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ORIGINAL PAPER

Necessary condition analysis (NCA): review of research topics and guidelines for good practice

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Abstract

Necessary condition analysis (NCA) is an increasingly used or suggested method in many business and management disciplines including, for example, entrepreneurship, human resource management, international business, marketing, operations, public and nonprofit management, strategic management, and tourism. In the light of this development, our work delivers a review of the topics analyzed with NCA or in which NCA is proposed as a method. The review highlights the tremendous possibilities of using NCA, which hopefully encourages other researchers to try the method. To support researchers in future NCA studies, this article also provides detailed guidelines about how to best use NCA. These cover eight topics: theoretical justification, meaningful data, scatter plot, ceiling line, effect size, statistical test, bottleneck analysis, and further descriptions of NCA.

Keywords Necessary condition analysis · NCA · Review of topics in NCA · Method review · Guidelines

Mathematics Subject Classification 62

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1 Introduction

Over the last decade, Necessary Condition Analysis (NCA) (Dul 2016b) has emerged as an increasingly used or suggested method in a variety of management and business fields including entrepreneurship (Linder et al. 2022; Torres and Godinho 2022), human resource management and organizational behavior (Costa et al. 2022; Korman et al. 2022), international management (Bolívar et al. 2022; Zahoor et al. 2023), marketing (Kopplin and Rösch 2021; Liu et al. 2022), operations and supply chain management (Knol et al. 2018; Stek and Schiele 2021), public and nonprofit management (Abner et al. 2022; Blom et al. 2022), strategic management (Du and Kim 2021; Klimas et al. 2022), technology and innovation management (Dabić et al. 2021; Gantert et al. 2022; Lyu et al. 2022), and tourism and hospitality management (Della Corte et al. 2023; Lee et al. 2022). Yet, the understanding is still scant of how NCA can be best used for diverse topics and which research questions can be addressed in various fields.

Against this background, it is timely to examine how NCA can support research in business and management research. However, such an overview is just a 'top of the iceberg' of potential research using necessity logic. Gary Goertz, a renowned thinker about necessity logic, states that 'for any research area one can find important necessary condition hypotheses' (Goertz and Starr 2003). We agree with this assessment and suggest researchers to consider formulating and analyzing their own research questions with necessity logic. This will not only increase the academic knowledge in their field, but also provide insights of high practical value. It is for these reasons of theoretical novelty and practical usefulness that NCA is considered an important tool for researchers in any field of business and management (e.g., Aguinis et al. 2022; Bergh et al. 2022; Robinson et al. 2022) and beyond (e.g., Tynan et al. 2020).

To support researchers in their future NCA studies, we also present guidelines for good NCA practice. Some guidelines are already scattered around in the literature (e.g., Dul 2020, 2021) but seem not sufficiently known. Therefore, we develop a comprehensive list of basic guidelines for good NCA practice which can be used by researchers, reviewers, and editors to enhance and ensure the quality of NCA studies.

We present and explain the guidelines along eight topics: theoretical justification, meaningful data, scatter plot, ceiling line, effect size, statistical test, bottleneck analysis, and descriptions of NCA. Notably, this article is not intended to be a tutorial for conducting NCA. Readers who are interested in the details of NCA are referred to NCA's core article (Dul 2016b) or books about NCA at introductory level (Dul 2020) and advanced level (Dul 2021). Also, summaries of the method are available for several research fields (e.g., Dul et al. 2021; Hauff et al. 2021; Linder et al. 2022; Richter and Hauff 2022; Tóth et al. 2019).

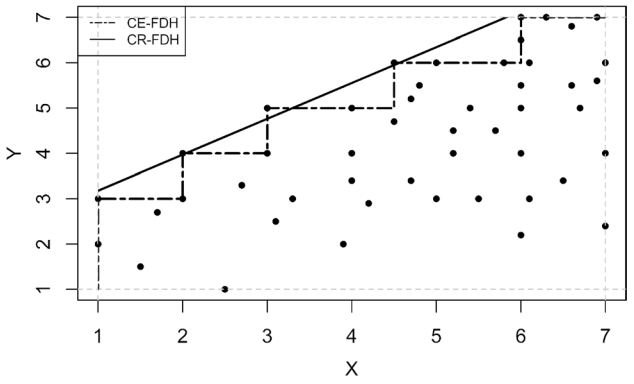
2 Fundamental concepts of NCA

Researchers use different expressions if they assume that a condition X is a necessary cause for an outcome Y. Examples are, "X is needed for Y", "X is critical for Y", "X must be there for Y to succeed", "X is a precondition for Y" or "Y requires X". Accordingly, a necessary condition denotes a constraint, a bottleneck, or a critical factor that must be overcome or satisfied in order to achieve a desired outcome. If the necessary condition is not met, there will be no outcome (Dul 2016b, 2020).

Following this logic, NCA does not pursue explaining how changes of a factor/determinant modifies an outcome (i.e., additive average effect logic represented in different forms of regression or structural equation analyses) but pursues to clarify if an outcome does not appear if a specific condition is not given. To do this, NCA identifies an empty space (i.e., where no cases are present) in a corner of an XY scatter plot. NCA draws a *ceiling line* that separates the area with, and without cases. Two defaults ceiling lines are Ceiling Envelopment—Free Disposal Hull (CE-FDH) and Ceiling Regression—Free Disposal Hull (CR-FDH) (see Fig. 1, panel A). The CE-FDH ceiling is a non-decreasing step-wise linear line. The CR-FDH ceiling line is a trend line through the upper-left CE-FDH corners.

The ceiling line can also be represented in a tabular form, which is called the *bottleneck table* (see Fig. 1, panel B). The first column in this table has the values of the outcome and the next column(s) has(have) the corresponding necessary values of the condition(s). The table shows the required (necessary) levels of all conditions for a given level of the outcome. This is particularly useful when there are multiple necessary conditions. If one of the conditions does not have the necessary level, the desired outcome will not occur, independently of the levels of the other conditions (hence, 'bottleneck' table).

A



B

Bottleneck table (CE-FDH)

Y (actual values)	X (actual values)
0	NN
1	NN
2	NN
3	NN
4	2.0
5	3.0
6	4.5
7	6.0

Notes: CE-FDH = Ceiling Envelopment – Free Disposal Hull; CR-FDH = Ceiling Regression – Free Disposal Hull, NN = not necessary

Fig. 1 Ceiling lines and bottleneck table

The key parameter in NCA is the *effect size* d, which is calculated by dividing the area without observations (also called the ceiling zone) by the total area that can contain observations given the minimum and maximum values of the condition and the outcome (also called the scope). Accordingly, d can range between $0 \leq d \leq 1$. In order to establish whether the effect size is practical meaningful, Dul (2016b) suggested that $0 < d < 0.1$ represents a small effect, $0.1 \leq d < 0.3$ a medium effect, $0.3 \leq d < 0.5$ a large effect and $d \geq 0.5$ a very large effect. The statistical significance of the effect size can be evaluated with NCA's approximate permutation test (Dul et al. 2020) which helps to avoid false positive conclusions about the effect size.

An NCA can be conducted with the NCA package that is available in the free programming language R. The usage of the package is easy also for novice users without knowledge of R or NCA (for a quick start guide see Dul 2023). Currently, NCA is also implemented in SmartPLS 4 (Ringle et al. 2022). An implementation in Stata is planned.

3 Review of topics in recent NCA research

Research with NCA has been strongly proliferating in the past years. Recently, Dul (2022a) has provided an overview on the diffusion of NCA by analyzing NCA applications in journal articles published between 2016 (the year when the first full version of the NCA method was introduced) and 2021. The publication focuses on the growth of the number of journal articles that apply NCA, the diversity of disciplines where NCA is applied, and the geographical spread of researchers who apply NCA. We extend this review by analyzing for which topics NCA has been applied or suggested in the field of business and management. First, we selected from the articles identified by Dul (2022a) those articles that focus on business and management. In addition, we searched for studies that suggested (rather than applied) the use of NCA for a specific discipline or topic in business and management. Further, we extended the search period, so that the most recent articles (published in 2022) were also integrated. For identifying articles, we followed the approach by Dul (2022a) and searched for articles published in journals listed in the Web of Science citing at least one of five core methodological publications on NCA (i.e. Dul 2016a, b, 2020; Dul et al. 2020; Vis and Dul 2018). We excluded articles with a problematic application of NCA (Dul 2022a, b). However, being included in the overview does not guarantee that the article correctly applies and describes NCA in all its aspects. In total, we identified 97 studies that use or suggest NCA in the business and management field (see Table 1). This illustrates the rapid increase of NCA publications: the number of NCA articles in 2022 has more than doubled in comparison to the number of NCA articles in the 2016–2021 period. Below we briefly introduce some of the articles that we found interesting, compelling and/or well-conducted. Such a choice is of course always subjective. However, our goal is not to provide a systematic review, but rather to highlight the diversity of NCA topics in the hope that this may inspire others.

Table 1 Studies using or suggesting NCA in different business and management disciplines

Authors (Year)	Journal	Discipline
Eggers et al. (2022)	Journal of Business Research	Entrepreneurship
Huang et al. (2022)	Journal of Innovation & Knowledge	Entrepreneurship
Linder et al. (2022)*	Entrepreneurship Theory & Practice	Entrepreneurship
Torres and Godinho (2022)	Small Business Economics	Entrepreneurship
Boon et al. (2019)*	Journal of Management	Human Resources Management and Organizational Behavior
Costa et al. (2022)	European Journal of Work and Organizational Psychology	Human Resources Management and Organizational Behavior
Garg (2017)		Journal of Human Values
Garg (2020)	Global Business Review	Human Resources Management and Organizational Behavior
Garg et al. (2019)	Vision: The Journal of Business Perspective	Human Resources Management and Organizational Behavior
Hauff (2021)*	The International Journal of Human Resource Management	Human Resources Management and Organizational Behavior
Hauff et al. (2021)	Human Resource Management Journal	Human Resources Management and Organizational Behavior
Jada and Mukhopadhyay (2019)	Personnel Review	Human Resources Management and Organizational Behavior
Korman et al. (2022)	Journal of Business and Psychology	Human Resources Management and Organizational Behavior
Pangarso et al. (2022)	Leadership & Organizational Development Journal	Human Resources Management and Organizational Behavior
Shahjehan et al. (2019)	Economic Research-Ekonomska Istraživanja	Human Resources Management and Organizational Behavior
Wang et al. (2022)	Journal of Management in Engineering	Human Resources Management and Organizational Behavior
Aguinis et al. (2022)*	Journal of International Business Studies	International Management
Bolívar et al. (2022)	Management International Review	International Management
Bouncken et al. (2022)	Global Strategy Journal	International Management
Fainshmidt et al. (2020)*	Journal of International Business Studies	International Management
Delgosha et al. (2021)	Information Systems Frontiers	International Management
Jovanovic and Morschett (2022)*	Industrial Marketing Management	International Management
Morse and Engle (2020)	Journal of Applied Business and Economics	International Management
Peng et al. (2022)	Technological Forecasting and Social Change	International Management

Table 1 (continued)

Authors (Year)	Journal	Discipline
Richter and Hauff (2022)*	Journal of World Business	International Management
Richter et al. (2021)	Journal of Business Research	International Management
Richter et al. (2020a)	European Journal of International Management	International Management
Schmuck et al. (2022)*	Management International Review	International Management
Zahoor et al. (2023)*	Journal of World Business	International Management
Bhattacharyya et al. (2023)	Journal of Business Research	Marketing
Cheung et al. (2022)	Journal of Retailing and Consumer Services	Marketing
Arbabi et al. (2022)	Journal of Risk and Financial Management	Marketing
Deng et al. (2022)	Industrial Management & Data Systems	Marketing
Frommeyer et al. (2022)	Journal of Business Research	Marketing
Jain et al. (2022b)	International Journal of Consumer Studies	Marketing
Koay et al. (2022)	British Food Journal	Marketing
Kopplin and Rausch (2022)	Review of Managerial Science	Marketing
Kopplin and Rösch (2021)	Journal of Retailing and Consumer Services	Marketing
Liu et al. (2022)	International Journal of Sports Marketing and Sponsorship	Marketing
Ogundipe et al. (2022)*	Industrial Marketing Management	Marketing
Pinochet et al. (2022)	Revista de Gestao	Marketing
Shahjehan and Qureshi (2019)	Economic Research-Ekonomska Istraživanja	Marketing
Sharma et al. (2022)	Technological Forecasting and Social Change	Marketing
Bokhorst et al. (2022)	International Journal of Production Economics	Operations and Supply Chain Management
Bokrantz and Dul (2023)*	Journal of Supply Chain Management	Operations and Supply Chain Management
Franke and Foerstl (2021)	Journal of Business Logistics	Operations and Supply Chain Management
Golini et al. (2016)	International Journal of Operations & Production Management	Operations and Supply Chain Management
Knol et al. (2018)	International Journal of Production Research	Operations and Supply Chain Management

Table 1 (continued)

Authors (Year)	Journal	Discipline
Knol et al. (2019)	International Journal of Operations & Production Management	Operations and Supply Chain Management
Lu et al. (2022)	International Journal of Emerging Markets	Operations and Supply Chain Management
Sousa and Da Silveira (2017)	International Journal of Operations & Production Management	Operations and Supply Chain Management
Stek and Schiele (2021)	Journal of Purchasing and Supply Management	Operations and Supply Chain Management
Abner et al. (2022)	Public Administration Review	Public and Nonprofit
Blom et al. (2022)	Public Administration Review	Public and Nonprofit
Lankoski and Lankoski (2023)	Ecological Economics	Public and Nonprofit
Saraf et al. (2022)	International Journal of Public Sector Management	Public and Nonprofit
Bouncken et al. (2020a)	Long Range Planning	Strategic Management
Bouncken et al. (2020c)*	Industrial Marketing Management	Strategic Management
Cheng and Jiang (2022)	Management Decision	Strategic Management
Du and Kim (2021)	Journal of Business Research	Strategic Management
Fredrich et al. (2019)	Journal of Business Research	Strategic Management
Fredrich et al. (2022)	Journal of Business Research	Strategic Management
Klimas et al. (2022)	European Management Journal	Strategic Management
Lexutt (2020)*	Industrial Marketing Management	Strategic Management
Ortigueira-Sánchez et al. (2022)	Sustainable Technology & Entrepreneurship	Strategic Management
Tho (2018)	Journal of Management Development	Strategic Management
Tho (2019)	Baltic Journal of Management	Strategic Management
Wang et al. (2023)	Corporate Social Responsibility and Environmental Management	Strategic Management
Bakır et al. (2023)	Sustainability	Technology and Innovation Management

Table 1 (continued)

Authors (Year)	Journal	Discipline
Battistoni et al. (2023)	International Journal of Production Economics	Technology and Innovation Management
Bouncken et al. (2020b)	Journal of Business Research	Technology and Innovation Management
Chaurasia et al. (2020)	Journal of Knowledge Management	Technology and Innovation Management
Gantert et al. (2022)	Journal of Business Research	Technology and Innovation Management
Dabić et al. (2021)*	Technovation	Technology and Innovation Management
Ding (2022)	Journal of Innovation & Knowledge	Technology and Innovation Management
Han and Zhang (2022)	Managerial and Decision Economics	Technology and Innovation Management
Hayat et al. (2022)	Technology in Society	Technology and Innovation Management
Jain et al. (2022a)	Research in Transportation Business & Management	Technology and Innovation Management
Jaiswal and Zane (2022)	Thunderbird International Business Review	Technology and Innovation Management
Kobarg et al. (2020)	Industry and Innovation	Technology and Innovation Management
Kopplin et al. (2022)	Review of Managerial Science	Technology and Innovation Management
Lyu et al. (2022)	Journal of Consumer Behaviour	Technology and Innovation Management
Sukhov et al. (2022)	Transportation Research Part A: Policy and Practice	Technology and Innovation Management
Tsekouras et al. (2022)	Information & Management	Technology and Innovation Management
van der Valk et al. (2016)	Journal of Purchasing and Supply Management	Technology and Innovation Management
Wei and Chen (2019)	Sustainability	Technology and Innovation Management
Yang and Hurmelinna-Laukkanen (2022)	Technovation	Technology and Innovation Management
Zheng et al. (2022)	PloS ONE	Technology and Innovation Management
Abdalla et al. (2022)	International Journal of Tourism Research	Tourism and Hospitality
Becker et al. (2023)*	International Journal of Contemporary Hospitality Management	Tourism and Hospitality
Della Corte et al. (2023)	International Journal of Contemporary Hospitality Management	Tourism and Hospitality
Lee and Jeong (2020)	Current Issues in Tourism	Tourism and Hospitality
Lee and Jeong (2021)	Journal of Hospitality and Tourism Management	Tourism and Hospitality

Table 1 (continued)

Authors (Year)	Journal	Discipline
Lee et al. (2022)	Journal of Hospitality and Tourism Management	Tourism and Hospitality
Thapa et al. (2023)	Journal of Transportation Engineering	Tourism and Hospitality
Tóth et al. (2019)	Annals of Tourism Research	Tourism and Hospitality
Yu et al. (2022)	International Journal of Contemporary Hospitality Management	Tourism and Hospitality

Many articles touch on different disciplines which makes the categorization sometimes difficult. The table represents our perspective which might diverge from that of the authors or other readers of these studies

Situation until December 8, 2022

*This article suggests using NCA. The other articles are applications of NCA

3.1 Entrepreneurship

Linder et al. (2022) point out that the study of necessary conditions can enhance the theory-method compatibility in quantitative entrepreneurship research. The authors emphasize that necessary conditions are "theoretically different from what enables firms to, say, outperform peers" and that NCA can be a "valuable analytical tool to identify necessary conditions that allow firms to, say, enter a market" (ebd. p. 2). They discuss the basics of necessity logic and its importance in entrepreneurship and illustrate the application of NCA using founder's experience. Results show that founders need to have some experience (e.g., in terms of managerial or start-up experience) for receiving loans (since banks obviously want to reduce their risks), but experience is no necessary condition for explorative or exploitative behavior of the founders.

Also focusing on the individual level, Huang et al. (2022) analyze which psycho-cognitive conditions are necessary conditions of women's entrepreneurial activity. Their results show that a high capability perception (i.e., the ability to complete a task, confidence in leadership, or the perception of task success) and a high opportunity perception (i.e., the ability of entrepreneurs to perceive entrepreneurial opportunities) can be considered a necessary condition for women's entrepreneurial activity. In contrast, entrepreneurial expectation, entrepreneurial motivation and low fear of failure do not represent cognitive elements that are necessary for female entrepreneurial activity.

NCA can also be applied to macro level questions in entrepreneurship research. Torres and Godinho (2022), for example, ask which elements of a digital entrepreneurial ecosystem are necessary in a country to produce high-quality entrepreneurship that relies on a well-functioning digital infrastructure (called "digitally-enabled unicorns"). Digital entrepreneurial ecosystems are referred to as "a combination of elements, in a particular territory, backing the growth of start-ups aiming to pursue new opportunities that arise from digital technologies" (ebd. p. 2). The authors found support for their assumption that cultural and informal institutions, formal institutions, regulation, and taxation, market conditions, physical infrastructure, human capital, knowledge creation and dissemination, finance, as well as networking and support are necessary conditions to produce digitally-enabled unicorns.

3.2 Human resource management (HRM) and organizational behavior

Boon et al. (2019) and Hauff (2021) suggested to use NCA for the study of HRM systems. For example, Boon et al. (2019) state: "Examining which practices need to be present for the system to be effective and which practices make the difference between average and good performance can also help to enhance knowledge about HR systems" (ebd. p. 2552). In their general introduction of necessity logic and NCA for HRM research, Hauff et al. (2021) apply the ability, motivation, and opportunity (AMO) model, which represents a core framework for HRM systems research, and analyze whether AMO-enhancing HRM-practices are necessary for employee performance. Results reveal that it is only the O-enhancing HRM practices that have a

meaningful necessary condition. However, considering the relation between human capital, employee attitudes, and employee performance, their study shows that both human capital and employee attitudes are necessary for employee performance.

Besides the study of HRM systems, NCA has also been applied in the context of leadership research. For example, Jada and Mukhopadhyay (2019) studied which leadership styles are necessary conditions for encouraging promotive voice (expression of new ideas or suggestions) and prohibitive voice (expression of concerns). Their findings reveal that empowering, transformational and ethical leadership as necessary conditions for high levels of promotive voice. For prohibitive voice, only empowering leadership had a substantial effect size. Costa et al. (2022) found that a supervisor's organizational embodiment (i.e., the perception of employees that their leader shares the values and norms of their organization) represents a necessary condition for high levels of organizational identification among employees, in contrast, ethical leadership is not necessary for organizational identification. Furthermore, Pangarso et al. (2022) found that empowering leadership represents a necessary condition for digital organizational culture which itself is necessary for high levels of employee performance.

Other studies have encountered necessary conditions for the well-being of employees and managers. Wang et al. (2022), for example found that need for competence and need for relationship are necessary for a high level of employee well-being. Korman et al. (2022) found that managers' sense of power and managers' self-efficacy are necessary conditions for low levels of burnout.

3.3 International management

For international management, Aguinis et al. (2022) and Richter and Hauff (2022) have proposed the use of NCA. Aguinis et al. (2022) consider NCA as a solution to provide better insights about causal relations in international management. Richter and Hauff (2022) argue that necessity logic and NCA provide a way in international management for "advancing the field with a new perspective on causality and data analysis". Searching for statements about necessary conditions in the two top journals (i.e., Journal of World Business and the Journal of International Business Studies), Richter and Hauff (2022) identified 41 articles that point to a necessity logic in their theoretical argumentation. Of these papers, 16 deal with internationalization patterns and the performance of MNE firms, 11 examine knowledge sharing and creation among intra- and inter-firm international partners, four refer to foreign entry mode success, and 10 articles relate to a diversity of topics (e.g., brand identification, ecological sustainability). Richter and Hauff (2022) illustrate the use of NCA by examining if certain institutional factors are necessary conditions for inward foreign direct investments. Their results show that foreign direct investments can only be achieved with a certain level of non-corruption, favorable taxation, flexible labor regulations, and political stability.

Drawing from the network theory of international business and the perspective of structural embeddedness of interorganizational relationships, Bolívar et al. (2022) study the role of access to network resources and mobilization of network

resources for the speed of international expansion of MNEs. NCA results indicate that access to network resources is a necessary condition for the mobilization of network resources; both access to and mobilization of network resources are necessary conditions for the speed of MNE international expansion.

A further topic is the study of cultural intelligence (CQ). Richter et al. (2020a) found that cognitive CQ, metacognitive CQ and motivational CQ are necessary conditions for expatriation intention. The results vary, however, across countries (in this case China, Germany, and the US). In the context of global virtual teams, Richter et al. (2021) hypothesized that the team's average level of motivational CQ, the motivational CQ of the least culturally intelligent member on the team, and the motivational CQ of the team leader are necessary conditions for strong social integration on the team and good team performance. Their results partially support these assumptions: the team's average level of motivational CQ is necessary for both social integration and performance; the motivational CQ of the team leader is necessary for social integration.

3.4 Marketing

An introduction of NCA for marketing research has been provided by Dul et al. (2021). The authors show how NCA can be applied to identify necessary conditions of marketing phenomena. Their work also discusses the opportunities of using NCA in the study of consumer markets, strategic marketing and marketing planning, marketing communications, personal selling and sales, and business-to-business (B2B) marketing.

Current applications of NCA in marketing research are focused on consumers attitudes and behaviors. For example, Liu et al. (2022) analyze the drivers and consequences of the "awe" emotion (understood as "an accommodation of stimulating experiences", ebd. p. 279) in outdoor sport. Results show that the perceived vastness of a natural environment and perceived professionalism form a necessary condition for awe. Awe itself acts as a necessary condition for both participants' satisfaction and behavioral intention. Kopplin and Rausch (2022) apply NCA in their analysis on the role of consumers' dietary behavior for the purchase of plant-based food substitutes. Results show that a certain level of animal welfare concerns is necessary for consumers' dietary behavior, while environmental concerns, health consciousness, and perceived consumer effectiveness are not. Furthermore, a positive attitude towards plant-based food substitutes is necessary for purchase intention, while subjective norm is not. In another study, Kopplin and Rösch (2021) analyze the causes of sustainable clothing purchase behavior. They found that environmental concern, self-expressiveness (i.e., an individual's perception that they may express their identity by purchasing and wearing sustainable clothing), social influence, and price value (i.e., the relation of cost and benefit) qualify as necessary conditions of purchase intention, while visibility (i.e., an individual's perception of the purchased good being visible to others) does not.

3.5 Operations and supply chain management

Already in 2010, Dul et al. explored the prevalence of necessity statements in operations management and identified 32 studies with necessary condition statements. These statements were particularly common in studies on the determinants of the successful implementation of operations management practices such as total quality management, business process reengineering, just in time flow, and enterprise resource planning (Dul et al. 2010). Extending this work, Bokrantz and Dul (2022) propose the application of NCA to supply chain management, with a particular focus on developing necessity theories in supply chain management. Their literature review identified 92 papers that contained statements about necessity, underscoring the high relevance of necessity theory in supply chain management. The range of topics covered in the field is huge. For example, studies cover typical relationships and exchanges among firms in the supply chain, such as internal and external collaboration or supply chain responsiveness. Other studies integrate concepts or mechanisms from general theory in necessary conditions related to operations and supply chain management. Among those is the study of absorptive capacity or the appliance of the resource-based view.

An early application of NCA in operations has been provided by Knol et al. (2018) who examined critical success factors for implementing lean practices in small- and medium-sized firms. The authors identified 12 critical success factors, namely top management support, shared improvement vision, good communication, leadership, people focus, learning focus, sufficient resources, improvement training, performance measurement system, supplier link, customer link and support congruence. Findings indicate that the 12 conditions are necessary for the implementation of lean practices. Notably, the authors used an earlier version of NCA which did not yet include a statistical test to reduce the risk of false positives (Dul 2020). In a more recent application of NCA, Bokhorst et al. (2022) analyzed whether the use of lean principles is necessary for the use of smart technology. Their findings show that smart manufacturing technologies like work-on-screen, product tracking, MES systems and flexible automation require the presence of lean principles.

Stek and Schiele (2021) analyzed which skills of purchasing and supply management professionals are necessary to be successful. The authors identified 15 different skills and analyzed exploratively which of the skills are necessary to achieve different outcomes (i. e. reducing costs and improving delivery, quality, sustainability, strategic competitive advantage, supplier satisfaction and innovation). Results revealed that different skills are needed depending on the objective.

3.6 Public and nonprofit management

Researchers in public and nonprofit management have only recently begun to apply NCA, with a focus on HRM and organizational behavior. Abner et al. (2022), for example, aim to identify the organizational conditions that are necessary for high employee engagement and satisfaction in the public sector. Their findings reveal that

certain levels of empowerment, effective senior leadership, effective leadership by supervisors, employee skills–mission match, pay, teamwork, innovation, work-life balance, and recognition are necessary for high levels of employee engagement and satisfaction. Blom et al. (2022) hypothesize that HRM autonomy is necessary for HRM integration and that HRM integration is necessary for HRM performance in government agencies. NCA results support both hypotheses.

3.7 Strategic management

In strategic management, NCA is applied to different topics including the necessity of organizational resources, the constraints of specific market conditions, or the need of adopting specific strategic orientations to be successful. Tho (2018), for example, applied the resource-based view to study whether marketing and innovativeness capabilities are necessary conditions for firm performance. Findings indicate that business relationship quality, responsiveness to customers, responsiveness to competitors, responsiveness to the macro-environment and innovativeness capability are necessary for high firm performance.

Bouncken et al. (2020a) research different configurations of value capture (in terms of sales) in inter-firm coopetition arrangements. They complement their fsQCA study by applying NCA. Results indicate that market overlap represents a necessary condition for the focal firm achieving sales from the coopetition arrangement. Klimas et al. (2022) study strategic frames for the adoption of coopetition strategies. They find that customer demands are the only single cause necessary for all internal coopetition factors revealing its key influence on coopetition. Furthermore, the NCA results reveal that the internal availability of resources shapes a single necessary condition for the external coopetition.

Regarding the necessity of specific strategic orientations, Tho (2019) found that strategic orientations, such as learning orientation and the entrepreneurial orientation's components of market orientation and proactiveness are necessary conditions for firm innovativeness. Similar, Du and Kim (2021) tested whether market orientation, political networking and entrepreneurial orientation are necessary for high new venture performance, but did not find substantial effects.

3.8 Technology and innovation management

In the field or technology and innovation management we see a huge variety of NCA applications. Several studies have applied NCA to identify necessary conditions for technology acceptance. Kopplin et al. (2022), for example, use an extended technology acceptance model for matchmaking tools in coworking spaces. Coworking spaces host often unrelated workers and entrepreneurs. For enfolding positive influence on work satisfaction, community feeling, creativity, and innovation these coworkers, often from different affiliations, need to get together. This is where matchmaking tools kick in. Results reveal that the behavioral intention of using these tools will only be high if three necessary conditions are met, namely performance expectancy, effort expectancy and hedonic motivation. Similar, Richter et al. (2020b)

show that emotional value, ease of use, perceived usefulness and compatibility form necessary conditions for the adoption intention of e-books. Lyu et al. (2022) analyze the simultaneous and countervailing influence of appreciation and fatigue when customers use mobile banking apps. The study is anchored in technology task fit theory and expectancy disconfirmation theory. Results reveal that lifestyle fit, function fit and non-core features are necessary conditions for appreciation. Furthermore, appreciation is a significant necessary condition for app use.

Gantert et al. (2022) study makerspaces which they perceive as genuine places of creativity and collaboration. As these places relate to open exchanges and help among individuals, makerspaces might have important linkages to the individual or the spaces' moral foundations. The authors found that moral foundations which 'regulate' the social interaction are a necessary condition of low and high innovativeness. In contrast and surprisingly, the technical facilities of makerspaces are not necessary at all for innovation. Differently, Zheng et al. (2022) show that operating mechanisms are needed for the innovativeness of a makerspace. In particular, their NCA results reveal that a high number of service functions and a high number of channels for resource gathering are necessary for makerspaces to achieve high innovation performance.

3.9 Tourism and hospitality management

Researchers in the field of tourism and hospitality have increasingly been attracted by NCA (Dul 2022b; Tóth et al. 2019). Studies on experiences and decisions of tourists have especially drawn attention of a necessity perspective. For example, Lee and Jeong (2020) studied whether hedonia (including positive affect, negative affect, carefreeness, and hedonic enjoyment) is necessary for eudaimonia (including meaning, self-connectedness, accomplishment, and personal expressiveness) in the context of tourist experiences. Results reveal that tourist hedonic experiences are necessary for eudaimonic experiences (except for negative affect). In another study, Lee et al. (2022) hypothesize that low perceived risks are necessary conditions for high travel intention. Findings support this assumption: low facility, functional, socio-cultural, physical and political terror risks are each necessary for high travel intentions.

Tourism research has also applied NCA to better understand organizational strategies. For example, Della Corte et al. (2021) examined the collaboration among high-end hotels in tourist destinations. Their findings indicate that relational capability can be considered a necessary condition for the propensity to collaboration. In contrast, the effect size for individual capability did not turn out to be significant.

4 Guidelines for good NCA practice

Our review has shown that NCA has been applied or suggested for a broad variety of topics. It highlights the flexibility and potential of NCA applications. To support researchers with their future NCA studies and to ensure a high quality of these studies, we present several guidelines in the following. The overall set of guidelines is shown in Table 2.

Table 2 Basic guidelines for good NCA practice

Topic	Guidelines
Theoretical justification	Explain why X is necessary for Y Formulate the relationship between X and Y in terms of a necessity hypothesis (e.g., in terms of 'X is necessary for Y') In explorative research, theoretically justify a necessary condition that is found ex post
Meaningful data	Use a good sample Use valid and reliable scores of X and Y (e.g., by using common approaches for evaluation of validity and reliability)
Scatter plot	Show the scatter plot (or contingency table) of all conditions that are evaluated for necessity Visually inspect the scatter plot (e.g., pattern of the border, potential outliers)
Ceiling line	Select the ceiling(s) based on the number of levels of X and Y and the expected or visually observed (non-)linearity of the border Only show the selected ceiling lines in the scatter plot. Do not show the two (default) ceiling lines if these are not selected for the analysis
Effect size	Report the estimated effect size Evaluate the practical relevance of the effect size (e.g., threshold level > 0.1)
Statistical test	Report the estimated p value Evaluate the statistical relevance of the effect size (e.g., threshold level < 0.05)
Bottleneck analysis (necessity in degree)	Present the bottleneck table for the non-rejected necessary conditions Decide how to present the bottleneck table (e.g., percentage of range, actual values, percentiles)
Descriptions of NCA	Refer to NCA as a method (including logic/theory, data analysis and statistical testing), not just as a statistical tool or data analysis technique Acknowledge that • NCA's necessity analysis differs from fsQCA's necessity analysis • NCA differs from a 'moderation analysis' in regression analysis • NCA is not a robustness test for other methods Properly describe elements of NCA, e.g. • Use only necessity wordings to describe the necessity relationship between X and Y (avoid imprecise or general words like (cor)related, associated, and incorrect sufficiency-based words like produce, explain) • Refer to NCA's statistical test as a permutation test (avoid incorrect descriptions like bootstrapping, (Monte Carlo) simulation, robustness check, or t-test) • Use the name 'multiple NCA' or 'multiple bivariate NCA' rather than 'multivariate NCA' when several conditions are analyzed in one run

4.1 Theoretical justification

NCA describes causal relationships between X and Y in terms of 'necessary but not sufficient'. When applying NCA, the relationship of interest must be explicitly understood and described as a necessity relationship.

Explain why X can be necessary for Y.

Although we acknowledge that there are differences between disciplines, we suggest that the first step (an exception is exploratory research, see below) in NCA should provide a theoretical justification of the necessary relationship by explaining why X is necessary for Y. This can be done by answering why cases with the outcome will almost always have the condition, why cases without the condition rarely have the outcome, and why the absence of the condition cannot be compensated or substituted by another factor (Bokrantz and Dul 2022; Richter and Hauff 2022). Because theories seldom hold universally, also the theoretical domain (sometimes called 'context' or 'boundary conditions') where the necessary condition hypothesis is supposed to hold should be specified.

- Formulate the relationship between X and Y in terms of necessity hypothesis (e.g., in terms of 'X is necessary for Y').

A hypothesis usually assumes a causal relationship including that X existed before Y was present (temporal requirement of causality). Two formats for a necessary condition hypothesis are possible. In the 'necessity' or 'enabling' format 'the presence of X is necessary for the presence of Y' and in the 'sufficiency' or 'constraint' format 'the absence of X is sufficient for the absence of Y'. The necessity format is the most common, and hypotheses are often formulated as simple as 'X is necessary for Y' implying that the presence (or a high level) of X is necessary for the presence (or a high level) of Y. Notably, also the necessity format can refer to absence/low level of X and Y or to a combination of the presence/high level or absence/low level of X and Y. For example, researchers can assume that the presence/high level of X is necessary for the absence/low level of Y, or that the absence/low level of X is necessary for the presence/high level of Y (see also below).

- In explorative research, theoretically justify a necessary condition that is found in explorative research ex post.

A theoretical justification of necessary conditions is not only important in theory-testing research before the empirical test is done, but also in theory-building and exploratory research. Then the theoretical justification follows the empirical data which has been analyzed and potential necessary conditions identified. For example, when data mining is done with 'big data' most likely relationship that look like necessity will be identified but are actually meaningless or trivial. Thus, also in explorative research, we suggest to always explain identified necessary conditions as described above (i.e., explain why the condition will be present if the outcome is present, why the outcome cannot be achieved without the condition, and why the

absence of the condition cannot be compensated by another factor). Like for any other type of cause-effect relations, causality cannot be observed from data only, which highlights the importance of theoretical justification.

4.2 Meaningful data

The quality of any data analysis depends on the quality of the data. NCA does not put additional requirements on the quality of the data but demands the same standards as of other empirical studies.

- Use a good sample.

Technically, NCA can be done with very small data sets (even n = 1 is possible). This, however, does not preserve researchers to gather a good sample. Most important, the cases should be selected such that they represent a larger set of cases (i.e., a sample of cases representing a population of cases).

- Use valid and reliable scores of X and Y (e.g., by using common approaches for evaluation of validity and reliability).

NCA is very flexible since it can handle (combinations of) dichotomous, discrete and continuous variables (Dul 2020). X and Y can also be indicator scores, construct or latent variable scores, factor scores, set membership scores, etc. (see Richter et al. (2020b) on how to apply NCA with latent variables scores in structural equation models and Dul (2021) on how to apply NCA with set membership scores). NCA requires, however, like any other data analysis technique, that the scores are valid (i.e., they measure what they are supposed to measure) and reliable (i.e., the same value is achieved in repeated measuring) or otherwise meaningful (e.g., calibrated set membership scores). Existing methods to assess the validity and reliability of X and Y can be used. There are no new requirements from the perspective of NCA.

4.3 Scatter plot

The scatter plot is an important graphical tool for NCA for different reasons. First, NCA evaluates bivariate relationships and scatter plots represent such relationships. This allows a visual inspection of the possibility of a necessity relationship by identifying areas without observations ('empty spaces'). Second, the scatter plot assists with empirically selecting the functional form of the ceiling line (e.g., Rönkkö et al. 2022). Third, the scatter plot helps to identify possible outliers (Aguinis et al. 2013). Given the importance of the scatter plot, researchers should consider some basic guidelines regarding its presentation.

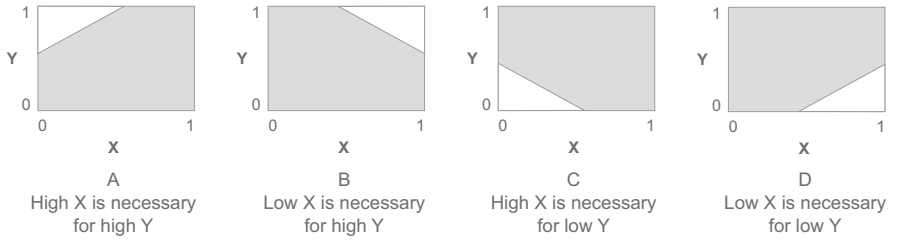


Fig. 2 Different expressions of necessity hypotheses. *Source* Dul (2020)

- Show the scatter plot (or contingency table) of all conditions that are evaluated for necessity.

For the three reasons mentioned, we suggest presenting the scatter plot of all bivariate relationships that are evaluated for necessity. This applies not only to scatter plots of confirmed necessity relations, but also to scatter plots with disconfirmed necessity relations.

- Visually inspect the scatter plot (e.g., pattern of the border, potential outliers).

The first visual inspection is a check if an empty space exists in the corner that is expected to be empty given the necessity hypothesis. If the hypothesis is formulated as 'the presence of X is necessary for the presence of Y', then the expected empty space is in the upper left corner (Fig. 2, Panel A). If the hypothesis is formulated as 'the absence of X is necessary for the presence of Y', then the expected empty space is in the upper right corner (Fig. 2, Panel B). If the hypothesis is formulated as 'the presence of X is necessary for the absence of Y', the expected empty space is in the lower left corner (Fig. 2, Panel C), and if the hypothesis is formulated as 'the absence of X is necessary for the absence of Y', the expected empty space is in the lower right corner (Fig. 2, Panel D).

The second visual inspection is an evaluation of the border between the empty and the full space. This allows for empirically selecting the functional form of ceiling line (linear or non-linear, see below).

The third visual inspection is meant for identifying outliers. Potential outliers are observations (cases) in the scatter plot that are used for drawing the ceiling line ('ceiling outliers'), or cases that define the minimum of maximum X and Y values ('scope outliers'). Outliers have a large influence on the effect size if removed and should be treated with particular care in the context of NCA. If outliers result from errors in the data collection process (e.g., sampling errors, measurement errors) they should be removed from the analysis. If this can be excluded, outliers can be particular cases that might help to better understand the research phenomenon (Gibbert et al. 2021). This applies in particularly when studying necessary conditions since an outlier in the otherwise empty space can represent a "best case" where a high level of the desired outcome can exist without the condition or with a comparatively low level of the condition. It is possible

to apply NCA while allowing a few outliers (for more details about outlier analysis with NCA see Dul (2021)).

4.4 Ceiling line

The ceiling line divides the areas with and without observations in the scatter plot. For most applications one of the default lines (CE-FDH or CR-FDH) is appropriate.

- Select the ceiling(s) based on the number of levels of X and Y and the expected or visually observed (non-)linearity of the border.

The guideline is to select a ceiling line and justify the choice. The Ceiling Envelopment—Free Disposal Hull (CE-FDH) line can be used when X or Y are discrete with a low number of levels or when the pattern of points near the border is irregular. The Ceiling Regression—Free Disposal Hull (CR-FDH) can be used when X and Y are continuous or discrete with many levels, when the pattern of points near the border is approximately linear, or when it is assumed that the theoretical ceiling line is a straight line (Dul 2016b, 2020). If the choice is difficult, (e.g., when the variables are discrete with moderate number of levels, or when the border is only a bit irregular without a specific expectation for the population), it is possible to perform the analysis with both default ceiling lines, for testing the robustness of the analysis by comparing the results.

For certain specific purposes a non-default ceiling line could be selected. For example, the Ceiling Envelopment—Varying Return to Scale (CE-VRS) ceiling technique could be used when the maximum value of outcome Y diminishes with increasing X. When perfect data are assumed without measurement error, as for example in most Monte Carlo simulation studies, the Ceiling—Linear Programming (C-LP) line could be useful as an alternative (Dul 2021).

- Show the selected ceiling lines in the scatter plot. Do not show (default) ceiling lines if these are not selected for the analysis.

The ceiling lines shown in scatter plots should correspond to the ceiling lines that are used for the analysis. Therefore, we suggest that to only display the ceiling lines that are considered appropriate for the analysis.

4.5 Effect size

The effect is the size of the space above the ceiling line (ceiling zone) as a fraction of the scope. The scope is the total zone where observations can be expected given the minimum and maximum observed values of X and Y (empirical scope) or theoretically possible values of X and Y (theoretical scope). By default, NCA uses the empirical scope. However, there may be good reasons to use the

theoretical scope to be able to compare the same phenomenon in different situations (e.g., different moments in time) or when the theoretical scope is known (e.g., in Monte Carlo simulations or when NCA is used with set membership scores). The choice for a theoretical scope should be justified since the effect size is usually larger with the theoretical scope and there is the risk of overestimating the effect size (Dul 2020).

- Report the estimated effect size.

The first guideline for the effect size is to report the effect size of all relationships that have been tested for necessity. We recommended to express effect sizes with an accuracy of two digits after the decimal point.

- Evaluate the practical relevance of the effect size (e.g., threshold level > 0.1).

The second guideline for the effect size is to evaluate its practical relevance. The effect size (d) can be classified as follows: small effect sizes $0 < d < 0.1$, medium $0.1 \leq d < 0.3$, large effect size $0.3 \leq d < 0.5$, and very large effect size ≥ 0.5 (Dul 2016b). Building on this classification, an effect size greater than or equal to 0.1 is often considered to be practically relevant. This can be seen as a general guideline. However, the researcher's judgment about the practical relevance you might also need to include that i) an effect size greater than 0.1 might not be practical relevant if higher levels of the outcome are not constrained by the condition (i.e., only lower levels of Y are constrained by X), ii) the magnitude of the effect size is not automatically an indicator of higher practical relevance since a small effect size can be equally relevant like a large effect size (i.e., if a small level of X is needed for the desired level of Y), iii) the practical relevance of the effect size depends on the specific context. Ultimately, it is a judgement by the researcher to consider the effect size as practically relevant or not. If such judgement is difficult, often the general guideline is used.

4.6 Statistical test

NCA's statistical test is a test of the randomness of the effect size using approximate permutation that resamples from the permutation distribution. The test evaluates the probability p that the empty space is a random result of two unrelated variables. The p value helps to avoid making the false positive conclusion that the empty space is caused by necessity whereas actually it is a random result of unrelated variables (Dul et al. 2020).

- Report the estimated *p* value.

The first guideline for the statistical test is to report the p value for each tested relationship. If computation time allows, we recommend using at least 10,000

resamples for acceptable accuracy of the estimated p value. We also recommend expressing the p value with an accuracy of three digits after the decimal point.

- Evaluate the statistical relevance of the effect size (e.g., threshold level < 0.05).

The statistical relevance of the effect size can be evaluated with the p value. A low p value represents a statistically significant result. The meaning of 'low' is judged by the researcher. Usually, a p value less than or equal to 0.05 is considered as a statistically significant result.

4.7 Bottleneck analysis

The bottleneck analysis is an analysis of necessity in degree: 'level X_c of X is necessary for level Y_c of Y' with X_c being the critical level of X and Y_c being the desired level of Y. The bottleneck analysis can be done with the bottleneck table.

- Present the bottleneck table for the non-rejected necessary conditions.

Our first guideline regarding the bottleneck table is to not include conditions that are rejected as necessary conditions. A bottleneck analysis for evaluating necessity in degree is only useful when there is theoretical and empirical support for a supposed necessary condition. In other words, when all three criteria for concluding about necessity *in kind* are satisfied (i.e., theoretical justification, large effect size, small p value), the necessity *in degree* can be evaluated with a bottleneck analysis.

- Decide how to present the bottleneck table

The levels of X and Y in the bottleneck table can be expressed as percentage of range, actual values, percentiles or percentage of maximum (Dul 2021). Depending on the option, the bottleneck table contains different information (see Table 3). In the default bottleneck table, the levels of Y and X's are expressed as percentages of their respective ranges, were a level of 0% of the range corresponds to the minimum level, and 100% the maximum level of X and Y. Often researchers use this default not referring to the other options. However, depending on the research question and the indented practical insights, using actual values or percentiles might be advantageous and, arguably, more insightful. Actual values are the values of X and Y as they are represented in the original dataset and the scatter plot. Thus, using actual values can help to better relate to the original measurement of X and Y and to better compare the results in the bottleneck table with the scatter plot results. The conditions can also be displayed as percentiles, which provides the percentage and number of cases that do not reach the required level for a corresponding level of the outcome. This is helpful in identifying important necessary conditions for a group of cases (i.e., conditions where a high percentage of cases in a sample has not reached the required level). Building on these considerations, we suggest not to automatically

Table 3 Options to present the bottleneck table Data from van der Valk et al. (2016)

Innovation (percentage range)	Contractual detail (percentage range)	Goodwill trust (percentage range)	Competence trust (percentage range)	Innovation (actual)	Contractual detail (actual)	Goodwill trust (actual)	Competence trust (actual)	Innovation (actual)	Contractual detail (percentile)		Goodwill trust (percentile)		Competence trust (percentile)	
Y	X_1	X_2	X_3	Y	X_1	X_2	X_3	Y	X_1		X_2		X_3	
0	NN	NN	NN	1	NN	NN	NN	1	0	(0)	0	(0)	0	(0)
10	NN	NN	NN	1.4	NN	NN	NN	1.4	0	(0)	0	(0)	0	(0)
20	NN	NN	NN	1.8	NN	NN	NN	1.8	0	(0)	0	(0)	0	(0)
30	NN	NN	NN	2.2	NN	NN	NN	2.2	0	(0)	0	(0)	0	(0)
40	NN	NN	NN	2.6	NN	NN	NN	2.6	0	(0)	0	(0)	0	(0)
50	NN	NN	NN	3.0	NN	NN	NN	3.0	0	(0)	0	(0)	0	(0)
60	8.3	2.2	NN	3.4	2.2	2.5	NN	3.4	8.3	(4)	4.2	(2)	0	(0)
70	27.4	35.2	26	3.8	2.9	3.3	3.5	3.8	31.2	(15)	20.8	(10)	27.1	(13)
80	46.5	68.2	54	4.2	3.7	4.1	4.1	4.2	58.3	(28)	68.8	(33)	62.5	(30)
90	65.6	NA	81.9	4.6	4.4	NA	4.6	4.6	81.2	(39)	NA	(NA)	79.2	(38)
100	84.7	NA	NA	5.0	5.1	NA	NA	5.0	89.6	(43)	NA	(NA)	NA	(NA)

use the default option but decide how to best present the bottleneck table. Notably, this also regards to the question of the steps in the bottleneck table. By default, the bottleneck table has ten steps. It is possible to adjust these steps for a better representation of the results. Furthermore, it is possible to select specific actual values for the outcome.

4.8 Descriptions of NCA

As NCA is a relatively new method, different elements of the method should be properly described and several incorrect descriptions avoided.

- Refer to NCA as a method (including logic/theory, data analysis and statistical testing), not just as a statistical tool.

NCA is not just a statistical tool. NCA is a method that includes theorizing about necessity logic, data analysis technique, and statistical testing. In other words, the analysis of necessary conditions should not be reduced to applying a statistical tool. Running the analysis without thinking about the causal relations is not appropriate.

- Acknowledgements that NCA's necessity analysis differs from fsQCA's necessity analysis.

The necessity analysis of fuzzy-set qualitative comparative analysis (fsQCA) is not the same as the necessity analysis of NCA (Vis and Dul 2018). The main differences are that a) NCA identifies both necessity in kind and necessity in degree whereas QCA only necessity in kind, that b) NCA normally uses variable scores whereas QCA is a set theoretic method that can only use set membership scores. Thus, the necessity analysis of NCA should not be confused with fsQCA's necessity analysis (for the usage of fsQCA in business and management research see also, e.g., Kraus et al. 2018; Kumar et al. 2022). QCA's necessity analysis should not be abbreviated as 'NCA' to avoid this confusion (Dul 2022b).

- Acknowledge that NCA differs from moderation analysis in regression analysis.

A necessary condition in NCA should also not be confused with a moderator in regression analysis. A moderator refers to a contingent or multiplicative relation where the average effect of one independent variable on the outcome depends on another independent variable called a moderator (e.g., Gardner et al. 2017). A moderator could be considered a necessary condition for a positive/negative average relation between X and Y, but this is not a necessary condition for the outcome Y. NCA analyses necessary conditions for the outcome. In order to illustrate the difference, consider the formula for a regression line with an interaction term: $Y = a + b_1 \cdot X + b_2 \cdot M + b_3 \cdot X \cdot M + \epsilon$ where M is the moderator, a is the intercept, b's are the

slopes, and ϵ is the error term. The formula illustrates that the (average) effect of X on Y might depend on M. The moderator is, however, not a necessary condition for Y since Y can still exist when M is zero. This does not correspond to the logic of necessity, according to which the absence of the necessary condition prevents the existence of the outcome, regardless of other conditions (Hauff et al. 2021).

- Acknowledge that NCA is not a robustness for other methods.

When NCA is used in multimethod research in combination with other methods like regression analysis, SEM or QCA, then NCA should not be described as a robustness test for the other method. NCA does not confirm or disconfirm the analysis of the other method. Instead, it complements the other method. NCA is an additional analysis based on a different causality and data analysis that complements other methods.

- Use only necessity wordings to describe the necessity relationship between X and Y (avoid imprecise or general words like (cor)related, associated, and incorrect sufficiency-based words like produce, explain).

An important guideline is to use only necessity wordings for describing the necessity relationship between X and Y. Necessity can be described in multiple ways, but there are specific words to do so (see Table 4). Not seldom researchers who apply NCA use imprecise or general words like '(cor)related' or 'associated', and sufficiency-based words like 'produce' or 'explain' to describe the necessity relationship. This should be avoided.

- Refer to NCA's statistical test as a permutation test (avoid incorrect descriptions like bootstrapping, (Monte Carlo) simulation, robustness check, or t-test).

Table 4 Common words representing necessity logic. *Source* Dul (2020)

Enablers (the presence of X is necessary for the presence of Y)	Constraints (the absence of X is sufficient for the absence of Y)
X is necessary for Y	X constrains Y
X enables Y	X limits Y
X is needed for Y	X blocks Y
X is critical for Y	X bounds Y
X is crucial for Y	X stops Y
X is essential for Y	X restricts Y
X is indispensable for Y	X is a barrier for Y
X is a prerequisite for Y	X is a bottleneck for Y
X is a requirement for Y	Without X there cannot be Y
X is a conditio sine qua non for Y	Absence of X is sufficient for absence of Y
X is a precondition for Y	
X allows Y	
There must be X to have Y	
Y requires X	

NCA's statistical test is an (approximate) permutation test (Dul et al. 2020). It should be referred to as such and not as bootstrapping, (Monte Carlo) simulation, robustness check, t-test, etc. These incorrect names do not represent what the NCA test actually performs.

- Use the name 'multiple NCA' or 'multiple bivariate NCA' rather than 'multivariate NCA' when several conditions are analyzed in one run.

When multiple necessary conditions are analyzed, such analysis can be called a 'multiple NCA' or 'multiple bivariate NCA' rather than 'multivariate NCA' (Dul 2021). The term 'multivariate' suggests that the necessity of a condition may depend on another condition. In NCA, the conditions are independent and multiple analyses can be done for each condition separately. For example, multiple conditions might be necessary to except a technology (e.g., emotional value, ease of use, perceived usefulness, and compatibility). The necessity of one of these conditions is independent of the necessity of another condition or of other causal factors. Therefore, NCA is always a binary analysis even if multiple necessary conditions are analyzed.

5 Conclusions

Research on NCA has been proliferating in several fields. This article identifies several topics, on which NCA has shown to deliver important insights or perspectives for future research, especially when applied properly. Therewith, we confirm Gary Goertz's assumption that any research field contains important necessary condition hypotheses (Goertz and Starr 2003). NCA has the potential to produce new theoretical and practical insights value (e.g., Aguinis et al. 2022; Bergh et al. 2022), and therefore we expect more NCA applications in the identified business and management fields, and beyond. To support researchers in their future NCA studies and to ensure the quality of future research with NCA, this paper proposes a list of basic guidelines for good NCA practice which are generic, and yet specific enough to be readily applicable. Notably, these guidelines represent the current state of the art. However, NCA is still a young method with great potential for applications. Future developments could therefore lead to an update of these guidelines—always with the goal of good NCA practice in mind.

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