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Does applying design thinking result in better new product concepts than a traditional innovation approach? An experimental comparison study☆

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ABSTRACT

Both practitioners and researchers have developed various approaches to support product development teams in their creative process of generating new and valuable product concepts. A key concern of all innovation approaches is to translate the needs, wants and aspirations of users and customers into product and service solutions that match the underlying needs. Many existing innovation approaches focus predominantly on the translation process itself by providing support for aggregating data and making trade-off decisions between user preferences traceable. For that reason, we label these approaches user preference-driven. In contrast, over the last two decades, design thinking (DT) has emerged as an approach that assumes knowledge of user needs information to be fuzzy and unreliable; it addresses this challenge by focusing on developing user experiences through empathic in-depth user research and iterative prototyping. Consequently, we label approaches such as DT user experience-driven. Although DT has generated particular interest among both practitioners and educators, the academic literature investigating the usefulness of DT remains scarce. To help close this gap, we study the performance implications of applying DT processes and tools in terms of new product concept creativity relative to applying a traditional innovation approach. Using an experimental design and collecting quantitative data from 53 teams and their projects, we find that teams applying DT outperform the control group that applies an alternative innovation approach, namely quality function deployment (QFD), in terms of the feasibility, relevance and specificity of concepts, but not the novelty. We discuss the implications of our findings for theory and practice.

1. Introduction

Successfully managing innovations has become an indispensable activity that contributes to a firm's competitiveness and long-term survival (Anderson, Potočnik, & Zhou, 2014). Fundamentally, every successful innovation has at its core a creative idea that emerges in the fuzzy front-end (FFE) of the new product development (NPD) process (Im, Montoya, & Workman, 2013). Obviously, a new product cannot be developed without novel ideas (Schulze & Hoegl, 2008), but generating and developing creative product ideas and concepts does not have to be left to chance or coincidence. Rather, it is a manageable yet complex interaction between an organization's resources and capabilities, and environmental factors (Shalley, Zhou, & Oldham, 2004; Woodman, Sawyer, & Griffin, 1993). Managing an organization's early product development phases successfully is therefore the basis for fruitful innovation management and competitive advantage (Amabile, 1988).

Practitioners and researchers have developed various approaches and methods to support product development teams in the creative early-stage processes of generating new and valuable product concepts. A key concern of most innovation approaches is

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to translate the needs, wants and aspirations of users and customers into product and service solutions that match a pre-defined problem. Thus, many of these existing approaches focus predominantly on the translation process itself by providing support for aggregating data and making trade-off decisions between user preferences traceable. This focus on the translation process, however, has some important shortcomings. By focusing too much on pre-defined user needs, there is a risk that product developers may generate solutions that, in the end, turn out to be the right solution to the wrong problem. This challenge highlights two basic issues that need to be addressed by innovation approaches. First, user needs (especially latent ones) are often not obvious, and thus require careful attention to be identified in the first place (Day, 1990; Lehrer, Ordanini, DeFillippi, & Miozzo, 2012). Second, existing approaches often implicitly assume that the present user need information is highly reliable. In fact, initial user need information is often only a first guess, which needs to be tested and re-evaluated iteratively through prototyping (Kelley, 2001).

To address these issues, both scholarly and practitioner literature streams have exhibited increasing and widespread interest in the application of the designers' perspective and, in particular, user-oriented design approaches to support creativity in the NPD process (Brown, 2008, 2009; Dorst, 2011; Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013; Martin, 2009). Having recently achieved prominence under the label 'design thinking' (DT), this approach emphasizes that users have many needs that they are unaware of or are unable to express (Chen & Venkatesh, 2013). Even more extensive than traditional approaches, DT aims at supporting the NPD process by uncovering tacit and latent customer needs through qualitative and empathic research (Beckman & Barry, 2007; Janssen & Dankbaar, 2008; Leonard & Rayport, 1997), thus improving the odds of creating radically new products and services (Veryzer & Borja de Mozota, 2005).

Despite its practical application and growing popularity (Carlgren, Rauth, & Elmquist, 2016), DT is an under-researched phenomenon requiring further empirical evidence to explain the underlying dynamics fully. Even though the body of literature on the value of design for NPD generally has grown tremendously in the past two decades (Luchs, Swan, & Creusen, 2016), research has only recently begun studying the impact of DT on NPD. In particular, researchers have examined the DT learning processes on the individual, group and organizational levels, identifying some boundary conditions. For example, Seidel and Fixson (2013) find that it is the quality rather than the quantity of brainstorming sessions that drive team performance during DT. Studying the implementation of DT in large, established organizations, Carlgren, Elmquist, and Rauth (2016) find that existing processes, cultures and power structures often make it difficult to implement DT to its full effect. As one of the first to investigate the effectiveness of DT, Wattanasupachoke (2012) finds a positive effect of DT on firms' innovativeness, as well as a positive indirect effect of DT on firms' performance through innovativeness. Providing further arguments for the usefulness of DT, Liedtka (2015) discusses the effect of DT through the reduction of cognitive biases. Most recently, Primus and Sonnenburg (2018) find evidence for individual and team flow experiences during DT that can further be enhanced through creative warm-ups. Still, empirical investigations of DT's effectiveness remain scarce (Liedtka, 2015).

Given these arguments, one of the most pressing research questions is what the impact is on developing new product concepts of an approach like DT that puts explicit emphasis on (1) exploring the fuzzy nature of user needs information via empathy and (2) reducing the unreliable nature of user need information via iterative prototyping.

The aim of this paper is to address this research question by investigating whether the application of DT results in the generation of superior new product (or service) concepts in terms of creativity compared to a more traditional, user preference-driven approach. In this study, we focus on the early NPD phases to examine the claim that DT particularly unfolds its advantageousness in the early stages of the NPD process (Luchs et al., 2016; Veryzer & Borja de Mozota, 2005). More precisely, we focus on the FFE of the NPD process, including activities such as problem framing, idea generation and concept development (Luchs & Swan, 2011; Reid & de Brentani, 2004).

The remainder of this paper is structured as follows. First, we provide an overview of the literature on innovation management approaches. This is followed by the development of hypotheses on the effects on the creativity of product concepts of applying DT, relative to using quality function deployment (QFD) as a typical representative of a traditional innovation approach. Using quantitative data from 53 student teams developing early-stage product concepts, we test our hypotheses and derive the implications of these findings for theory and managerial practice. Finally, we discuss the limitations of this study and avenues for future research.

2. Innovation methods in the FFE

2.1. *Traditional innovation methods: a user preference-driven approach*

A long tradition of literature has focused on analysing and utilizing systematic approaches to guide and support product concept generation in NPD's early phases (Griffin, 1997; Hidalgo & Albors, 2008). Generally, two major directions of approaching product concept generation evolved in the past: the marketers' perspective and the engineers' perspective. Painted in very broad strokes, while the marketers' perspective focuses on identifying which product characteristics will most appeal to customers by listening to the 'voice of the customer' (Griffin & Hauser, 1993), the engineers' perspective tries to meet these characteristics that customers value most by focusing on developing the right product characteristics (Michalek, Feinberg, & Papalambros, 2005). Methods and approaches supporting product development teams in the early stages of the NPD process that traditionally stem from a marketer's perspective include, for example, the Kano model (Chen & Chuang, 2008; Kano, Seraku, Takahashi, & Tsuji, 1984; Yang, 2005) or conjoint analysis (Choi & DeSarbo, 1994; Green & Krieger, 1991; Green & Rao, 1971; Moore, Louviere, & Verma, 1999). An example of a method that traditionally stems from the engineers' perspective is the theory of inventive problem solving (TIPS/TRIZ) (Althsuller, 1984; Dumas & Schmidt, 2015; Ilevbare, Probert, & Phaal, 2013).

More recent studies have suggested that the engineers' and marketers' perspectives complement one another (Katz, 2004; Maltz, Souder, & Kumar, 2001; Pullman, Moore, & Wardell, 2002; Shen, Tan, & Xie, 2000) and that considering both perspectives when applying the methods is a promising approach. Despite the broad range of these methods, they have in common that they aim at identifying current or obvious customer wants and needs (Gaskin, Griffin, Hauser, Katz, & Klein, 2010). These so-called traditional approaches make the implicit assumption that user needs information is relatively easy to acquire, and that it exhibits a high degree of reliability. In other words, once identified, prioritized and quantified, the information can be aggregated and compared to make objective feature and configuration decisions, often focusing on concrete product concepts early on (Michalek et al., 2005). Therefore, the marketers' intention of meeting market requirements and the engineers' intention of exploiting the firm's capabilities need to be aligned (Carnevalli & Miguel, 2008; Govers, 1996; Yung, 2006). Prior research primarily addressed the challenges that arise from this trade-off between crafting a superior product based on organizational know-how on the one hand, and simultaneously predicting its market acceptance and success on the other (Luchs et al., 2016). Against this background, we propose to synthesize innovation methods incorporating both the marketers' and the engineers' perspectives as user preference-driven approaches.

2.2. Design thinking: A user experience-driven approach

More recently, scholars have made considerable effort to investigate the value stemming from a company's focus on design and its importance for a firm's innovativeness (D'Ippolito, 2014; Hertenstein, Platt, & Veryzer, 2005; Kotler & Rath, 1984; Luchs & Swan, 2011; Luchs et al., 2016; Schneider, 1989). In particular, product design is increasingly perceived as an essential element of the NPD process (Abecassis-Moedas & Mahmoud-Jouini, 2008; Perks, Cooper, & Jones, 2005).

One concept that builds on this design-oriented NPD perspective is DT, which has been increasingly applied as a problem-solving approach to support product development teams in the early NPD phases (Veryzer & Borja de Mozota, 2005). DT can broadly be described as a creative problem-solving approach utilizing a designer's perspective including the respective principles, mindsets, methods and tools (Brown, 2008, 2009). In the managerial realm, DT is often described as a human-centred problem-solving approach that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, dealing with complexities and ill-defined problems, and concurrent business analysis (Brown, 2008; Carlgren, Rauth, et al., 2016; Glen, Suciu, & Baughn, 2014). So far, no generally accepted definition of DT has emerged (Liedtka, 2015), and according to Carlgren, Elmquist, et al. (2016) descriptions of DT range from a mindset that managers can learn from designers to process models that can be applied step by step. Based on a review of DT practices, Liedtka (2015) proposes that DT generally consists of three stages: data gathering about user needs, idea generation, and testing. This is in close correspondence to what Seidel and Fixson (2013, p. 19) term "needfinding, brainstorming, and prototyping". Note that although distinct phases have emerged, the nature of DT is an iterative approach.

Researchers in the growing field of customer co-creation, and especially user innovation, recognized early on the importance of user experiences for product innovations (von Hippel, 1976) and emphasized their value for NPD processes (Poetz & Schreier, 2012). Customer involvement can range from more passive participation—i.e. using customers as an information source in NPD—to co-creating products together with customers, to the most extreme interpretation, where users develop innovations on their own (Cui & Wu, 2016; Nambisan, 2002). In contrast to producer innovators that create innovations in order to sell them, user innovators develop innovations because they personally want to benefit from them (Gambardella, Raasch, & von Hippel, 2017). Thus, user-generated products are largely the direct result of users' own unmet needs based on their personal experiences (von Hippel, 2005). Developed products that are based on users' own experiences therefore incorporate a great extent of deep user understanding and may even be relevant for other users with similar needs (De Jong, von Hippel, Gault, Kuusisto, & Raasch, 2015). Despite the advantages of utilizing user-generated products, what degree of customer involvement under which boundary conditions is most beneficial for a company is still not fully understood (Chang & Taylor, 2015). Consequently, companies may still have to rely on their own NPD activities and can therefore only integrate customers into the NPD process to a certain extent. In those cases, a remaining major challenge of integrating customer information in the NPD process lies in the company's ability to gather, interpret and transfer the information obtained into meaningful product concepts (Cui & Wu, 2017). DT's clear empathy-driven mindset and emphasis on user experiences as a source of new products may be a viable way of improving the odds of coming up with products that better suit latent user needs, and may therefore be able to counteract companies' liabilities related to their lack of customer proximity. Against this background, DT puts much more emphasis on uncovering tacit and latent user needs through qualitative analysis and empathic observations than most traditional approaches do, these tending to focus more on measuring attribute-based preferences quantitatively (Leonard & Rayport, 1997). In this way, DT acknowledges that user needs are often not obvious, and it aims at getting a deeper understanding of these needs beyond discrete product attributes (Luchs et al., 2016; Luo, Kannan, & Ratchford, 2008; Veryzer & Borja de Mozota, 2005).

A second major characteristic of DT is that it supports this process of unearthing and interpreting these latent needs by employing visualizations, which is especially important in helping participants from different domains to communicate and collaborate effectively (Liedtka, 2015). Moreover, DT includes early interactions of users with early conceptualizations of the product idea, such as sketches, mock-ups and prototypes (Veryzer & Borja de Mozota, 2005). Therefore, DT can be characterized as an approach for concept generation that has a stronger focus on the user experience itself than traditional approaches. Therefore, we view DT as a user experience-driven approach to product development, whereas we label comparatively traditional approaches as user preference-driven. Table 1 shows a broad comparison of the characteristics of user experience-driven approaches and traditional user preference-driven approaches to support product development teams in the FFE of the NPD process.

3. Development of hypotheses

To assess the relative effectiveness of different methods for early-stage product development requires determining the actual characteristics of a superior new product concept. Researchers generally agree that superiority of an idea or concept can be measured in terms of creativity (see, for example, Dennis, Minas, & Bhagwatwar, 2013; Diehl & Stroebe, 1987; Drazin, Glynn, & Kazanjian, 1999; Garfield, Taylor, Dennis, & Satzinger, 2001). Dean, Hender, Rodgers, and Santanen (2006) conducted an extensive literature review to develop a consolidated view of the most relevant aspects of concept creativity. Mainly pointing to MacCrimmon and Wagner (1994), who first conceptualized different dimensions of concept creativity, Dean et al. (2006) show that highly creative product concepts stand out against less creative ones along the following four dimensions: novelty, feasibility, relevance and specificity. The more a concept fulfils these dimensions, the more creative it is (Dean et al., 2006).

First, novelty refers to the quality of a concept being somewhat rare, unusual or uncommon (Connolly, Routhieaux, & Schneider, 1993; MacCrimmon & Wagner, 1994). There are two general ways that a new product concept can achieve a high degree of novelty. One way is that the concept addresses an entirely new problem—a problem that looks worth being addressed in hindsight, but no one cared about it earlier. The second way that a new product concept achieves a high level of novelty is through developing an entirely new and unexpected solution to a known problem (Dillon, 1982). Finding a good solution—or at least finding a better solution than one started out with—requires developing an in-depth understanding of the problem space and the associated user. Given the fuzzy nature of latent and unarticulated user needs, developing this deep understanding of the problem-user pair demands collecting data in multiple ways—i.e. quantitative and qualitative, such as interview notes and quotes, observations in pictures and videos, impressions through sketches and drawings, etc. Similarly, creating entirely unexpected solutions to a known problem is supported by drawing new analogies across seemingly unrelated data points or even data sets (Bonnardel, 2000).

As a user experience-driven innovation approach, DT exhibits several aspects supporting the above described work. In terms of putting people first (Brown & Katz, 2011), DT advises product development teams to spend a significant amount of time empathically observing people's lives to search for underlying and fundamental needs, emotions and aspirations of users. DT supports the generation of qualitative data through different ethnographic methods, such as observation, interviews and visual stories (Cagan & Vogel, 2002; Veryzer & Borja de Mozota, 2005). To find something really new or surprising, DT encourages the study of extreme users who are thinking and using existing solutions in often extraordinary ways (Brown & Katz, 2011). Finally, during synthesis, DT supports the process of making sense of these diverse data in search of better problems and solutions. In this way, DT guards against path dependencies or projection biases to which humans easily fall victim (Liedtka, 2015). In contrast, most user preference-driven approaches focus on identifying and aggregating knowledge from existing markets quantitatively (Prasad, 1998). The often larger numbers can increase the statistical representativeness, but they are less likely to increase the novelty of the concept, because the data is still prone to subjective cognitive biases. In fact, there have been studies aiming at integrating qualitiative user data into user preference-driven approaches, e.g. QFD. For example, Logan and Radcliffe (1997) used videotaping to better identify user needs. Yet, this approach of generating qualitative data on customer needs are only seldomly applied in QFD practice.

In summary, DT supports product development teams finding truly novel concepts by emphasizing the value of spending time on in-depth user research to identify fundamental needs and latent aspirations, and by providing tools for this qualitative form of user research. Therefore, we propose that applying a user experience-driven approach such as DT to generate new product concepts leads to higher concept novelty compared to applying user preference-driven approaches in the early product development phase.

Hypothesis 1. Applying a user experience-driven approach, such as DT, leads to higher degrees of concept novelty compared to applying a user preference-driven approach.

Second, for creative new product concepts to be successful, they need to be not only novel but feasible. Feasibility refers to a concept's capability of not violating known constraints and of being easily implementable (Diehl & Stroebe, 1987; MacCrimmon & Wagner, 1994). It ensures that the concept can be implemented given the constraints in markets, society and technology. Avoiding violation of these constraints requires the integration of external market knowledge—for example, consumer needs—with internal capabilities rooted in different organizational functions, such as marketing or engineering. An effective integration of both aspects is a substantial challenge in NPD (Clark & Fujimoto, 1990). To meet this challenge, internal and external integrity must be achieved (Pullman et al., 2002). Internal integrity refers here to a common understanding of the product concept and the alignment of relevant expertise across the product development team members' backgrounds, such as marketing, engineering or design. External integrity refers to the fit between the product concept and the target user, and the respective knowledge alignment between the market or user on the one hand and the product developers on the other (Veryzer & Borja de Mozota, 2005).

We suggest that DT's emphasis on early and iterative prototyping improves both internal and external integrity through two specific mechanisms. First, early prototyping enables intensive concept-related interactions between members of the product development team, and between the team and potential users (Luo et al., 2008). Second, the iterative nature of prototyping in DT forces continual examination of one's understanding of the problem-solution match, and a simultaneous consideration of how the solution could be created (Wiltschnig, Christensen, & Ball, 2013).

Prototyping supports internal integrity by providing a tool for communication and development through cross-fertilization of team members' knowledge (Bogers & Horst, 2014). The prototype acts as a boundary object, or integrating device, that processes information and transfers knowledge across functional, hierarchical and organizational boundaries (Bogers & Horst, 2014; Carlile, 2002). Through this improved communication between different disciplines, such as design, marketing and engineering, prototyping helps prevent the development of concepts that are not feasible to manufacture or implement.

Similarly, prototyping supports external integrity, because early and repeated iterative consumer interaction with prototypes unveils early potential solution characteristics that the consumer will not like or that he/she will not accept in a future product. Interacting with prototypes gives users the opportunity to express and explain their feedback explicitly. In this way, DT provides a greater chance to overcome users' inability to describe their own behaviour or needs accurately, often labelled as the 'say/do' gap (Liedtka, 2015). In contrast, user preference-driven innovation approaches concentrate on integrating preferences for predefined attributes into a final concept. For example, user feedback is often only integrated after the final choice of product attributes has already been made. Hence, attributes the user dislikes will be detected far later than with DT (Carnevalli & Miguel, 2008; Govers, 1996; Yung, 2006).

Understanding the limitations of a product concept helps to weed out dead-end concepts, and directs the focus to its core characteristics, therefore reducing overall complexity and improving feasibility. Undeniably, product development teams applying established methods may also have the market and engineering knowledge to generate feasible product concepts. However, DT especially emphasizes early and iterative refinement of the concept through prototyping, which improves the communication and information transfer across different disciplines and with potential consumers. Therefore, we argue that via early and iterative prototyping, DT improves concept feasibility.

Hypothesis 2. Applying a user experience-driven approach, such

Table 1
Overview of user experience-driven and user preference-driven approaches.

	User preference-driven approaches	User experience-driven approaches
Type of user research	Technology and/or market-driven	Empathy-driven
Type of data	Quantitative and objective data	Qualitative and subjective data
Presentation of data	Calculation-driven	Visualization-driven
Type of elaboration	Specification-driven	Iteration-driven

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as DT, leads to higher degrees of concept feasibility compared to applying a user preference-driven approach.

The third dimension for a new product concept to be considered creative is its relevance. Concept relevance refers to a concept being applicable to the initial problem and representing an effective solution (Aiken, Vanjani, & Paolillo, 1996; Kramer, Kuo, & Dailey, 1997; MacCrimmon & Wagner, 1994). Of course, for an innovative solution to be successful, it needs to create a good match with the underlying problem it claims to address. DT supports improving this match primarily through two mechanisms. The first mechanism is DT's propensity to help developers gain a deep understanding of the user's context and experiences (Dorst & Cross, 2001). This empathic approach often opens up entirely new areas in the problem space, and may help to identify problems that are not obvious but are of high relevance to the user. If the solution to be generated is based on a problem that is more relevant for the user, the final solution is likely to be more relevant, too. The second mechanism to create a better problem-solution match is iterative user involvement alongside the product development process through prototyping, which enables substantial learning through short feedback loops (Brown, 2008; Liedtka & Ogilvie, 2011). In other words, for a given problem, short cycles of iteration can be understood as an optimization process through continued improvements. This continued guidance through the user keeps design thinkers from projecting too many of their own preferences onto others (Liedtka, 2015). As a result, the solution is likely to be a better match to the underlying problem.

User preference-driven approaches also provide support for finding relevant solutions to a given problem. In fact, it is even one of their main objectives to translate given customer requirements into design specifications. QFD, for example, provides a set of matrices including several processes aimed to support product development teams in bridging this gap (Cristiano, Liker, & White, 2001). There also exists research suggesting the integration of marketing tools in order to improve customer satisfaction (e.g. Matzler & Hinterhuber, 1998). Kano's model (Kano et al., 1984), for example, suggests 'walking in your customer's shoes' to explore relevant customer requirements. Yet, the model lacks specific processes that support product developers identifying non-obvious problems. Hence, product development teams may only identify problems that users are able to express or problems that product developers already identified in their own lives, leaving non-obvious problems potentially unexplored. Therefore, applying traditional innovation approaches may result in appropriate solutions for clearly pre-defined problems that, however, may ultimately be irrelevant for the user.

In summary, DT fosters an understanding of the user and how the product (or an early version of it) is perceived and used in a real-life situation. The earlier the product development team understands latent user needs, and the deeper this understanding, the more likely it is that it addresses a problem of high relevance to the user. In addition, repeated iteration improves the likelihood that the solution effectively addresses the identified problem. Thus, DT improves the chance of developing not only novel concepts, but ones that better address the user's latent needs (Veryzer & Borja de Mozota, 2005). Therefore, we propose that DT leads to higher concept relevance compared to existing approaches.

Hypothesis 3. Applying a user experience-driven approach, such as DT, leads to higher degrees of concept relevance compared to applying a user preference-driven approach.

Fourth, specificity refers to the quality and level of detail with which the concept is thoroughly described (MacCrimmon & Wagner, 1994). As already mentioned, designers tend to think and work visually. Whenever possible, they use hand-drawn sketches, renderings or mockups to represent their ideas (Kim & Ryu, 2014; Kim & Wilemon, 2002). These visualizations stimulate the designer's creative process (Perks et al., 2005), but also support the communication of new ideas to others (Liedtka, 2015; Veryzer & Borja de Mozota, 2005). In particular, they facilitate others' understanding of one's own ideas, thus enhancing the acceptance of ideas that would otherwise be perceived as odd or unusual (Kelley, 2001). DT encourages the use of various tools to promote visualization along the creative process, including, but not exclusively, through physical prototypes (Carlgren et al., 2016b; Liedtka, 2015). In comparison, while established user preference-driven methods also aim at enhancing a shared understanding of concepts, these methods do not encourage visualizing concepts through sketches and images, but rather focus on compiling quantitative data for a calculation model (Govers, 1996; Hauser & Clausing, 1988; Prasad, 1998). Especially research on QFD has developed various quantitative methods in order to enhance its reliability and objectiveness (Chan & Wu, 2002). For example, there exist studies that integrated marketing research methods (e.g. Gustafsson, Ekdahl, & Bergman, 1999) or operations research methods (e.g. Chuang, 2001) into QFD. In this way, QFD helps to prioritize customer needs and design targets. Yet, applying these quantitative methods does not support product developers in realizing the details of the concept. In contrast, through visualizations, DT enhances both external integrity and internal integrity (Maltz et al., 2001). Working with tangible concepts in the early stages of the product development process through both visualizations and prototypes improves communication and information integration across disciplines within the product development team. This, in turn, increases the team's shared understanding of the product concept, which makes it easier to consider different requirements for the solution from the different domains. If, for example, the marketing department has a proper understanding of the initial idea, it will be able to access and provide better information regarding market acceptance. The same applies to the engineering domain, which will positively influence the development of a concept in case of an adequate understanding of its core characteristics. Therefore, DT fosters cooperative development across all relevant disciplines and facilitates the incorporation of all relevant requirements by forcing unclear issues to the surface and solving these issues collaboratively. The use of visual representations and prototypes enables the multi-disciplinary product development team to generate concepts with a greater depth of elaboration. Hence, when it comes to evaluating the concept, it is likely that the concept will be perceived as more detailed, making it easier to communicate the advantageousness of the developed product solutions. Therefore, we propose that DT leads to higher concept specificity compared to user preference-driven approaches.

Hypothesis 4. Applying a user experience-driven approach, such as DT, leads to higher degrees of concept specificity compared to applying a user preference-driven approach.

4. Method

4.1. Experimental procedure

To investigate the usefulness of applying DT in the early product development phases, we selected an experimental research design. Since we were particularly interested in comparing the performance effects of DT relative to a user preference-driven approach to supporting product development, it was important that the two approaches to be compared covered the essential parts of the FFE in the NPD process—i.e. problem framing, idea generation and concept development (Luchs & Swan, 2011).

Thus, in both conditions, teams were asked to apply a predefined method to generate creative concepts on a product development task. We chose to use QFD as a baseline approach because QFD is an adequate representative of the user preference-driven approach (as outlined above). Moreover, QFD is widely used and commonly accepted among product developers in practice (Chan & Wu, 2002; Michalek et al., 2005; Pullman et al., 2002). To further validate this view, we conducted eleven interviews with innovation managers from large German manufacturing companies. When asked for the standard approach or method they use to develop new product concepts in the FFE, the majority answered QFD. Additionally, when asked for the approach they consider for future use, the majority named design thinking. Therefore, we consider comparing DT with QFD in an experimental design a useful and relevant approach, given current industry trends.

We strove to insulate the effects of interest by studying (1) a homogeneous group of people, who (2) are novices to either of the methods, and (3) act outside other factors of organizational influence (Seidel & Fixson, 2013). To meet these requirements, we selected graduate student teams as our objects of analysis, which we could easily supply with identical resources, instructions and time to provide fair basic conditions. We therefore integrated the experiment into teamwork as part of a Master's Creativity and Innovation Management course at a major European university. Although experimental research on creativity, especially on the individual and team level, has long employed students as study subjects (DeTienne & Chandler, 2004; Diehl & Stroebe, 1987; Kudrowitz & Wallace, 2013; Černe, Nerstad, Dysvik, & Škerlavaj, 2014), there are, however, voices questioning the validity of the use of student samples in applied research (Highhouse & Gillespie, 2009).

The major issue regarding the appropriateness of using student samples concerns the generalizability of the results. In this context, the key question is whether it is likely that obtained results can also be transferred to real-life contexts (Bello, Leung, Radebaugh, Tung, & van Witteloostuijn, 2009), i.e., causal generalization as extrapolation. Every experiment consists of the elements *persons, treatment, outcome,* and *settings* (Shadish, Cook, & Campbell, 2002, p. 21). Any attempt to generalize requires asking whether any of these elements differ in other settings, and how this difference may impact the results. We will address each element in turn. First, the study participants were recruited from a course of a business school, which is why it can be assumed that those students will find themselves in similar real work-life situations in the future (Croson & Donohue, 2006). The same persons are likely to develop new products and services together with their team members. Second, we have no reason to believe that the treatment itself, the training in these innovation processes, differs in a commercial setting. In fact, some of the authors have taught the same concepts to audiences ranging from graduate students, to managers, to executives. Third, the outcome of the work processes are the results of the teams' activities. Assessing these artefacts across the treatment conditions should not differ between our setting and a commercial organization. On the contrary, in business situations it can be expected that previous experiences with one or the other innovation approach could influence the outcome of the experiment. Moreover, our approach by having multiple coders who assess the outputs anonymously ensures equal handling of the outcome of both treatment conditions. Fourth, many of our graduate students have already gained work experience and can therefore relate to the given task (Meissner & Wulf, 2017). In other words, the task itself can be considered realistic, and is therefore comparable to a real-life assignment. While it is possible that another setting, e.g., being an employee within a hierarchical organization, may impact a person's decisions and behaviour, we have no reason to believe that this effect will be of different magnitude between our treatment conditions. Therefore, it is highly unlikely that there exists a *systematic* bias when comparing results across our two different treatment groups (QFD and DT).

Thus, the key to the generalizability of our results is the random assignment of the student teams to one of the two experimental conditions. We therefore created an experiment that allowed us to assign participants randomly to one of two conditions to be able to compare the performance effects. First, all of the 261 course participants were randomly assigned to 55 teams of approximately five members each. In a second step, each team was randomly assigned to one of two conditions (DT condition or QFD condition). Teams in the DT condition ($n = 30$) had to apply DT, and teams in the QFD condition ($n = 25$) had to apply QFD.

The experiment proceeded as follows. First, participants in each condition separately received a condition-wise introductory session. Based on the assigned condition, the teams were invited to appear at different time slots to minimize the risk of communication between participants in different conditions. At no time did we hear of issues concerning students having to work with different methods. During the introductory session, the approach that had to be applied was explained. Explanations were read from a script and summarized in a printed guideline provided to each participant. To meet experimental standards, the guidelines were designed to look similar for both conditions regarding the general structure and layout. Additionally, the two guidelines ran to an equal number of pages. The guidelines included general information on the approach (DT vs. QFD, as described above), and a toolbox with several techniques and tools explained. In the DT condition, teams were introduced to creating a persona, a customer journey map and a storyboard; teams in the QFD condition were introduced to the Kano model, pairwise comparisons and the six thinking hats. To rule out the effects of specific ideation techniques, we made sure that both conditions applied the same ideation technique: brainstorming. Note that the instructions did not include the known terms DT or QFD. Instead, we replaced them with more generic terms to avoid placebo effects (Stewart-Williams & Podd, 2004).

As a next step, participants applied their respective approach to a mini-case to internalize the given approach during the introductory session. In both conditions, the task for the mini-case was to improve the gift-giving experience. After completing the mini-cases, participants had the opportunity to ask questions regarding the general procedure and about the specific approach to clarify potential queries. No major issues surfaced. At the end of the introductory session, participants were informed about their main project task, which was to improve the learning experience. We did not specify the realm of learning or education. Thus, concepts could include learning for students as well as learning for infants, elders and even animals. We chose this task because of the similar qualification of each participant and because of the relative breadth of the task, providing sufficient solution space for creative concepts. The kind of concept to be generated was not specified and could include, for example, a new product or a new service.

From this moment forward, the teams were given two weeks to elaborate their concepts. During their project work, the handout we provided to participants in both conditions helped the teams to orient whenever they were stuck in the creative process. Approximately half way through the project time (after approximately one week), each team was assigned to appear in an arranged room for one of two 3-h time slots. In this room, we provided prototyping materials that the teams could use to develop their concepts. Although teams under both conditions had to create at least one prototype, teams in the DT condition were advised to use prototypes iteratively, whereas teams in the QFD condition rather built

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their prototype as a physical representation of their final concept. After the prototyping session, a questionnaire was sent to the participants to gather the control variables used for our analyses. The final result of each team's work was submission of a 1-min video in which the participants described their final concepts. See Fig. 1 for an overview of the experimental design.

4.2. Measurement and rating procedure

Six experts in different fields of the assigned task of improving the learning experience (i.e. schoolteachers, professors, and teaching associates) independently rated the creativity of the concepts following the approach of Dean et al. (2006). Assessing the creativity of newly generated product concepts is not an easy task, as the concepts often differ substantially from one another; a valid evaluation therefore needs multiple dimensions that cover a range of different perspectives and layers. In their analysis of the literature on creativity evaluation, Dean et al. (2006) derived and validated a measurement tool that has been applied in a variety of studies focused on, for example, the evaluation of creativity of concepts contributed to an innovation platform (Frey, Lüthje, & Haag, 2011) or the assessment of new business concepts (Gielnik, Frese, Graf, & Kampschulte, 2012). Thus, we followed the approach of Dean et al. (2006) and rated concept creativity along the four distinct dimensions of creativity, namely novelty, feasibility, relevance and specificity, including nine sub-dimensions (see Appendix).

The experts were introduced to the measurement procedure and had the opportunity to ask questions before each of them rated the concepts in a randomized order. The experts rated all concepts along the nine sub-dimensions of creativity as suggested by Dean et al. (2006), but were blind to the conditions and blind to the study's aim. We measured intercoder reliability using intra-class correlations (ICC; Shrout & Fleiss, 1979). The resulting ICCs (see Appendix) exceeded values of 0.60, thus confirming consistency among the raters (Cicchetti, 1994). Hence, we averaged the scores of the experts. Following Dean et al. (2006), we calculated the four dimensions by adding up the respective scores of the sub-dimensions. To control for the influence of the teams' video production abilities on their final submission, the experts rated *the quality of the videos* separately on a ten-point scale (1 = very bad to 10 = very good). The ICC(2,6) for rating video quality was 0.88.

Through the questionnaire that was sent after the prototyping session, we gathered further data regarding team-relevant factors that previous studies have shown to influence team creativity. We assessed the team's shared mental model, which measures whether a participant perceived a common understanding among the members of the team regarding relevant team and task aspects of their work (Klimoski & Mohammed, 1994) using Santos, Uitdewilligen, and Passos' (2015) four-item Likert-type scale ranging from 1 to 7 (1 = totally disagree to 7 = totally agree). The Cronbach's α of this scale was 0.87. Cognitive trust refers to a participant's confidence in other team members' expertise and reliability, and was assessed using Barczak, Lassk, and Mulki's (2010) three-item Likert-type scale ranging from 1 to 7 (1 = totally disagree to 7 = totally agree). The Cronbach's α of this scale was 0.83. Moreover, we assessed the team's cognitive abilities by asking participants to evaluate their undergraduate grade point average (GPA) on a five-point scale (1 = worst GPA to 5 = best GPA). Since the level of analysis in this study was the team, we aggregated all individual survey responses by team for further analysis. In two teams, one in each condition, fewer than half of the members answered the questionnaire. Thus, we eliminated these teams from our sample. For the remaining 53 teams, at least 60 per cent of the team members answered the questionnaire.

5. Results

The aim of this study was to investigate the impact of DT relative to more traditional product development approaches stemming from the user preference-driven perspective of concept generation, here QFD. More specifically, we were interested in whether DT leads to relatively high concept creativity in the early product development stages, as measured by four dimensions of creativity. To rule out possible effects due to differences in the demographic and control variables between the DT group and the QFD group, we conducted several chi-squared tests for the variables on the individual level and the team level. None of the tests showed significant differences between the two groups. Descriptive statistics for the variables are shown in Table 2.

To test for the hypothesized effects, we conducted a multivariate analysis of covariance (MANCOVA), controlling for the team's shared mental model, cognitive trust, cognitive ability and the quality of the video.

H1 hypothesized that applying a user experience-driven approach, such as DT, leads to higher degrees of concept novelty compared to applying a user preference-driven approach, such as QFD. Analysis revealed no significant difference in concept novelty between the DT condition ($M = 4.01$, $SD = 1.15$) and the QFD condition ($M = 4.08$, $SD = 0.75$), $F(1,52) = 0.303$, $p > .10$, $\eta_p^2 = 0.006$. Hence, H1 is not supported.

H2 hypothesized that applying a user experience-driven approach, such as DT, leads to higher degrees of concept feasibility compared to applying a user preference-driven approach, such as QFD. Analysis revealed a significant difference in concept feasibility between the DT condition ($M = 6.77$, $SD = 0.85$) and the QFD condition ($M = 6.19$, $SD = 0.79$), $F(1,52) = 9.08$, $p < .01$, $\eta_p^2 = 0.162$. Hence, H2 is supported.

H3 hypothesized that applying a user experience-driven approach, such as DT, leads to higher degrees of concept relevance compared to applying a user preference-driven approach, such as QFD. Analysis revealed a significant difference in concept relevance between the DT condition ($M = 5.71$, $SD = 0.82$) and the QFD condition ($M = 5.29$, $SD = 0.80$), $F(1,52) = 4.97$, $p < .05$, $\eta_p^2 = 0.096$. Hence, H3 is supported.

H4 hypothesized that applying a user experience-driven approach, such as DT, leads to higher degrees of concept specificity compared to applying a user preference-driven approach, such as QFD. Analysis revealed a significant difference in concept specificity between the DT condition ($M = 6.96$, $SD = 1.07$) and the QFD condition ($M = 6.17$, $SD = 1.39$), $F(1,52) = 8.64$, $p < .01$, $\eta_p^2 = 0.155$. Hence, H4 is supported. Our results are summarized in Table 3.

6. Discussion

6.1. Theoretical implications

To our knowledge, this study is the first to investigate the impact of user experience-driven approaches to product development, such as DT, in the early stages of the product development process. This was accomplished by measuring the outcomes of two processes, one employing a user experience-driven method, the other a traditional user preference-driven product development approach, the latter currently considered a standard method in practice. Thus, this study extends the existing literature on FFE innovation methods in general and the growing yet primarily conceptual body of literature on DT as a creative problem-solving approach (Dorst, 2011). More specifically, due to the experimental character of this study and the use of novice teams, confounding factors, such as an overvaluation of the method due to the hype for

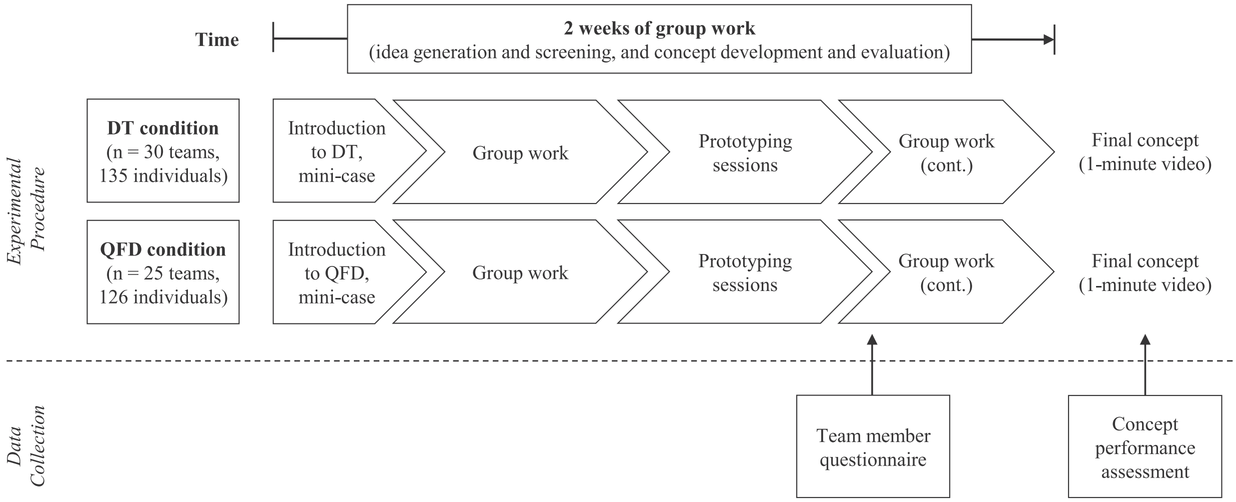

Fig. 1. Experimental procedure and data collection process.

Table 2
Descriptive statistics for demographic and control variables.

	Individual level (n = 254)				Team level (n = 53)			
	QFD (n = 121)		DT (n = 133)		QFD (n = 24)		DT (n = 29)	
Variables	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Female (in %)	50.4		52.6					
Age	24.9	1.85	25.1	2.92				
Major (in %)								
Business education	29.8		30.1					
General mgmt.	25.6		24.1					
Industrial eng.	25.6		19.5					
Mechanical eng.	11.6		11.3					
Marketing	5.8		12.0					
Other	1.6		3.1					
Video quality					5.63	1.55	5.88	1.53
Shared mental model					5.17	.76	5.40	.57
Cognitive trust					5.76	.70	5.91	.54
Cognitive ability					4.35	.42	4.46	.45

Notes: General mgmt. = general management; Industrial eng. = industrial engineering; Mechanical eng. = mechanical engineering.

DT, or the influence of past experience, could be eliminated, thus increasing the power of the results. The results of this study show that applying DT helps novice teams to generate product concepts that are more creative compared to when a current standard method is applied. This result is interesting, given that the intervention is a brief, few hours-long instruction at the beginning of a two-week project. In general, this finding is in line with effects proposed in earlier work on DT (Wattanasupachoke, 2012).

In addition to showing that a user experience-driven approach to product development, such as DT, leads to overall better performance in producing more creative concepts, this study also shows statistically significant results in that DT positively affects the feasibility, relevance and specificity of the generated concepts. These results are in line with Liedtka's (2014) observation that the use of DT in business practice not only produces more unusual solutions, but also more effective ones. Consequently, Liedtka (2015) asserts that DT works through reducing biases that humans otherwise quickly fall victim to—biases that hinder the development of creative concepts.

For one of the four dimensions of creativity, concept novelty, our findings did not reveal a statistically significant effect of DT when compared to a baseline method. At first sight, this finding seems surprising, since DT is often associated with increasing the likelihood of breakthrough products (Brown & Katz, 2011; Dunne & Martin, 2006). However, a closer look at the data reveals some interesting data points. For example, among the five concepts rated as most novel, there is only one concept that was generated applying QFD, whereas four were generated using the DT approach. In addition, the data also exhibit a greater standard deviation of the variable concept novelty for the DT condition compared to the QFD condition. This could be due to the fact that whereas QFD is rather intuitive and leads to concepts of passable levels of novelty, applying DT has the potential to lead to concepts of greater novelty, but is more unusual and challenging and thus requires stronger guidance and support, especially for novices. To become skilled in ethnographic observation and interview techniques may require substantially more training and practice than was available in this experiment. One possible explanation for the lack of a significant effect could therefore be that the mechanisms of the DT approach that are primarily responsible for concept novelty—i.e. a deep and qualitative understanding of latent user needs and aspirations—are for some participants difficult to learn in the time frame available for the projects in this experiment. Hence, further research is needed to investigate the dynamics of DT, especially in the need-finding and idea generation phases.

Finally, our results complement studies in the field of customer co-creation. Previous researchers have highlighted the problem of inefficient utilization of information due to the lack of in-depth customer knowledge when companies integrate customer information in their NPD activities (Cui & Wu, 2017; Nambisan, 2002). In contrast, DT may offer a way to bridge the liability of customer proximity in corporate NPD processes. By iteratively and actively integrating the customer in the early NPD phases, DT may be a

Table 3
MANCOVA results.

Dependent variable	Mean (SD)			
	QFD	DT	p	eta^2
Novelty (H1)	4.08 (.75)	4.01 (1.15)	.585	.006
Feasibility (H2)	6.19 (.79)	6.77 (.85)	.004	.162
Relevance (H3)	5.29 (.80)	5.71 (.82)	.031	.096
Specificity (H4)	6.17 (1.39)	6.96 (1.07)	.005	.155

Note: We controlled for video quality, shared mental model, cognitive trust and cognitive ability.

viable way to overcome these issues. Moreover, due to the strong emphasis on perspective-taking, DT offers a valuable opportunity to link customer and firm perspectives closely to come up with product concepts that better fit customer needs, although customers may not co-create the products or develop the products on their own (Cui & Wu, 2016).

6.2. Managerial implications

The results of this study offer guidance to open questions in innovation management practice. Our findings reveal that adopting DT in NPD generally seems to be a beneficial way to support creativity in the product development process. More specifically, our results show that DT, in comparison to QFD, can help novice product development teams to generate product concepts with higher degrees of feasibility, relevance and specificity. This means that companies and teams that build their product development activities around empathic user observation, understanding and improvement of the user experience, and fast feedback through iterative prototyping are likely to produce concepts of higher creativity. This seems to be of particular importance, since the ability to generate creative product concepts is the basis for successful innovations (George, 2007). Moreover, the fact that in our study DT increased the usefulness dimensions of the concepts rather than the novelty is also interesting for practitioners. Our results show that DT does not necessarily deliver concepts that are more novel (although it has the potential), but ones that are more well thought out. Therefore, companies and teams that currently apply QFD or similar techniques in the product development process could switch to using DT to improve concept creativity in the early product development phases, not only when newness is needed. Certainly, this change will not occur overnight: training and practice in DT need to be provided for the employees involved in the product development process. Therefore, companies could train their employees in DT through workshops designed in accordance with the suggestions made by Seidel and Fixson (2015).

Based on this suggestion, the results of this study could also be useful for management consultants who increasingly offer such workshops. One pressing question for them is whether short-term training in DT is a viable approach to teach this method to teams with novices that have never used DT before (Razzouk & Shute, 2012; Seidel & Fixson, 2013). The results of the present study reveal that a quick improvement is possible with DT, and that short-term training in DT, especially for employees who are unfamiliar with this method, seems to be fruitful.

7. Limitations and further research

This study is, of course, limited in a number of ways, suggesting several avenues for further research. First, in this study we focused on the influence of DT on concept creativity in the early stages of the product development process. However, DT might also affect processes that follow the idea generation and concept development stages. Therefore, future research could investigate the impact of DT in the back end of the NPD process. Moreover, an open question at this point is how lasting the effects are, especially given the brevity of the intervention (Meinel, Wagner, Baccarella, & Voigt, 2018). Therefore, it also seems interesting to examine the effects of applying DT principles over a longer period.

Second, in this study we investigated the influence of either DT or QFD as a whole on the creativity of new product concepts. Thus, this study is not able to draw conclusions on the effect of the individual characteristics of either method, as described in Table 1. For example, the question arises as to whether it is the external subjective customer feedback that drives concept creativity or the improved internal understanding through early visualization of the concept. Hence, further research could provide a more differentiated perspective on the usefulness of DT by investigating the effects that each of its individual characteristics have on new concept creativity.

Third, the product development task for the teams was very broad and undirected in nature. Although early innovation phases especially can be characterized by the presence of a certain 'openness' with a variety of different and often still vague product ideas (Kim & Wilemon, 2002), this open task could be a better fit for product development teams who have to apply DT. Future studies could therefore differentiate between different degrees of openness regarding underlying development tasks to validate the results of this study.

Finally, our study was conducted under supervised conditions relying on a sample of novices in product development and design. While the use of novice teams may limit the generalizability of our results to a degree, this setting allowed us to control for various influencing variables occurring in real-life settings—e.g. pre-existing social ties across team members—which could have influenced the phenomena that we set out to investigate. In a similar vein, our study did not aim to include the influence of previous individual experience in DT on team performance. Since prior research has already shown that organizational structures, values and processes in existing organizations can hinder the effective use of new approaches such as DT (Carlgren, Rauth, et al., 2016), a study replicating the effects in settings in existing organizations could extend the external validity of our findings.

Dimension Subdimension	Definition	Range	ICC(2,6)
1. Novelty	The degree to which an idea is original and modifies a paradigm.	2–8	
1.1 Originality	The degree to which the idea is not only rare but is also ingenious, imaginative or surprising.	1–4	.79
1.2 Paradigm relatedness	The degree to which an idea is paradigm preserving (PP) or paradigm modifying (PM). PM ideas are sometimes radical or transformational.	1–4	.63
2. Feasibility	An idea is feasible if it can be easily implemented and does not violate known constraints.	2–8	
2.1 Acceptability	The degree to which the idea is socially, legally or politically acceptable.	1–4	.75
2.2 Implementability	The degree to which the idea can be easily implemented.	1–4	.87
3. Relevance	The idea applies to the stated problem and will be effective at solving the problem.	2–8	
3.1 Applicability	The degree to which the idea clearly applies to the stated problem.	1–4	.66
3.2 Effectiveness	The degree to which the idea will solve the problem.	1–4	.70
4. Specificity	An idea is specific if it is clear (worked out in detail).	3–9	
4.1 Implicational explicitness	The degree to which there is a clear relationship between the recommended action and the expected outcome.	1–3	.79
4.2 Completeness	The number of independent subcomponents into which the idea can be decomposed, and the breadth of coverage with regard to who, what, where, when, why and how.	1–3	.73
4.3 Clarity	The degree to which the idea is clearly communicated with regard to grammar and word usage.	1–3	.81

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Appendix

Measurement Construct for Idea Creativity (Dean et al., 2006).

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.emj.2020.02.002.

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