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Antecedents and effects of individual absorptive capacity: a micro-foundational perspective on open innovation

Sandor Lowik, Jeroen Kraaijenbrink and Aard J. Groen

Abstract

Purpose – The paper aims to understand how individuals differ in individual absorptive capacity – their ability to recognize, assimilate, transform and exploit external knowledge. These individual absorptive capacities are a key knowledge management building block for an organization's open innovation practices. The study examines individual antecedents – human capital, social capital and cognition – and innovation outcomes of individual absorptive capacity.

Design/methodology/approach – This is a quantitative study of 147 employees in a single medium-sized Dutch industrial firm. Based on a survey and structural equation modeling, the antecedents' prior knowledge diversity, network diversity and cognitive style are examined in relation to individual absorptive capacity. Further, the mediating effects of individual absorptive capacity on its antecedents and innovation outcome are investigated.

Findings – The main findings are that prior knowledge diversity, external network diversity and a bisociative cognitive style explain differences in individual absorptive capacity. A bisociative cognitive style appears to be the most important factor. Also, this study finds that individual absorptive capacity mediates between its antecedents and individual innovation performance and is therefore a relevant factor to capture value from external knowledge sources.

Research limitations/implications – The study extends open innovation theory by exploring individual-level factors that explain the ability to capture value from external knowledge. It suggests that differences in open innovation practices are explained by heterogeneity at the individual level. Further, it explains how individuals' potentials for open innovation are mediated by their absorptive capacities. These insights enable future researchers to further examine individual-level factors in knowledge management practices and to explore cross-level individual-organizational interactions for open innovation.

Practical implications – This paper highlights that individuals' engagements in open innovation practices are explained not only by individuals' motivations but also by their abilities to absorb external knowledge. Further, it helps managers to design knowledge management practices to promote employees' absorptive capacities, to improve open innovation processes.

Originality/value – This study investigates the neglected individual-level factors of open innovation practices from a micro-foundational and knowledge management perspective. To our best knowledge, this is the first study to examine individual-level antecedents and outcomes of individual absorptive capacity.

Keywords Open innovation, Cognitive style, Individual absorptive capacity, Micro-foundations, Network diversity, Knowledge diversity

Paper type Research paper

Introduction

The open innovation management literature seeks to explain why firms differ in their abilities to engage in open innovation practices and how they can improve their capabilities to better capture value from these open innovation practices (Chesbrough, 2003; Lichtenthaler, 2011). To answer these questions, many studies have examined the open

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innovation phenomenon at the organization and inter-organization levels (Van de Vrande *et al.*, 2010; West *et al.*, 2006).

However, there is a growing interest in exploring open innovation at the individual level because individuals bring open innovation into practice (Bogers *et al.*, 2017; West and Bogers, 2017). For instance, individuals search for and recognize external knowledge in their roles as boundary-spanners and knowledge brokers (Fleming and Waguespack, 2007; Hargadon and Sutton, 1997). Further, they are the *locus* of knowledge-creation and innovation (Grant, 1996; Felin and Hesterly, 2007; West *et al.*, 2006) through knowledge-sharing and integration. In contrast, individuals can obstruct the adoption of open innovation practices, for instance, by sticking to the *not-invented-here* and *not-sold-here* syndromes (Chesbrough, 2006; Lichtenthaler, 2011). While prior studies have mainly stressed individuals' relevance for open innovation practices, little attention has been paid to the underlying mechanisms that determine individuals' capabilities and activities that influence open innovation practices.

This study explores individuals' capabilities and activities from a knowledge management perspective by using absorptive capacity (ACAP) theory. Open innovation practices concern the inter-organizational exchange of knowledge and the inflow of external knowledge into an organization. However, these activities do not take place either automatically or easily (Szulanski, 1996) and require ACAP (Cohen and Levinthal, 1990; Lichtenthaler, 2011; West and Bogers, 2017). ACAP is considered a firm-level dynamic capability and concerns the identification and acquisition of external knowledge and its integration with internal knowledge via transformation and exploitation (Zahra and George, 2002). Thus, a firm's ACAP determines its ability to capture value from open innovation practices (Lichtenthaler and Lichtenthaler, 2009).

Parallel to the call for individual-level studies in the open innovation literature, as mentioned above, there is also a call for individual-level studies in the dynamic capability (Felin *et al.*, 2012; Teece, 2007) and ACAP literatures (Volberda *et al.*, 2010). This has resulted in the micro-foundations research stream, which seeks to understand the actions and interactions of individuals that create capabilities (Abell *et al.*, 2008; Felin *et al.*, 2012). This micro-foundational lens is very useful to understanding the underlying mechanisms of individuals' abilities to absorb new knowledge, which is a key activity in open innovation (Lichtenthaler, 2011). In all, this leads to our research question of how individuals' characteristics affect the ability to recognize and assimilate external knowledge and to integrate it with internal knowledge via transformation and exploitation to improve innovation outcomes.

To answer this question, we investigate individuals' prior knowledge diversity, network diversity and cognitive styles in relation to their individual ACAP and innovation performance, of 147 employees and managers of a medium-sized Dutch kitchen manufacturer. The results show that differences in prior knowledge diversity, external network diversity and a bisociative cognitive style explain differences in individual ACAP. Further, we show that individual ACAP mediates between individuals' characteristics and their innovative behaviors.

We contribute to open innovation and knowledge management theory and practice in four ways. First, our study suggests that differences in open innovation practices are explained by heterogeneity at the individual level. By examining individuals' characteristics and their influences on individual ACAP, combined with the knowledge that individual ACAP is a key micro-foundation for organization-level ACAP (Cohen and Levinthal, 1990; Lowik *et al.*, 2016), we extend ACAP theory to better understand open innovation practices (Lichtenthaler and Lichtenthaler, 2009).

Second, our study shows that individual ACAP mediates between individual characteristics and innovation performance, which shows that individual characteristics alone do not

explain open innovation practices. These characteristics are the potential that needs deployment through individual ACAP so as to create innovations (Helfat *et al.*, 2007). This can also explain why earlier studies, such as Alexy *et al.* (2013) found weak relationships between cognition and the adoption of open innovation practices.

Third, for practitioners, our study contributes to managerial questions on how to go from closed to open innovation. When individuals are studied in the open innovation literature, the focus is on motivational factors to avoid the *not-invented-here* or *not-sold-here* attitudes (Chesbrough, 2003; Lichtenthaler, 2011). We argue that resistance to open innovation can be explained not only by a lack of motivation but also by limited ability, in this case low individual ACAP, which is partly determined by individual characteristics. This gives managers new insights into how to overcome resistance to open innovation.

Fourth, our study has implications for practitioners on how to improve open innovation practices. Because we examine the antecedents of individual ACAP, we offer practitioners suggestions on how to enhance employee ACAP. For instance, our results show that an employee's cognitive style is most relevant for their individual ACAP. This suggests that managers need to install recruitment and selection processes so as to indicate prospective employees' cognitive styles. Practices to increase employees' knowledge diversity and external network diversity are also recommended.

Theoretical background

Open innovation as a multilevel concept

To create and capture value from external sources, organizations need to develop and maintain open innovation practices (Gassmann and Enkel, 2004; Lichtenthaler and Lichtenthaler, 2009; Lichtenthaler, 2011; Moustaghfir and Schiuma, 2013). Gassmann and Enkel (2004) distinguish between three core open innovation processes: outside-in (integrating external knowledge), inside-out (bringing ideas to the market through selling and licensing) and coupled processes (combining outside-in and inside-out processes in alliances). We focus on outside-in processes because these are still most often used by firms (Lichtenthaler, 2011), especially by small- and medium-sized enterprises (SMEs) (Parida *et al.*, 2012).

To successfully engage in open innovation practices, organizations need to develop and maintain capabilities to connect new external knowledge with the organization's existing knowledge base. This requires that a firm is able to tap into external technology sources and is able to then integrate the acquired knowledge with in-house research and development (R&D) activities (Chesbrough, 2003). Cohen and Levinthal (1990) called this absorptive capacity (ACAP). This is an organization's ability to recognize, assimilate, transform and exploit new external knowledge to create an organizational capability (Zahra and George, 2002). That is, ACAP is a dynamic organizational capability that enables open innovation practices (Gassmann and Enkel, 2004; Lichtenthaler and Lichtenthaler, 2009; Zahra and George, 2002).

Using ACAP as a dynamic capability theoretical lens enables us to better understand the multilevel characteristics of the open innovation paradigm (Lichtenthaler, 2011; West *et al.*, 2006; West and Bogers, 2017). Organizations' capabilities are understood to operate in a hierarchy, whereas lower-level operational capabilities enable higher-level dynamic capabilities (Eisenhardt and Martin, 2000; Grant, 1996; Teece, 2007). Further, in the capability literature, the micro-foundations research stream seeks to break down organization-level capabilities into their constituent components, explicitly addressing individual-level factors (Abell *et al.*, 2008; Felin and Hesterly, 2007; Felin *et al.*, 2012). So, by examining the micro-foundations of ACAP, we can better understand how capabilities are created and why they differ. Because capabilities are needed for the execution of

routines and processes, differences in capabilities explain why some open innovation practices are more successful than others.

Open innovation literature distinguishes between individual, organizational, value network, industry and national levels of analysis (Bogers *et al.*, 2017; West *et al.*, 2006). While most open innovation studies focus on the company and the inter-organization levels (Van de Vrande *et al.*, 2010; West and Bogers, 2017), the individual level has remained largely unexplored.

Individual factors of open innovation

To date, the open innovation literature has mainly addressed two factors at the individual level: motivation to engage in open innovation practices and knowledge acquisition processes by brokers and boundary-spanners.

Chesbrough (2003) addressed individual motivation factors not only via the *not-invented-here* attitude (Katz and Allen, 1982), which mainly relates to R&D employees but also via the *not-sold-here* attitude, which can be found among sales people and managers. Lichtenthaler (2011) extended Chesbrough's (2003) two motivational attitudes by a third one: the *not-connected-here* attitude and linked these attitudes to open innovation knowledge processes. In the first knowledge acquisition process, the *not-invented-here* attitude results in neglecting opportunities that external knowledge can provide. During knowledge assimilation, the *not-connected-here* attitude leads to not integrating new external knowledge into existing processes owing to confidentiality issues and a lack of trust. At the knowledge exploitation stage, the *not-sold-here* attitude is driven by the fear of strengthening competitors' market positions or by the fear of losing exclusive rights when new ideas are outsourced. An example of an empirical study that addresses individuals' motivations to engage in open innovation practices is Lichtenthaler *et al.* (2010) work on *not-sold-here* attitudes. Another example is Sieg *et al.* (2010), who address the motivation barriers of R&D scientists to share engineering problems with an open source platform.

The second individual factor in the open innovation literature relates to individuals' roles as brokers and boundary-spanners. Brokers are individuals who connect otherwise disconnected others (Burt, 1992). These individuals are able to control knowledge flows from one knowledge network to another. Thus, they are the first to have access to novel external knowledge that can be used for open innovation activities. In the open innovation literature, brokers are mostly examined in studies on innovation intermediaries (Hargadon, 2002; Hargadon and Sutton, 1997). Boundary-spanners are located at organizations' boundaries and connect the external to the internal worlds (Tushman, 1977). They are generally the ones who identify and acquire external knowledge and transfer it into their organization, so that others can capture its value (Cohen and Levinthal, 1990). Although brokers and boundary-spanners seem very similar, they are distinct. While a boundary-spanner connects external parties to the internal organization, a broker links multiple external parties to one another. A broker can span boundaries, but a boundary-spanner does not have to be a broker (Fleming and Waguespack, 2007).

Besides these two individual-level factors, the open innovation literature also addresses individuals as *sources* of new knowledge (West *et al.*, 2006). Examples are found in the user innovation research (Von Hippel, 2005) and research into open innovation communities (Fichter, 2009). However, these studies are beyond our scope because we focus on individuals' abilities to absorb knowledge rather than on their roles as sources of external knowledge.

Although the aforementioned studies provide valuable insights into the motivations and knowledge acquisition aspects of open innovation practices via brokers and boundary-spanners, we still need to understand individuals' characteristics and activities to

explain how open innovation practices can be successfully managed (Lichtenthaler, 2011; West and Bogers, 2017). Particularly, we need to further examine individuals' abilities to integrate acquired knowledge into an existing knowledge base and to use such knowledge to create new products and services to explain how value is created from external sourcing through internal R&D (Chesbrough, 2003). We seek to explain which factors determine individuals' external knowledge absorptive capabilities and how these contribute to individual innovation performance.

In line with the ACAP literature and the (dynamic) capability literature (Abell *et al.*, 2008; Zahra and George, 2002), we define individual ACAP as an *individual's activities* to recognize, assimilate, transform and exploit new external knowledge (Lowik *et al.*, 2016; Ojo *et al.*, 2014). Individuals' *recognition* activities concern searching for new knowledge, identifying it and evaluating it as opportunities for potential beneficial use (Tang *et al.*, 2012; Teece, 2007). Through *assimilation* activities, individually recognized and acquired knowledge is adapted to the organizational context by making it understandable and transferable to other organizational members (Huber, 1991; Nonaka, 1994; Zollo and Winter, 2002). During knowledge *transformation* processes, the new assimilated knowledge is combined and integrated with existing knowledge from others to create new ideas for products, services and processes (Grant, 1996; Kogut and Zander, 1992). Finally, exploitation at the individual level concerns the internalization of the new knowledge in own work routines (Nonaka, 1994).

Hypotheses: antecedents and outcomes of individual absorptive capacity

We selected three primary antecedents based on the dynamic capability and the ACAP literatures. Acknowledging that ACAP is a dynamic capability (Zahra and George, 2002), we followed Adner and Helfat's (2003) classification of three individual dynamic managerial capabilities: human capital, social capital and cognition. Human capital refers to prior knowledge and experience, which is generally considered a key element of ACAP (Cohen and Levinthal, 1990; Hayton and Zahra, 2005). Social capital relates to both internal and external networks, which are necessary to facilitate knowledge exchanges (Lenox and King, 2004; Todorova and Durisin, 2007; Zahra and George, 2002). Cognition refers to beliefs and mental models as a basis for decision-making (Adner and Helfat, 2003), which determines an individual's information-processing style and creativity (Lane *et al.*, 2006; Todorova and Durisin, 2007; Zahra and George, 2002). In this section, we will discuss the three antecedents – prior knowledge diversity (human capital), network diversity (social capital) and cognitive style (cognition) – in relation to individual ACAP and its outcomes.

Relating prior knowledge diversity to individual absorptive capacity

In the ACAP literature, prior knowledge is considered to be a key antecedent of organizational ACAP (Cohen and Levinthal, 1990; Volberda *et al.*, 2010; Zahra and George, 2002). Yet the organization's prior knowledge is built on the prior knowledge of its individual members (Cohen and Levinthal, 1990). Prior knowledge diversity is the variety of knowledge an individual possesses, which results from education, work experiences and life experiences.

Individuals' prior knowledge diversity affects all processes of individual ACAP. First and foremost, it determines individuals' abilities to *recognize* new knowledge. The premise is that the identification of the value of new knowledge is more likely when a connection can be made to knowledge one already possesses (Cohen and Levinthal, 1990; Shane, 2000). This suggests that the broader one's knowledge base, the more likely new associations with existing knowledge can be made – “connecting the dots” (Baron, 2006) – which thus enhances the recognition of new knowledge's potential value. Additionally, prior knowledge diversity also influences the *locus* of search (Shane, 2000; Zahra and George, 2002). People tend to search in areas they are familiar with and where they had earlier successes

(Zahra and George, 2002). This implies that people who are experts in a specialized knowledge field tend to search in-depth for new knowledge, whereas generalists tend to search more broadly (Katila and Ahuja, 2002; Laursen and Salter, 2006). This suggests that individuals with high prior knowledge diversity are inclined to search more broadly and are therefore more likely to identify new opportunities.

Besides opportunity recognition and search, prior knowledge diversity is also considered to facilitate knowledge transfer and learning, which are required for *assimilation*, *transformation* and *exploitation* activities (Cohen and Levinthal, 1990; Fiske and Taylor, 2007). On the one hand, knowledge diversity can enhance innovation and creativity because new ideas and insights emerge from combinations of existing knowledge (Smith *et al.*, 2005). On the other hand, knowledge diversity facilitates the establishment of a shared knowledge base, which is needed to enable knowledge integration (Grant, 1996; Hargadon and Sutton, 1997). Individuals with a more diverse knowledge base have a broader domain-specific repertoire and can better understand people from other (functional) domains (Iansiti, 1993; Madhavan and Grover, 1998).

In short, prior knowledge diversity positively affects all individual ACAP activities. Thus, we infer that individuals with a high prior knowledge diversity level will exhibit a higher individual ACAP level, which leads to our first hypothesis:

- H1.* Individuals with a high prior knowledge diversity have a higher individual ACAP level, than individuals with a low prior knowledge diversity.

Relating network diversity to individual absorptive capacity

A key assumption in the ACAP literature is that the place where the knowledge is recognized and acquired is distant from the place where it is transformed and exploited (Cohen and Levinthal, 1990). This is why social integration mechanisms are central to understanding ACAP processes. These organizational arrangements build connectedness and shared meanings, facilitating communication and knowledge exchanges (Jansen *et al.*, 2005; Todorova and Durisin, 2007; Zahra and George, 2002). At the individual level, social integration mechanisms' effectiveness depends on individuals' social capital, which has several dimensions, such as network diversity, network size and network density (Koka and Prescott, 2002; Reagans and Zuckerman, 2001). We focus on network diversity because it indicates the likelihood that individuals will come into contact with persons from other knowledge domains, which increases new knowledge-sharing activities (Ahuja, 2000; Burt, 1992; Todorova and Durisin, 2007). Further, several studies have shown that heterogeneous individual networks positively contribute to individual innovative performance (Baron, 2006; Cross and Cummings, 2004). We distinguish between external and internal network diversity because they affect individuals' performance differently (Cross and Cummings, 2004).

External network diversity is the extent to which individuals have contact with people outside their organizations, such as with customers, suppliers, universities, family and friends. The more diverse people's external networks, the more likely they are to be exposed to potential new knowledge, which positively affects the *recognition* of new knowledge (Cohen and Levinthal, 1990; Tushman, 1977). Further, during *transformation* and *exploitation* activities, individuals integrate knowledge from different sources, which could also include external sources. The external knowledge that is acquired in these transformation and exploitation processes is easily available and readily applicable (which does not concern the new external knowledge that is acquired through recognition activities). The more diverse an individual's external network, the easier it is to find the required knowledge and the more likely an individual will engage in transformation and exploitation activities. We do not expect external network diversity to play a prominent role in individual *assimilation* processes because these are primarily oriented to making new knowledge understandable for the own organization.

To conclude, we propose that external network diversity will enhance individual recognition, transformation and exploitation activities and will therefore lead to higher individual ACAP, which results in the following hypothesis:

H2A. Individuals with a high external network diversity will have a higher individual ACAP level than individuals with a low external network diversity.

An individual's internal network diversity refers to the heterogeneity of contacts with persons in the organization from different functional domains. The more diverse these contacts, the more likely individuals know who knows *what* and who knows *whom*. This internal social capital eases knowledge retrieval from the organizational memory, internal communication and knowledge exchanges, which are mostly relevant for *assimilation*, *transformation* and *exploitation* activities (Hansen, 1999; Jansen *et al.*, 2005). Especially for more complex problems, such as innovation projects, integration of knowledge from multiple individuals from different domains is needed (Grant, 1996). Individuals with a diverse internal network are more likely to find more relevant information, which can contribute to effective problem-solving (Cross and Cummings, 2004). We expect that internal network diversity is less important for *recognition* activities because these are primarily outwardly oriented.

Thus, we propose that an individual's internal network diversity relates positively to activities regarding assimilation, transformation and exploitation, contributing to a higher individual ACAP. We hypothesize:

H2b. Individuals with a high internal network diversity will have a higher individual ACAP level than individuals with a low internal network diversity.

Relating cognitive style to individual absorptive capacity

Individuals' cognitive abilities are often mentioned in the organizational ACAP literature in relation to learning, problem-solving and creativity (Cohen and Levinthal, 1990; Lane *et al.*, 2006; Todorova and Durisin, 2007). However, there have been very few empirical studies on the relationship between individual cognition and individual ACAP. Individual cognition refers to the ways individuals tend to process information and make decisions (Fiske and Taylor, 2007). Although there are multiple classifications of cognitive styles (Hayes and Allinson, 1994), two primary cognitive styles can be distinguished. As Miller (1987) quotes Nickerson *et al.* (1985: 50): "[. . .] the view that there are two qualitatively different types of thinking is widely shared. Among the terms used to describe one type are analytic, deductive, rigorous, constrained, convergent, formal and critical. Representative of the terms used to describe the other type are synthetic, inductive, expansive, unconstrained, divergent, informal, diffuse and creative. No doubt the partitioning into two types involves something of an oversimplification, but possibly a useful one".

In the ACAP literature, Koestler's (1964) distinction between bisociative and associative cognitive styles is used to explain differences in individuals' information-processing and decision-making (Todorova and Durisin, 2007; Zahra and George, 2002). Bisociation is a decision-making style in which individuals use imagination and intuition to seek solutions outside disciplinary boundaries to discover connections that are not readily apparent. Bisociation involves unlearning and changing the "rules of the game" (Payne *et al.*, 1990). The other decision-making style is association. Individuals with an associative style tend to rely on rational thinking, emphasizing verbal reasoning and articulate expressions of ideas. They pay attention to the aspects of a problem for which conventional solutions are at hand and try to adhere to existing rules and methodologies within disciplinary boundaries (Payne *et al.*, 1990). The cognitive styles of bisociation and association are not bipolar, as opposed to other cognitive style dimensions (Allinson and Hayes, 1996; Kirton, 1976) but are independent subscales (Jabri, 1991). It is argued that individuals have both styles but that

they might have a tendency to prefer one over the other, depending on the tasks at hand (Payne *et al.*, 1990).

In the ACAP literature, cognitive style is primarily addressed in relation to *transformation* activities. During transformation processes, new knowledge is combined with existing knowledge to generate new ideas. This creative process is best facilitated by a bisociative cognitive style (Todorova and Durisin, 2007; Zahra and George, 2002). Further, a bisociative cognitive style stimulates knowledge *recognition* because individuals with such a cognitive style tend to search for differences and unknown solutions. We also expect a bisociative cognitive style to have a positive relationship with *exploitation* activities because people need to incorporate new working methods, which requires openness to change and unlearning. During *assimilation*, new external knowledge is connected to existing knowledge in the organization. This requires the identification of similarities and the articulation of an initial idea or insight. Thus, it is expected that individuals who tend toward an associative cognitive style are better at assimilation compared to those with a bisociative cognitive style. In sum, we hypothesize that:

H3a. Individuals with a high bisociative cognitive style will have a higher individual ACAP level than individuals with a low bisociative cognitive style.

H3b. Individuals with a high associative cognitive style will have a higher individual ACAP level than individuals with a low associative cognitive style.

Relating individual absorptive capacity to individual innovation performance

Open innovation results in new or improved products, services or processes (Laursen and Salter, 2006; Parida *et al.*, 2012), which – in turn – create growth and revenues (Chesbrough and Crowther, 2006). Because we take a capability perspective on ACAP to explain open innovation practices (West and Bogers, 2017), we define individual performance in terms of innovative behavior. This relates to two aspects: idea generation and idea exploitation (Axtell *et al.*, 2000; Ng and Feldman, 2010; Parker *et al.*, 2006). Individual innovative behavior requires individuals to be creative in decision-making (Ford and Gioia, 2000; Lane *et al.*, 2006) so as to anticipate expected problems and to solve them once they occur. These anticipated solutions take the form of ideas generated by individuals (Kanter, 1988; Scott and Bruce, 1994; West and Farr, 1990) as a result of recognition, assimilation and transformation activities. Exploitation activities then result in the implementation of ideas generated by these individuals or by others (Zahra and George, 2002).

Because the antecedents' prior knowledge diversity, network diversity and cognitive style are individual characteristics, one could regard these as the potential for open innovation outcomes, once they are deployed. We propose that such deployment takes place via individual ACAP as a set of distinctive yet interrelated activities, acting as a mediator between these individual antecedents and innovative outcomes. Thus:

H4. Individual ACAP mediates between individual characteristics (of prior knowledge diversity, network diversity and cognitive style) and individual innovation performance.

Study design and methodology

We conducted the empirical research at a Dutch kitchen furniture manufacturer whose management had approached the authors to conduct a study to enhance the firm's social innovation capabilities. The firm, which has around 200 employees, has one facility for marketing, sales, engineering, production and logistics. We found this an appropriate research setting because the firm was large enough to offer a sufficient mix of individual diversity while being small enough to assume that organizational conditions are as constant as possible because we were only interested in individual differences.

We conducted a survey among all 197 employees during working hours to ensure a high response rate. Finally, 147 questionnaires were useful for further analysis – a 74.6 per cent response rate. Around 60 per cent of the respondents had been working for the firm for more than 10 years, around 80 per cent of had an education level up to intermediate vocational education, whereas 68 per cent was between 30 and 50 years old. The division of the 147 respondents across departments is approximately 44 per cent production and logistics, 33 per cent sales and back office, 9 per cent operation support (planning, engineering, maintenance) and 14 per cent general support (finance, housekeeping, management team).

The authors developed a self-administered paper-and-pencil questionnaire. All employees were assigned to a group of ten employees by the organization's management. For each group, a time slot of one hour during working time was reserved to fill out the questionnaire to minimize common method variance and to assure a high response rate. The managers and team leaders were assigned to a separate group, as not to influence their employees' responses. During two days, the first author was present at the firm to guide the survey process.

Common method bias

To minimize the effects of common method bias, we followed suggestions by [Conway and Lance \(2010\)](#) as well as [Podsakoff et al. \(2012\)](#) in our research design. To assure that the respondents were able to answer the questions adequately, the survey was pre-tested with four employees. Ambiguities in wording and meaning were discussed and questions and instructions were changed when needed. To increase motivation and to avoid socially desirable answers, we administered the survey anonymously. Also, before the questionnaire was handed to the respondents, they were told that there are no right or wrong answers and that they should answer the questions as honestly as possible. The first author was available to answer questions or clarify ambiguities. The questionnaire design addressed the stylistic answering of questions by using reversed wording and changed item ordering.

Due to granted animosity, it was not feasible to separate the dependent variable from the independent variables by asking supervisors to assess individual innovation performance for each employee separately. However, to assess self-reporting bias, we asked supervisors to list the total number of ideas that had been generated and the total number of employees that were actively involved in implementing ideas in the past 12 months. Then, we calculated the non-parametric bivariate Spearman's correlation coefficient for the two ratings of supervisors and the sum of the employees' scores, which was positive and significant ($r_s = 0.64, p < 0.001$), indicating that self-report bias is not expected. Also, in other studies, the method of self-reported individual performance measures has been shown to be reliable ([Axtell et al., 2000](#); [Parker et al., 2006](#)).

Partial least squares analysis

For analysis, we chose the variance-based structural equation method partial least squares (SEM-PLS) for two reasons. First, the sample size for PLS can be much smaller compared to covariance-based SEM ([Chin, 2010](#)). Second, PLS is less strict concerning distributional assumptions regarding multivariate normality and independence of observations ([Chin, 2010](#)), which better fits our data characteristics. For data analysis, we used the software ADANCO 2.0.1 ([Henseler and Dijkstra, 2015](#)). To determine the estimates' standard errors, we used non-parametric bootstrapping with 4,999 replications ([Henseler et al., 2016](#)).

To assess the statistical power and robustness of our sample size, we used [Cohen's \(1992\)](#) power tables, which consider the variable that has the highest number of predictors ([Chin, 2010](#)). In our study, most predictors point to the construct of individual ACAP. The minimum sample size to detect medium to large effect sizes at a 0.99 confidence interval is 126

observations for five predictors (Cohen, 1992). This shows that our sample of 147 respondents provides sufficient statistical power.

Measures and construct validity and reliability

For all measures, we used existing scales from literature. An overview of the items is presented in the Appendix. To assess constructs' validity and reliability, we followed the recommendations of Henseler *et al.* (2016). For internal consistency reliability, we used Dijkstra–Henseler's $\rho_A > 0.7$ and to assess convergent validity the AVE > 0.5 . For discriminant validity, the Heterotrait–Monotrait Ratio of Correlations (HTMT) should be significantly < 1 , and the square root of the AVE should be higher than the inter-item correlations (Fornell and Larcker, 1981). The constructs' means, standard deviations, reliabilities, HTMT and the AVE's square root are presented in Table I.

Individual absorptive capacity

We used Lowik *et al.*'s (2016) measurement scale for individual ACAP, where individual ACAP is operationalized as a second-order construct consisting of individual activities of recognition ($\rho_A = 0.78$, AVE = 0.60), assimilation ($\rho_A = 0.77$, AVE = 0.68), transformation ($\rho_A = 0.82$, AVE = 0.65) and exploitation ($\rho_A = 0.73$, AVE = 0.63). The path coefficients and their significance levels of the four dimensions to individual ACAP are depicted in Figure 1.

Prior knowledge diversity

To measure prior knowledge diversity, we adapted Walsh's (1988) and Bunderson and Sutcliffe's (2002) measure of individual functional diversity, which was calculated as $1 - \sqrt{\sum(X_i/X)^2}$, where X_i = number of years worked in a particular function and X = total number of work experience years.

Internal network diversity

We measured internal and external network diversity similarly to functional diversity. In the network literature, network breadth is often measured using Blau's (1977) heterogeneity index (Koka and Prescott, 2002). For internal network diversity, we asked respondents to list the number of people in each of the organization's departments – such as sales, planning, service and production – with which they had work-related contact in the past 12 months. We calculated internal network diversity as $1 - \sqrt{\sum(Y_i/Y)^2}$, where Y_i = number of people contacted in a particular department and Y = the total number of people contacted in the past 12 months.

External network diversity

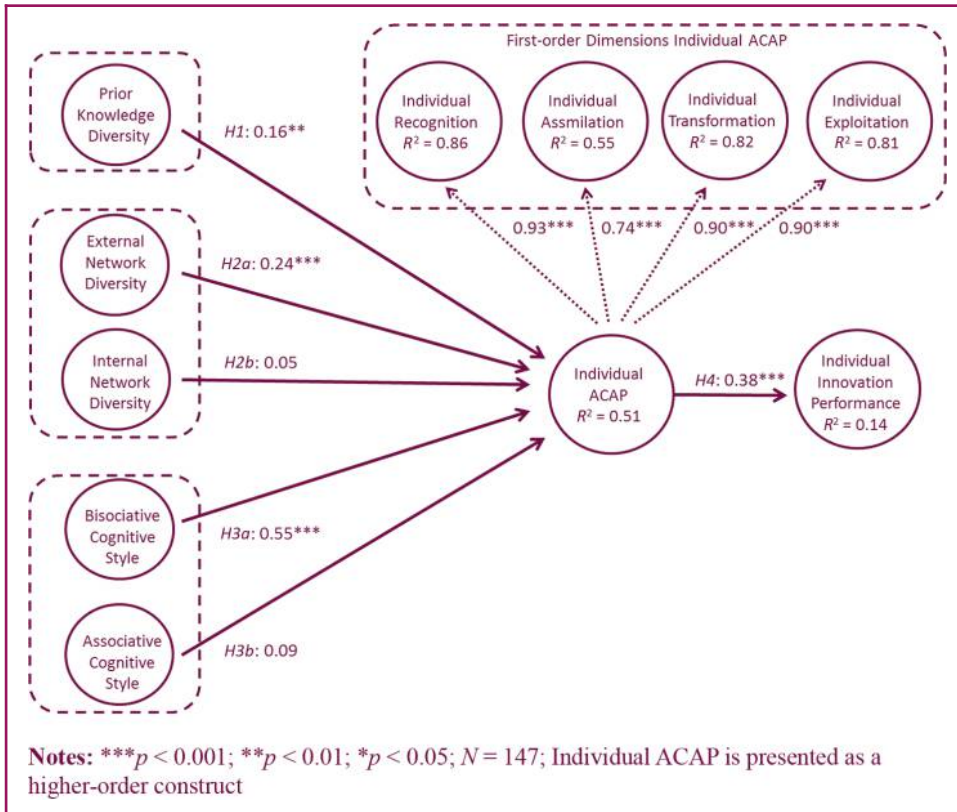
This was measured by asking respondents to list the number of external parties with which they had work-related contact in the past 12 months. The 11 categories of parties that

Table I Means, standard deviations, reliability and heterotrait–monotrait ratio of correlations (HTMT)

Construct*	Mean	SD	CR	ρ_A	AVE	1	2	3	4	5	6
1. Associative cognitive style	5.76	1.36	0.84	0.77	0.56	0.75					
2. Bisociative cognitive style	4.29	1.54	0.88	0.84	0.55	0.21	0.74				
3. Individual ACAP	4.34	1.72	0.93	0.92	0.49	0.23	0.69	0.70			
4. Individual performance	5.45	15.65	0.90	0.80	0.81	0.03	0.21	0.44	0.90		
5. External network diversity	0.84	0.18	n.a.	n.a.	n.a.	0.01	0.10	0.39	0.45		
6. Internal network diversity	0.46	0.22	n.a.	n.a.	n.a.	0.04	0.04	0.23	0.21	0.55	
7. Prior knowledge diversity	0.87	0.15	n.a.	n.a.	n.a.	0.02	0.13	0.34	0.40	0.37	0.38

Notes: SD = standard deviation; CR = composite reliability; ρ_A = Dijkstra–Henseler's rho; AVE = average variance extracted; *For multiple-item constructs; figures on the diagonal represent the square root of the AVE; $N = 147$

Figure 1 Structural model results



respondents could choose from included customers, suppliers, research institutes, family and friends. We calculated external network diversity as $1 - \sqrt{\sum(Z_i/Z)^2}$, where Z_i = the number of organizations contacted in a particular category and Z = total number of organizations contacted in the past 12 months.

Cognitive style

We measured cognitive style as decision-making heuristics, using Jabri's (1991) distinction between association and bisociation. Jabri's (1991) measurement scale is based on Koestler's (1964) work on creativity, which is also addressed in the work of Zahra and George (2002) as well as Todorova and Durisin (2007). For the analysis, we used four items of associative cognitive style ($\rho_A = 0.77$, AVE = 0.56) and six items of bisociative style ($\rho_A = 0.84$, AVE = 0.55) that reflected the latent constructs most significantly.

Individual innovation performance

We based the measure for individuals' innovation performance on the number of ideas generated in the past 12 months (*idea generation*), and the number of innovation and improvement projects employees were actively involved in during the past 12 months (*idea implementation*) (Axtell *et al.*, 2000; Ng and Feldman, 2010; Parker *et al.*, 2006). The construct showed good reliability and validity ($\rho_A = 0.80$, AVE = 0.81).

Department

We included department as a control variable. Although we selected one organization to exclude organizational influences on individual ACAP, there could still be differences at the

departmental level that affect individual ACAP. We included ten departments for analysis, including sales, service, procurement, finance and IT, machining and assembly.

Results

Tests of direct effects of antecedents on individual absorptive capacity

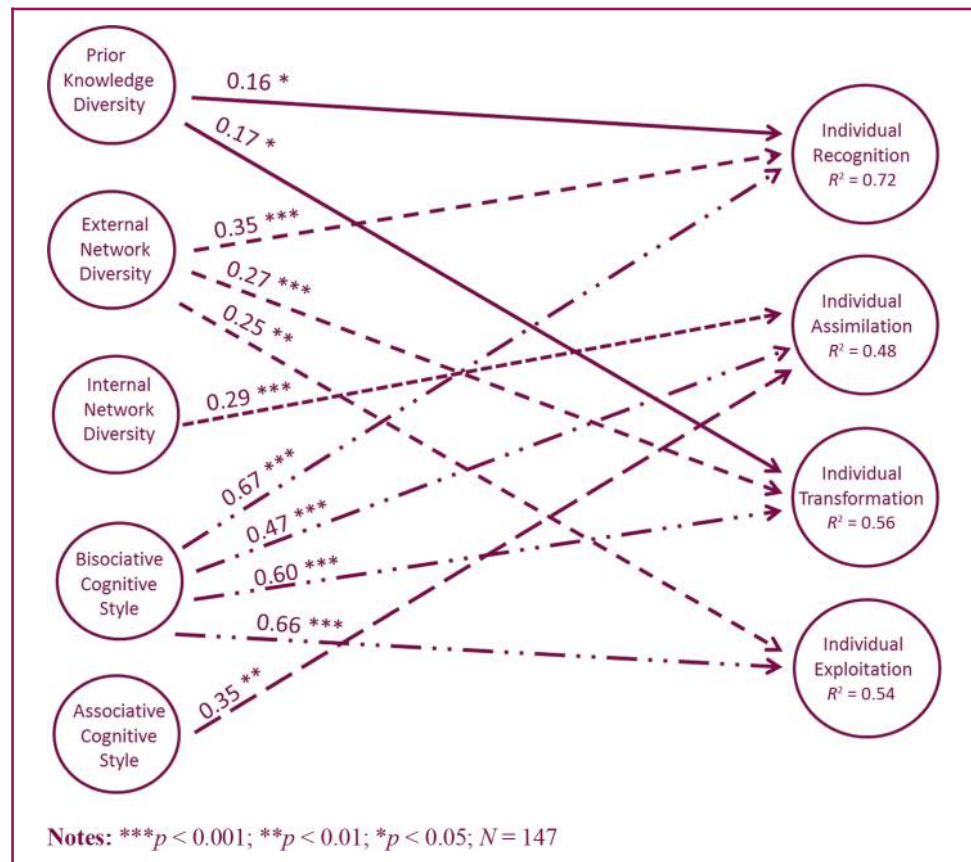
We sought to determine the factors and relationships that explain heterogeneity of individual ACAP and performance. Figure 1 shows the results of PLS analysis of the primary relationships between the latent constructs.

To assess overall goodness of model fit for PLS, Henseler *et al.* (2016) suggest to use the standardized root mean square residual (SRMR). For both the saturated and the estimated model, the SRMR is 0.084 (HI95 = 0.068, HI99 = 0.085), which shows satisfactory goodness of fit. Also, the values of unweighted least squares discrepancy ($d_{ULS} = 3.05$, HI95 = 2.02, HI99 = 3.12) and the geodesic discrepancy ($d_G = 0.98$, HI95 = 0.94, HI99 = 1.07) indicate satisfactory goodness of fit.

To examine the effects of the antecedents on each of the four dimensions of individual ACAP, we ran separate PLS analyses with recognition, assimilation, transformation and exploitation as dependent variables. These results are graphically represented in Figure 2.

H1, which proposed that prior knowledge diversity would positively affect individual ACAP, was supported ($\beta = 0.16$, $p < 0.01$). We further proposed that this would be owing to higher recognition, assimilation, transformation and exploitation activities. We did find significant positive relationships for recognition ($\beta = 0.16$, $p < 0.05$) and transformation ($\beta = 0.17$, $p < 0.05$), yet no significant relationships for assimilation and exploitation.

Figure 2 Structural model of results with first-order dimensions of individual ACAP



H2A – about the contribution of a diverse external network to individual ACAP – was supported ($\beta = 0.24, p < 0.001$). We also found significant positive relationships for the hypothesized activities of recognition ($\beta = 0.35, p < 0.001$), transformation ($\beta = 0.27, p < 0.001$) and exploitation activities ($\beta = 0.25, p < 0.01$). The hypothesized positive effect of a diverse internal network on individual ACAP in *H2B* was not supported ($\beta = 0.05, n.s.$).

H3A was strongly supported: a bisociative cognitive style leads to high individual ACAP ($\beta = 0.55, p < 0.001$). The hypothesized dimensions of individual ACAP are all supported: recognition ($\beta = 0.67, p < 0.001$), transformation ($\beta = 0.60, p < 0.001$) and exploitation ($\beta = 0.66, p < 0.001$). Yet we also found an unexpected positive significant relationship for assimilation ($\beta = 0.47, p < 0.001$). Although we found support for the hypothesized positive effect of an associative cognitive style on individuals' assimilation activities ($\beta = 0.35, p < 0.01$), the overall effect of an associative cognitive style on individual ACAP is non-significant ($\beta = 0.09, n.s.$). Thus, *H3B* was not supported. Taken together, the antecedents in the primary model (Figure 1) explained 51 per cent of the variance (R^2) in the individual ACAP construct.

Additionally, we used department as another control variable because differences between departments or units could affect individuals' ACAP and performance. Using mixed linear model analysis, we tested three random intercept models (Snijders and Bosker, 2012) with department as factor, and individual ACAP ($ICC = 0.103; n.s.$), individual idea generation ($ICC = 0.166; n.s.$) and individual idea implementation ($ICC = 0.147; n.s.$) as dependent variables. Because we found positive yet non-significant intra-class correlation coefficients (ICC) for all three models, we concluded that for further analysis, organizational factors were sufficiently controlled for.

Tests of mediation

To test *H4*, the structural measurement model in Figure 1 showed a positive significant effect of individual ACAP on individual innovation performance ($\beta = 0.38, p < 0.001$), which explained 14 per cent of the variance (R^2). We also explored the mediation paths of the five antecedents to individual performance, following the method suggested Nitzl *et al.* (2016), and Zhao *et al.* (2010). First, we assessed the significance of the indirect effect, using the bootstrapping procedure in PLS. Based on the outcome, we determined the type of effect and/or mediation by assessing the direct effect and its significance. In addition, we determined the variance accounted for value.

The results of the test for mediation are presented in Table II. Our analysis shows full mediation of individual ACAP for bisociative cognitive style and innovation performance. We found partial complementary mediation (Nitzl *et al.*, 2016; Zhao *et al.*, 2010) for the antecedents' prior knowledge diversity and external network diversity. For internal network diversity and associative cognitive style no effect was found. These analyses support *H4*,

Table II Results of tests of mediation

Path	Indirect effect via Individual ACAP	Direct effect	Mediation	VAF (%)
Prior knowledge diversity → Individual performance	0.036**	0.219**	Complementary partial mediation	14.1
External network diversity → Individual performance	0.057**	0.290***	Complementary partial mediation	16.4
Internal network diversity → Individual performance	0.012	-0.108	No effect	
Associative cognitive style → Individual performance	0.021	-0.021	No effect	
Bisociative cognitive style → Individual performance	0.129**	-0.0167	Full mediation	

Notes: *** $p < 0.001$; ** $p < 0.01$; VAF = Variance Accounted For; $N = 147$.

that individual ACAP (partly) mediates between the antecedents – prior knowledge diversity, network diversity and cognitive style – and individual innovation performance.

Discussion

With this study, we sought to answer the question how individuals' characteristics affect the ability to recognize and assimilate external knowledge and to integrate it with internal knowledge through transformation and exploitation to improve innovation output. We showed that employees differ in individual ACAP owing to differences in individual characteristics, such as knowledge diversity, network diversity and cognitive style. Our results also indicate that bisociative cognitive style is the strongest predictor of individual ACAP. Further, we showed that individual ACAP activities mediate between these individual characteristics and individual innovation performance.

Our first contribution is that we extend open innovation literature at the individual level (Bogers *et al.*, 2017; Lichtenthaler, 2011; West and Bogers, 2017). Prior studies mainly addressed the relevance of individuals for open innovation while we examine the underlying mechanisms that explain why some individuals are better able to absorb new external knowledge and turn it into innovative output than others. We extend the open innovation literature on the individual level by exploring which characteristics individuals need to engage in knowledge processes that enable open innovation practices. This complements earlier work on individuals' motivations for open innovation practices (Chesbrough, 2003; Lichtenthaler *et al.*, 2010) and knowledge acquisition practices such as brokerage and boundary-spanning (Fleming and Waguespack, 2007; Haas, 2015). In addition, because individual ACAP is a key micro-foundational factor of organizational ACAP (Cohen and Levinthal, 1990; Lowik *et al.*, 2016), and ACAP is a core capability for open innovation (Lichtenthaler and Lichtenthaler, 2009), we suggest that heterogeneity at the individual level can explain differences in open innovation practices across firms. Our study answers call for more insights into how knowledge processing activities affect open innovation practices (West and Bogers, 2017).

As a second contribution, our results suggest that individual ACAP mediates between personal characteristics and innovation performance. This is in line with the capability literature, where individual characteristics are seen as a potential that needs deployment via activities to create value (Helfat *et al.*, 2007). The results indicate that knowledge management processes at the individual level serve as a precondition to create value from open innovation. For instance, this could explain why Alexy *et al.* (2013) only found a weak relationship between employees' cognitive styles and the adoption of open innovation practices. Based on our study, we would argue that a bisociative cognitive style only leads to open innovation performance when it is deployed via individual ACAP.

Third, our study contributes to the managerial question how to go from a closed to an open innovation paradigm. While many studies have focused on motivational factors to avoid the *not-invented-here* and/or the *not-sold-here* attitudes (Chesbrough, 2003; Lichtenthaler, 2011), our study highlights limited knowledge absorptive abilities as potential barriers to engaging in open innovation practices. The mediating role of individual ACAP suggests that low knowledge processing abilities can hamper innovation performance. This means that managers must address motivational aspects and management systems when transitioning from closed to open innovation (Alexy *et al.*, 2013; Burcharth *et al.*, 2014; Chesbrough, 2003; Chiaroni *et al.*, 2010), but they also need to increase their employees' absorptive capabilities.

Our study's fourth contribution is its suggestions to practitioners on how to improve open innovation practices. Based on the relative importance of individual ACAP antecedents, managers can determine which actions to take. For instance, managers could enhance employees' knowledge diversity by investing in training and education. Also, job-rotation,

working in cross-functional teams (Jansen *et al.*, 2005) and exchanging personnel between firms (Lowik *et al.*, 2012) improves knowledge diversity. To increase network diversity, managers could set up programs to regularly send employees to local network meetings, conferences and trade fairs (Kraaijenbrink, 2007). To employ individuals with a bisociative cognitive style, managers need to establish recruitment and selection practices so as to hire the right people.

We limited our study's scope to outside-in innovation processes. But can we extend our findings to inside-out and coupled innovation processes? Gassmann and Enkel (2004) argued that the three core process archetypes of open innovation need three distinct capabilities. Outside-in processes need ACAP, as we argued here. Inside-out processes need multiplicative capability to multiply technology via different applications, for instance, by licensing and selling IP. Finally, coupled processes need relational capability to build and maintain long-lasting relationships with trusted partners. However, we can expect that ACAP is beneficial not only for outside-in processes but also for inside-out and coupled processes. To transfer one's own knowledge to external partners, one needs to be able to articulate and codify it (Gassmann and Enkel, 2004), which are aspects of assimilation activities of ACAP. Further, to learn from one another, organizations and individuals need a shared knowledge base to enable efficient knowledge exchanges (Grant, 1996; Lane and Lubatkin, 1998). This implies that a knowledge provider with a broader knowledge base can more easily adjust knowledge transfer to a recipient because the provider better understands the recipient's current knowledge level. Thus, we expect that individuals with a higher individual ACAP can also promote outside-in and coupled open innovation processes. However, this only holds in case the knowledge distance between the knowledge provider and the recipient is not too large (Nooteboom *et al.*, 2007). When knowledge bases differ significantly, knowledge disseminative capabilities of the knowledge provider can mitigate the knowledge recipient's limited ACAP (Mu *et al.*, 2010). Disseminative capability is the complementary inverse of ACAP (Schulze *et al.*, 2014). We have not explicitly addressed disseminative capability, and we encourage researchers to explore this further.

Future research

There are two primary avenues for future research. One is to further explore antecedents and outcomes at the individual level. In the knowledge management and open innovation management literatures, there have been calls for more individual-level research so as to better understand how knowledge capabilities such as ACAP are created, are maintained, and decay (Volberda *et al.*, 2010; West and Bogers, 2017). For instance, it would be useful and interesting to study whether an individual can have too much individual ACAP, which could lead to arrogance, which – in turn – can promote a *not-invented-here* attitude. Along these lines, Sieg *et al.*'s (2010) study suggests that R&D engineers were reluctant to post complex problems to an open source platform because they believed that others were incapable of solving them. Also, some firm-level studies have shown an inverted U-shaped relationship between ACAP and openness, indicating that too little as well as too much ACAP result in fewer open innovation practices and performance (Ardito and Messeni Petruzzelli, 2017; Barge-Gil, 2010; Diaz-Diaz and De Saá-Pérez, 2014). Some recent studies have indicated that this might also apply to individuals (Salter *et al.*, 2015), which warrants more understanding of how individual behavior affects firm-level capabilities for open innovation practices.

The second avenue for open innovation research is cross-level studies that explore the complex interrelationships between individual and organizational-level factors (Bogers *et al.*, 2017; West *et al.*, 2014). However, as a precondition to explore these individual-organizational links, theories on both the individual and organizational levels need to be fully understood (Devinney, 2013). Our study contributes to this precondition of

understanding mechanisms at the individual level. Cross-level researchers can use our concepts and results as a basis for further research, for instance, to examine how organizational-level HR practices and incentive schemes stimulate employees to increase their individual ACAP (Ardito and Messeni Petruzzelli, 2017) or to lower motivational barriers, such as the *not-invented-here* attitude (West *et al.*, 2014).

Limitations

This study has limitations. We designed a quantitative study in a single firm to explore the primary effects of antecedents on individual ACAP and to show individual ACAP's mediating role. The choice of a single-firm context was justified because we were interested in heterogeneity at the individual level and we were able to control for collective-level conditions. Further, single-case studies can be powerful means to provide new conceptual insights and theoretical perspectives (Eisenhardt, 1989; Siggelkow, 2007). Our intention in exploring the antecedents and outcomes of individual ACAP was to advance theory and thus to generalize toward theory. However, future empirical studies are needed to test the broader generalizability of our theoretical contributions.

The case study firm was medium-sized. Company size might affect the results of individual activities and outcomes. For instance, SMEs might show a higher willingness to be more open toward external sources than large firms (Barge-Gil, 2010). This might reflect in the extent to which employees engage in individual ACAP activities. Larger firms could be more prone to the *not-invented-here* and/or *not-sold-here* attitudes, which might affect individuals' ACAP. We suggest that researchers examine individual ACAP in larger firms.

We have examined individuals' ACAP to facilitate open innovation practices. However, besides individuals' ACAP, social integration mechanisms are needed to build and maintain ACAP as an organizational capability (Cohen and Levinthal, 1990; Zahra and George, 2002), or to mitigate undesirable effects of too much ACAP (Ardito and Messeni Petruzzelli, 2017). While some studies have begun to examine the cross-level interactions between individual-level and team-level or organizational-level factors (Lowik *et al.*, 2016), as noted, more research is needed.

We did not account for managerial positions as a variable. Managers are expected to have higher individual ACAP owing to their organizational position because they are often at the interface of organizational units and their internal and external environments (Cohen and Levinthal, 1990; Tushman, 1977), and they are the primary change agents in organizations (Jones, 2006), which require them to create, extend, and modify the firm's knowledge base (Augier and Teece, 2009; Volberda *et al.*, 2010). For this study, 19 individuals held managerial positions, including team supervisor, department head and top management team member. However, this number in our sample is too small to make inferences about the effect their organizational position could have on both individual characteristics, individual ACAP and performance.

Our study focused on how individuals absorb external knowledge to increase innovation performance. This overlooks individuals who have mainly an internal orientation and are innovative as well. For instance, Dahlander *et al.* (2016) distinguished between *cosmopolitans*, who have an external orientation, and *locals*, who have an internal orientation, whereas both types showed to be innovative. This means that there are other mechanisms, next to absorption of external knowledge, that drives innovation. We suggest that managers choose those strategies that fits the individual characteristics of their employees best.

Finally, our study was cross-sectional. This poses questions regarding endogeneity, specifically the risk of reversed causality. We are aware of this limitation because the concept of micro-foundations implies complex relationships between individual-level and collective-level factors. We encourage more longitudinal and process studies to further untangle the concept of individual ACAP into activities, their antecedents and their outcomes.

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Appendix

Table A1 Questionnaire items, item loadings, construct reliability and validity

Questionnaire item	Item loading	ρ_A	AVE
<i>Individual absorptive capacity</i>			
Recognition		0.78	0.60
I am always actively looking for new knowledge for my work	0.79		
I intentionally search for knowledge in many different domains to look "outside the box"	0.83		
I am good at distinguishing between profitable opportunities and not-so-profitable information or opportunities	0.75		
I easily identify what new knowledge is most valuable to us	0.72		
Assimilation		0.77	0.68
I frequently share my new knowledge with colleagues to establish a common understanding	0.78		
I translate new knowledge in such a way that my colleagues understand what I mean	0.85		
I communicate newly acquired knowledge that might be of interest for our unit	0.85		
Transformation		0.82	0.65
I often sit together with colleagues to come up with good ideas	0.80		
I attend meetings with people from different departments to come up with new ideas	0.77		
I develop new insights from knowledge that is available within our firm	0.84		
I can turn existing knowledge into new ideas	0.80		
Exploitation		0.73	0.63
I often apply newly acquired knowledge to my work	0.73		
I exploit new knowledge to create new products, services, or work methods	0.81		
I constantly consider how I can apply new knowledge to improve my work	0.85		
Cognitive style			
<i>Association</i>		0.77	0.56
I enjoy being methodical and consistent in the way I tackle problems	0.80		
I enjoy paying strict regard to the sequence of steps needed for the completion of a job	0.76		
I enjoy being strict on the production of results, as and when required	0.75		
I enjoy being precise and exact about production of results and reports	0.68		
<i>Bisociation</i>		0.84	0.55
I enjoy pursuing a problem, particularly if it takes me into areas I do not know much about	0.70		
I enjoy to link ideas which stem from more than one area of investigation	0.80		
I enjoy to be fully occupied with what appear to be novel methods of solution	0.69		
I enjoy searching for novel approaches not required at the time	0.72		
I enjoy struggling to make connections between apparently unrelated ideas	0.80		
I enjoy spending time tracing relationships between disparate areas of work	0.74		
<i>Prior knowledge diversity</i>			
Please indicate your number of years of work experience in each functional domain: sales and/or marketing; manufacturing or operations; finance and/or accountancy; human resources; warehousing and/or logistics; research and development; procurement; administrative support; planning, quality assurance and/or production engineering; support services, such as ICT and maintenance; general management	n.a.	n.a.	n.a.
<i>Internal network diversity</i>			
Please indicate for <i>each department</i> the <i>number of different persons</i> you contacted in the past 12 months to discuss work-related issues: marketing, sales and services; operations; project management; engineering; production and logistics; finance and human resources management (For each department, we provided a list of positions)	n.a.	n.a.	n.a.
<i>External network diversity</i>			
Please indicate the number of different customers, suppliers and other parties you have contacted in the past 12 months to discuss work related issues: current customers; potential customers; current suppliers; potential suppliers; competitors; trade-associations; consultants and/or accountants; government agencies; research institutes; educational establishments; family and friends	n.a.	n.a.	n.a.

(continued)

Table A1

Questionnaire item	Item loading	ρ_A	AVE
<i>Individual innovation performance</i>		0.78	0.81
Idea generation Please indicate the number of suggestions for innovations and improvements you have made in the past 12 months, concerning: creating new products or services; improving existing products or services; entering new markets; expanding existing markets; creating new work methods or (production) processes; improving existing work or (production) processes	0.91		
Idea implementation Please indicate the number of innovation or improvement projects where you have been actively involved in implementation in the past 12 months, concerning: creating new products or services; improving existing products or services; entering new markets; expanding existing markets; creating new work methods or (production) processes; improving existing work or (production) processes	0.89		

Notes: ρ_A = Dijkstra–Henseler's rho; AVE = Average Variance Extracted

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