about an early-stage idea, only to find that body language in an encounter where they might do so causes them to change their mind. It is also difficult to establish to what extent the idea that respondents had in mind when answering the scenario question is representative of the approach they would adopt for other ideas. As a result, we are unable to discern whether network mobilization patterns might differ according to the nature of the idea (e.g. conventional vs path-breaking; novice in field vs expert in field), its context (e.g. core vs non-core in relation to strategic objectives), or the situation (e.g. does or does not build largely on the work of others). Thus, future research could shed light on how each of these factors might conceivably affect the individual propensity for engaging in inside-out network sequencing, as well as the benefits of doing so. Relatedly, our measure of innovative performance has a rather short time horizon: a single year. Radical innovations are likely to take longer to bring to fruition and might, therefore, benefit from a different network sequencing strategy. Future research could explore how radical innovators can best sequence their network mobilization to surmount the significant hurdles often placed in their way in more established organizations. Finally, in terms of approach, future research could adopt a more direct route in order to capture variance in how individuals seek feedback and support for different ideas; for instance, using diary-based methods to monitor interactions as ideas proceed through their developmental stages.

Third, in our conceptualization and measurement of inner- and outer-circle ties, we focused on the structural aspects of network relationships, specifically the social cohesion around relationships in terms of shared third-party ties (Tortoriello et al., 2012). Although relational qualities such as tie strength tend to correlate with social cohesion (Reagans & McEvily, 2003), we did not directly observe how tie strength matters for the sequence in which ties are best mobilized during the elaboration of novel ideas. While social cohesion affects the benefits of network sequencing through the hypothesized commitment and information redundancy effects, tie strength may also matter, for example because idea creators are more comfortable confiding uncertain ideas to their most trusted colleagues. Future research may help further disentangle considerations of tie strength and social cohesion in network sequencing.

Fourth, our study has shed light on the performance implications of different network sequencing approaches but has not directly explored why and how such differences arise. We suggest that confidence may play a critical role in this regard, and would expect that its effects could break two ways depending on whether it is backed up by a strong track record. Thus, one might expect confidence to reduce any tendency to adopt the careful inside-out network sequencing approach, but also that failure to adopt such an approach might backfire for individuals whose confidence is not supported by a strong track record. Overconfidence may be the very reason why individuals fall into the trap of outside-in or all-in-one sequencing. Besides exploring the role of confidence, future research could explore the roles of political skill (Ferris et al., 2007) and personality and cognition factors (Casciaro et al., 2015) in individuals' proclivities to pursue a considered inside-out network sequencing strategy in preference to the approaches we found to be less effective in our study.

Finally, as we have focused on the role of sequencing effects in the *elaboration* of ideas, we do not observe how networks and network mobilization may have contributed to the very *generation* of ideas (Mannucci & Perry-Smith, 2021), or their developmental journey toward implementation (Lu et al., 2019; Perry-Smith & Mannucci, 2017). In addition, the idea elaboration stage may need further unpacking in future research. Our theory focuses on the relative sequence, rather than the exact stage of idea elaboration, in which certain ties are best mobilized. We believe this is justified, because individuals might differ in the level of evidence, and thus at which idea elaboration stage, at which they feel comfortable exposing their ideas to their different circles. Future research may investigate this further by examining directly how the strength of the evidence base of an idea's merit and feasibility affects the willingness of an individual to expose their ideas to others and the performance implications of doing so.

CONCLUSION

Bottom-up innovation in organizations crucially depends on the ability of individual employees to develop novel and useful ideas; yet transforming the original gist of an idea into an elaborate compelling proposition is rarely a solitary activity. Often the success of idea creators to do so is ascribed to those with resourceful networks that offer rich opportunities for feedback and support. The notion of inside-out network sequencing complements this view by explicating the sequence effects of networks. Good ideas tend to come from individuals with networks rich in structural holes, but these ideas may become more compelling and credible by virtue of savvy choices in network sequencing that enable idea creators to fully leverage the opportunities their network affords.

Table 1: Descriptive statistics and pairwise correlations

		Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Innovation rating *	1.62	0.79	1.00	3.00														
2	Inside-out network sequencing	0.47	0.19	0.00	0.92	0.06													
3	Emphasis on accountability	-0.06	0.49	-1.82	2.31	-0.04	0.03												
4	Lack of innovation support	2.22	0.43	1.00	4.42	0.00	0.10	-0.02											
5	Lack of organizational slack	5.47	0.95	2.50	6.75	-0.09	0.05	0.00	0.11										
6	Reluctance to cannibalize	2.32	0.63	1.00	3.28	0.03	-0.03	-0.02	-0.10	-0.30									
7	Relative speed to promotion	0.67	0.47	0.00	1.00	0.19	0.03	0.07	0.07	-0.05	0.03								
8	Junior	0.78	0.42	0.00	1.00	0.08	0.04	0.07	0.07	0.02	-0.15	-0.07							
9	Job tenure	6.41	3.37	1.00	20.00	0.17	-0.04	-0.14	-0.02	-0.03	0.01	0.10	-0.01						
10	Managerial support	5.84	1.15	1.00	7.00	0.10	0.04	-0.04	-0.06	0.03	0.07	0.16	0.00	-0.09					
11	Research portfolio time horizon	0.50	0.33	0.00	1.00	0.00	-0.10	0.00	-0.17	-0.06	0.03	0.10	-0.18	-0.05	-0.12				
12	Female	0.24	0.43	0.00	1.00	0.02	0.03	0.03	-0.06	0.04	-0.02	0.03	0.04	-0.20	-0.02	0.05			
13	Intrinsic motivation	-0.02	1.09	-5.78	1.73	0.17	-0.04	0.02	0.01	0.03	-0.03	0.18	-0.02	0.00	-0.01	0.11	0.12		
14	Network constraint	0.43	0.14	0.13	1.13	-0.02	-0.20	0.01	-0.04	0.00	0.05	-0.08	0.08	0.07	0.11	-0.07	-0.08	0.03	
15	Network prominence	4.21	4.99	0.00	35.00	0.13	-0.06	-0.08	-0.08	0.00	0.04	0.10	-0.58	0.04	0.05	0.20	-0.05	0.11	-0.08

Note: correlations greater than |0.117| are significant at the 5% level; N = 301. We mean-centered our independent and moderator variables in our regressions but show the original values here.

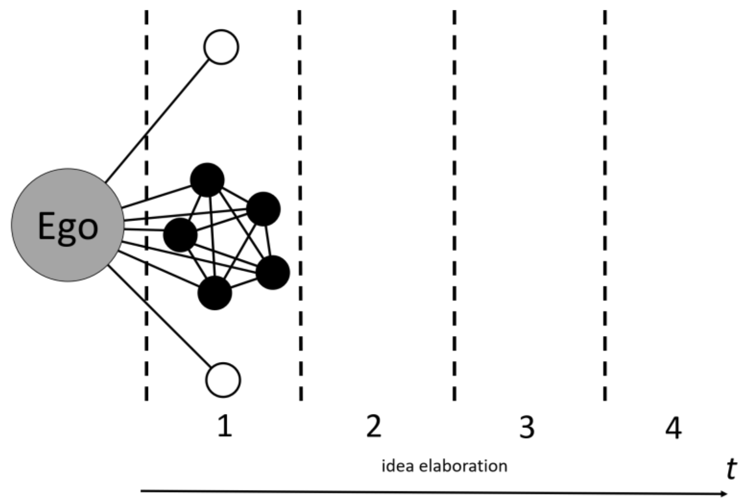
* Pairwise Pearson correlation coefficients cannot be interpreted as measures of co-variation between an ordinal variable (i.e. innovation rating) and continuous variables. Inside-out network sequencing increases with innovation rating: bottom-rated have lower inside-out network sequencing (0.461) than middle- and top-rated (0.489, $t = 1.289$, $p = 0.099$).

Table 2: Ordered probit regression predicting innovation performance (N =301)

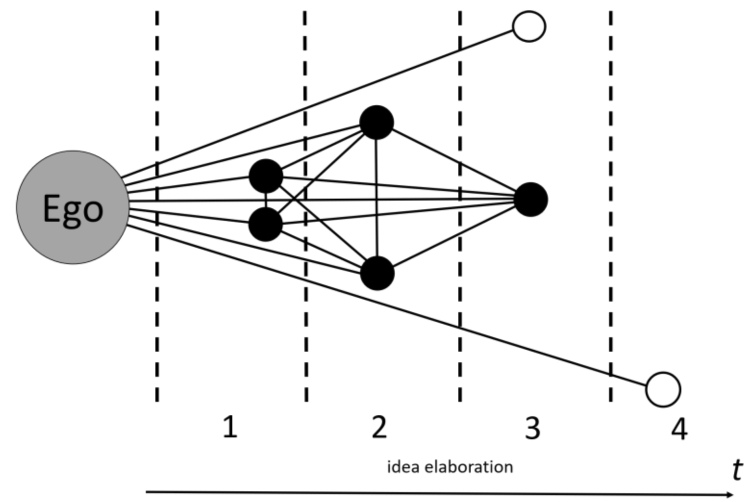
	1	2	3	4	5	6
Emphasis on accountability	-0.01	-0.02	-0.02	-0.03	-0.03	-0.03
	(0.08)	(0.08)	(0.09)	(0.09)	(0.08)	(0.08)
Lack of innovation support	-0.05	-0.08	-0.12	-0.14	-0.13	-0.14
	(0.10)	(0.09)	(0.10)	(0.10)	(0.09)	(0.09)
Lack of organizational slack	-0.02	-0.02	-0.03	-0.03	-0.03	-0.03
	(0.04)	(0.04)	(0.03)	(0.03)	(0.02)	(0.02)
Reluctance to cannibalize	0.16***	0.17***	0.17**	0.16**	0.19*	0.17*
	(0.04)	(0.05)	(0.05)	(0.05)	(0.09)	(0.07)
Relative speed to promotion	0.41**	0.40*	0.39*	0.39*	0.41*	0.41*
	(0.14)	(0.16)	(0.16)	(0.16)	(0.20)	(0.19)
Junior	0.80**	0.79**	0.81**	0.81**	0.80**	0.79**
	(0.27)	(0.26)	(0.29)	(0.29)	(0.27)	(0.29)
Job tenure	0.07***	0.07***	0.06***	0.06***	0.07***	0.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Managerial support	0.09***	0.09***	0.11***	0.11***	0.10***	0.10***
	(0.02)	(0.01)	(0.02)	(0.02)	(0.02)	(0.02)
Research portfolio time horizon	-0.10	-0.07	-0.01	0.00	-0.04	-0.07
	(0.20)	(0.22)	(0.18)	(0.18)	(0.18)	(0.19)
Female	0.15	0.14	0.15*	0.15*	0.14	0.13
	(0.09)	(0.09)	(0.07)	(0.07)	(0.07)	(0.07)
Intrinsic motivation	0.19***	0.20***	0.18***	0.19***	0.19***	0.20***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)
Network constraint	-0.51*	-0.35***	-0.25*	-0.25*	-0.17***	-0.18***
	(0.20)	(0.10)	(0.11)	(0.12)	(0.04)	(0.04)
Network prominence	0.07*	0.07*	0.07*	0.07*	0.07*	0.07*
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Inside-out network sequencing (IONS)		0.63**	0.67***	0.68***	0.76***	0.78***
		(0.21)	(0.08)	(0.08)	(0.19)	(0.22)
IONS × Emphasis on accountability			1.83**	1.81***	1.75**	1.74***
			(0.56)	(0.55)	(0.56)	(0.53)
IONS × Lack of innovation support				0.42***	0.30***	0.30***
				(0.08)	(0.02)	(0.00)
IONS × Lack of organizational slack					1.01***	1.19***
					(0.22)	(0.10)
IONS × Reluctance to cannibalize						1.02***
						(0.25)
cut1	3.15**	3.02**	2.92*	2.66*	2.93	2.73
	(1.11)	(1.16)	(1.25)	(1.22)	(1.62)	(1.42)
cut2	3.79***	3.66**	3.57**	3.30**	3.59*	3.40*
	(1.12)	(1.17)	(1.27)	(1.24)	(1.64)	(1.44)
Log-likelihood	-268.9	-267.7	-264.5	-264.4	-261.6	-260.5
Log-likelihood Ratio test		2.42(1)	6.42(1)	0.17(1)	5.67 (1)	2.19(1)
p-values		0.06	0.00	0.34	0.01	0.07

* $p < .0.05$; ** $p < .01$; *** $p < .001$. Standard errors in parentheses are clustered by *Junior*. Dummies for six industrial sectors are included. Independent and moderator variables are mean-centered.

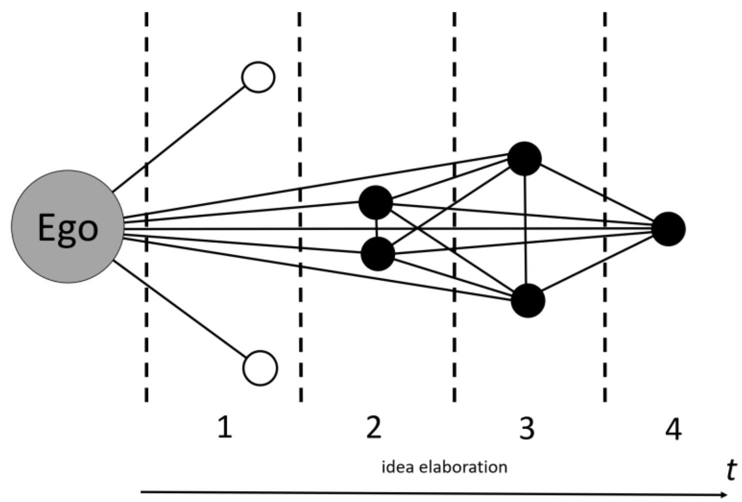
Figure 1: Stylized representations of patterns of network mobilization during idea elaboration



Counterfactual #1: All-in-one network mobilization



Inside-out network sequencing



Counterfactual #2: Outside-in network sequencing

Black nodes depict inner-circle ties
(many third-party ties shared with ego)
and white nodes depict outer-circle ties
(few or no shared third-party ties).

<u>Stages of idea elaboration:</u>
1: Almost immediately after conception
2: After formulating basic concept
3: After first proof of concept
4: After validation in a lab/trial environment

Figure 2: Infographic of inside-out network sequencing

Notes: The sequence of network mobilization describes the stage of idea elaboration at which an individual first exposes their idea to each of their network contacts for feedback or support. The figure illustrates how inside-out network sequencing varies with its two constituent components of dispersion and consistency, keeping network structure (of a stylized network of size 7 and average density) constant. In the network graphs below, the larger node represents ego (the focal individual), the five nodes shown to the left of ego within the smaller circle depict inner-circle ties, and two nodes to the right of ego in the larger circle represent outer-circle ties.

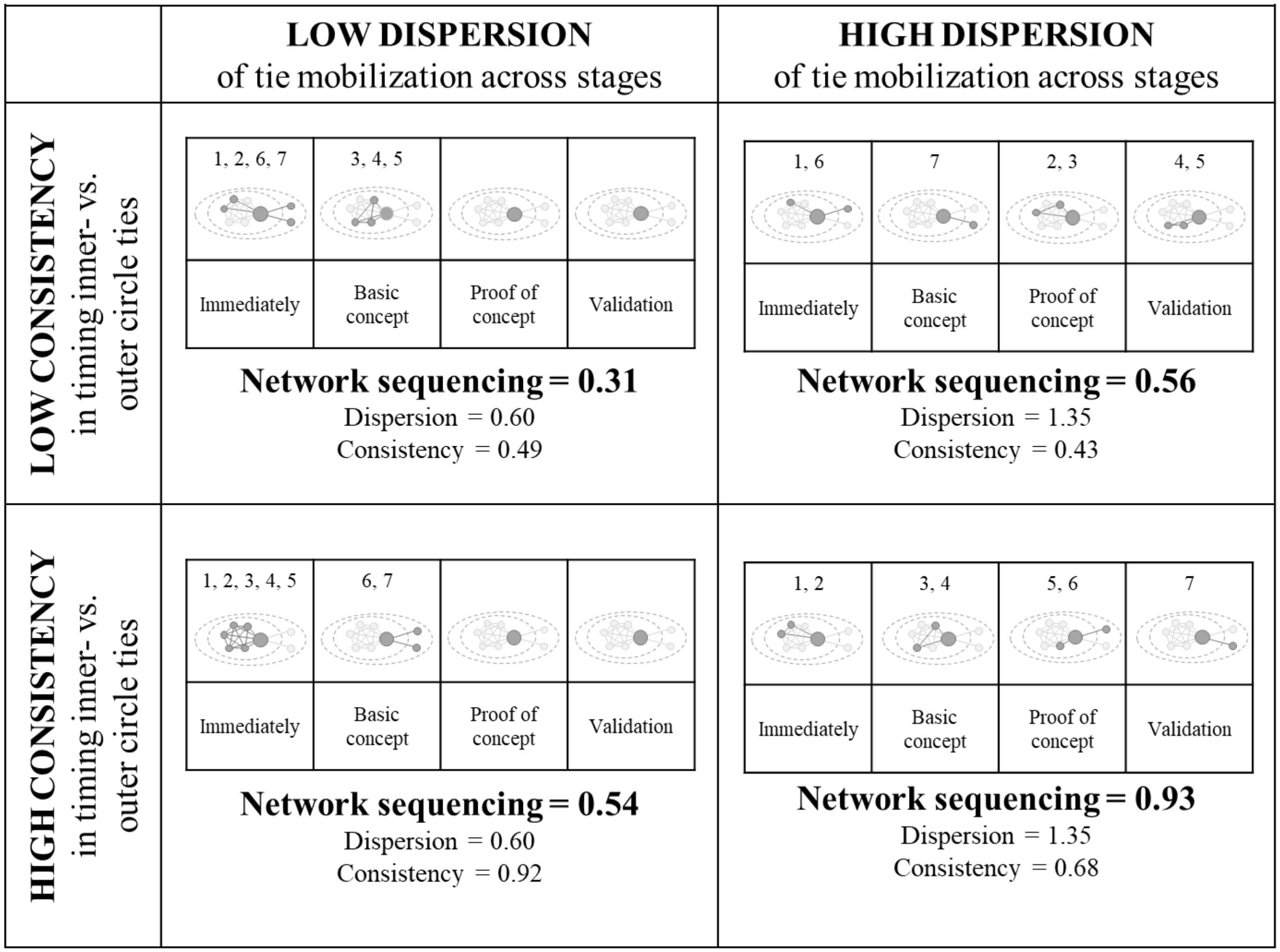
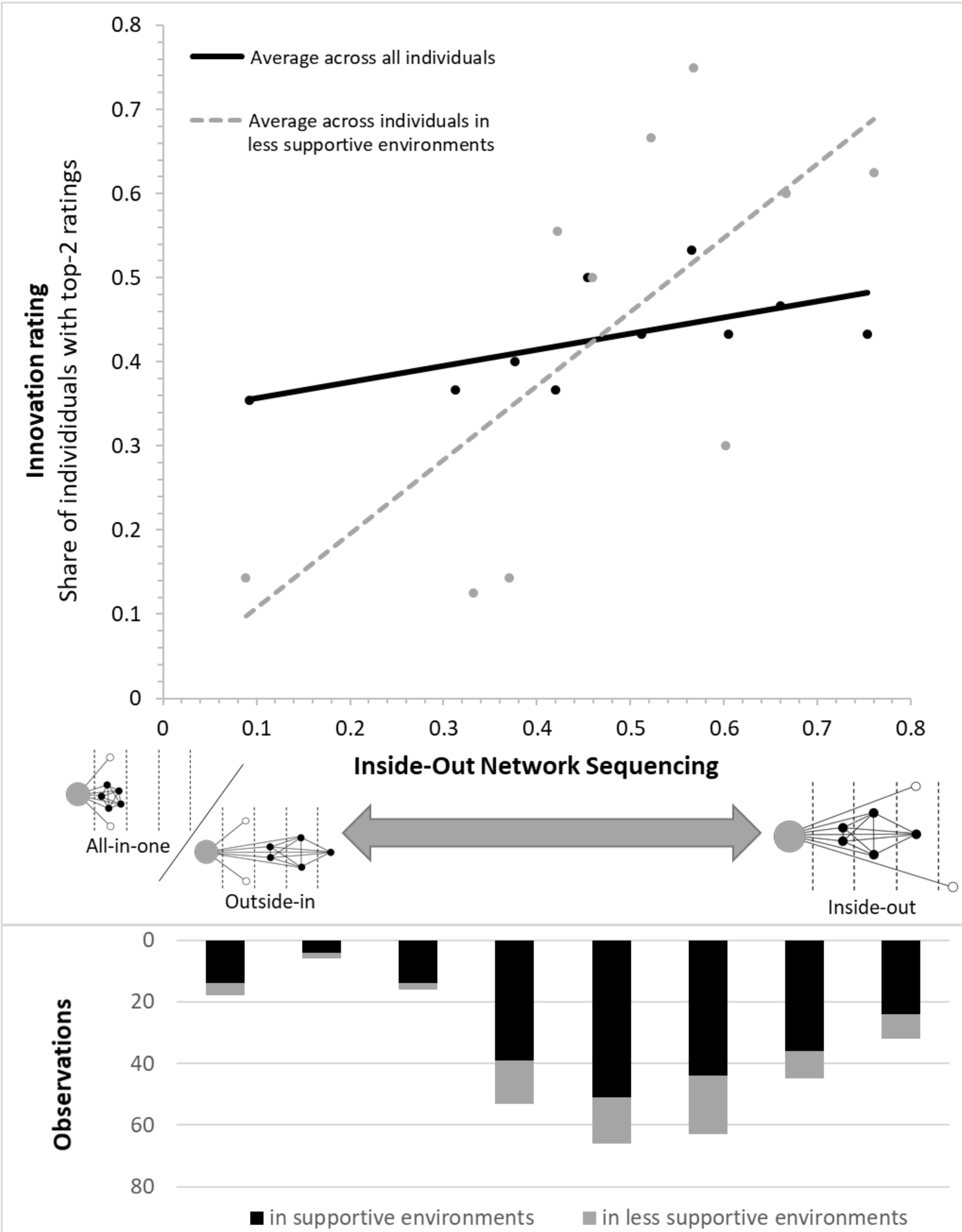
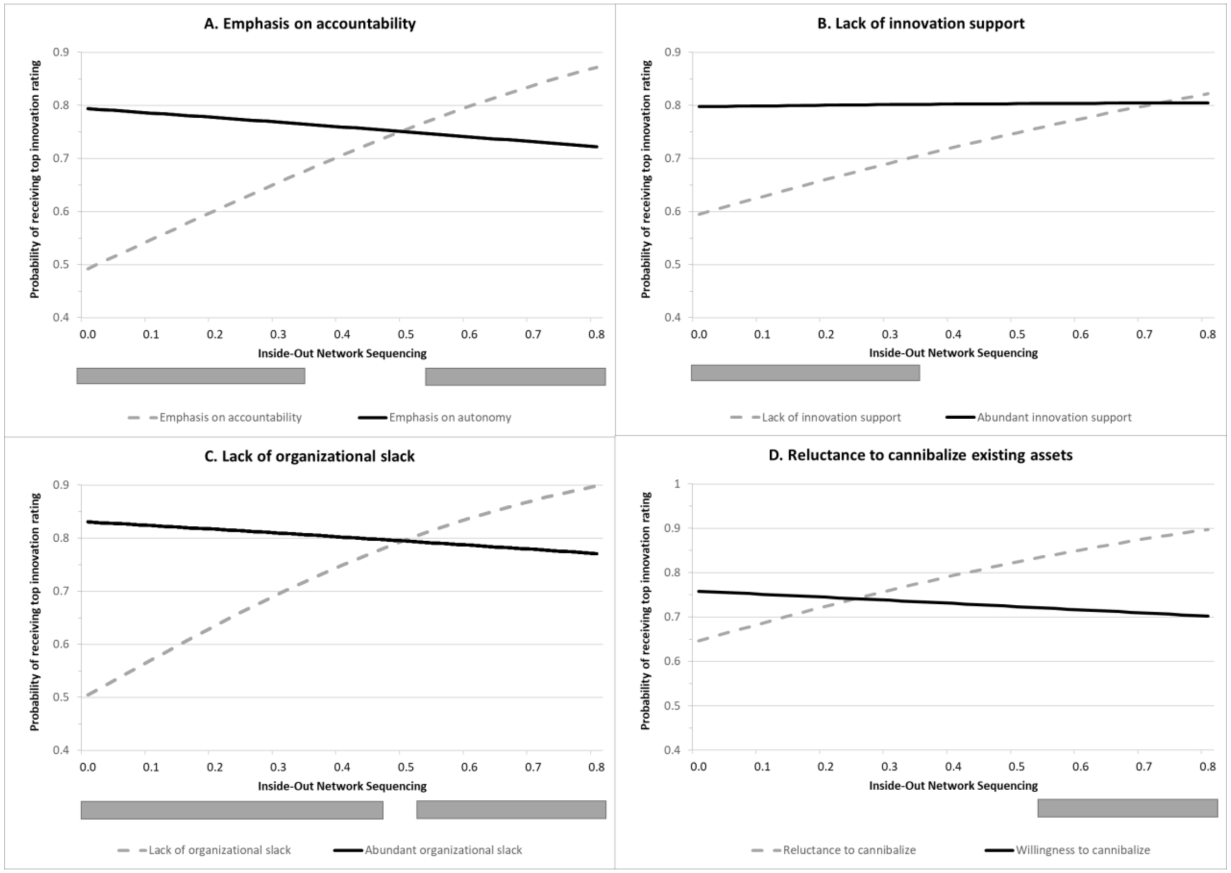


Figure 3: Inside-out network sequencing and innovation rating



Notes: Dots depict averages of inside-out network sequencing for ten decile groups of observations. Individuals are classified as working in less supportive environments if they scored above-median on three or more of the four moderator variables. The bar chart below the graph indicates the number of observations for each ten-point interval from 0–0.1 to 0.7–0.8.

Figure 4: Moderation effects of a (less) supportive work environment on benefits of inside-out network sequencing for individual innovation performance



Notes: These graphs plot the predicted probabilities of receiving a top innovation performance rating for high and low values of the moderator variables over the range of inside-out network sequencing, keeping all other continuous variables at their mean values and significant binary variables at 1. Bars underneath the horizontal axis indicate for which values of inside-out network sequencing the difference in predicted probabilities of receiving a top innovation rating in supportive vs less supportive work environments is statistically significant (90% confidence interval). Low and high values, respectively, of *Emphasis on accountability* and *Lack of organizational slack* are mean–1SD and mean+1SD. Low and high values, respectively, of *Lack of innovation support* and *Reluctance to cannibalize* are mean–2SD and mean+2SD.

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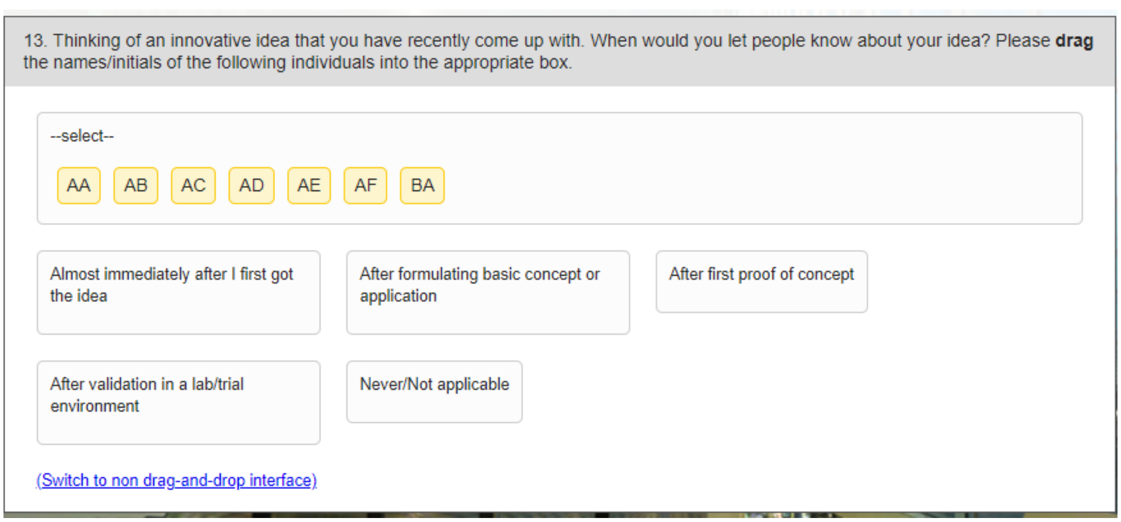
Appendix A: Formulation of name generator questions and alter–alter matrix

Please specify the initials of your **individual contacts** below by answering the following questions. The individuals you mention can be **either from within or outside Neptune.**	
Over the last six months**,** from which work-related contacts did you regularly seek information and advice as input for your research and development work?	1. AA 2. AB 3. AC
Suppose you were moving to a new job and wanted to leave behind the best network advice that you could for the person moving into the current job. Which individuals would you name whose knowledge and expertise is critical as a source of new ideas?	1. AD 2. AA 3. AC
Which work-related contacts do you regard as a source of support for implementing your new ideas – that is, someone you are comfortable with discussing your new ideas?	1. AE 2. AF 3. AC
Is there anyone who has been an important source of new knowledge and ideas to you over the last six months**,** who you have not listed in the previous questions?	1. BA 2. AF

Check the box for any two people who you believe are connected (e.g. they seek information and advice from each other, etc.).

	AA	AB	AC	AD	AE	AF	BA
AA		☐	☐	☐	☐	☐	☐
AB			☐	☐	☐	☐	☐
AC				☐	☐	☐	☐
AD					☐	☐	☐
AE						☐	☐
AF							☐

Appendix B: Scenario-based question measuring the timing of network mobilization



The names/initials listed were generated from the question listed in Appendix A. Participants could switch to a regular interface with scroll-down menu for each listed contact in case their browser did not support the drag-and-drop interface.

Appendix C: Scale items for moderator variables

Emphasis on accountability (to managers) *(R&D managers survey)*
Own scale

- I provide detailed work plans and guidelines for my scientists/engineers to work on.
- Scientists/engineers bring more valuable contributions to a project when I set clear expectations from the outset.
- I expect my scientists/engineers not to deviate from the project's requirements (reverse-coded).
- I give my scientists/engineers specific instructions about how to prioritize their work (reverse-coded).

Lack of innovation support *(R&D scientists/engineers survey)*
Adapted from a supervisory support scale developed by Greenhaus, Parasuraman, and Wormley (1990). All items are reverse-coded to create a measure of the *lack* of innovation support.

- My manager takes the time to understand my technical input in a project.
- My manager demonstrates clear appreciation for my work when I achieve something substantial.
- My manager supports my project work with useful knowledge on what the business needs.
- My manager gives me relevant feedback and advice on the feasibility and risk associated to my technical input.
- My manager supports my requests to obtain additional resources for a project.
- My manager provides a setting in which I feel comfortable raising and discussing new ideas.

Lack of organizational slack *(R&D directors survey)*
Adapted from Danneels (2008). Items are coded as indicated below (reversed with respect to the original to indicate a *lack* of organizational slack):

- All available resources are locked up in current official projects.
- We have a reasonable amount of resources in reserve (reverse-coded).
- We have sufficient discretionary financial resources (reverse-coded).
- We can always find the manpower to work on special projects (reverse-coded).

Reluctance to cannibalize *(R&D directors survey)*
Adapted from a scale developed by Chandy and Tellis (1998) and modified by Danneels (2008). Items are coded as indicated below (reversed from the original to create a measure of reluctance, as opposed to willingness, to cannibalize):

- I support promising R&D projects even if they could potentially take away sales from existing products (item omitted, due to low factor loading).
- I tend to oppose new technologies that cause our manufacturing facilities to become obsolete.
- I am very willing to sacrifice sales of existing products in order to improve sales of our new products (reverse-coded).
- I do not support the aggressive pursuit of a new technology that causes existing assets to lose value.

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