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Familiarity with digital twin totality: Exploring the relation and perception of affordances through a Heideggerian perspective

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Abstract

The concept of affordances has become central in information systems literature. However, existing perspectives fall short in providing details on the relational aspect of affordances, which can influence actors' perception of them. To increase granularity and specificity in this regard, researchers have suggested that it be supplemented with other concepts or theories. In this article, we argue that the Heideggerian concepts of 'familiarity' and 'referential totality' are well suited for increasing our understanding of the relational aspects of affordances in information systems research. To explore this idea, we conducted a case study of a project concerning the development of a digital twin (i.e., digital representation of a physical asset) in the Norwegian grid sector. We found that users' familiarity with the digital twin totality enabled them to perceive digital twin affordances, and that without this familiarity, affordances remained latent for the users. Through our study, we offer a nuanced perspective on the relational aspect of affordance perception, contributing to affordance theory in that regard. Further, we contribute to practice and information systems research by providing valuable insights into how digital twins are understood and applied in practice.

KEYWORDS
affordance, digital transformation, digital twin, familiarity, referential totality

1 | INTRODUCTION

The theory of affordances has proven valuable in information systems (IS) research when investigating and explaining socio-technical phenomena (Chatterjee et al., 2021; Leidner et al., 2018). Affordances are broadly viewed as possibilities of actions in the relation between an IT artefact and a goal-directed actor (Leidner et al., 2018; Markus & Silver, 2008; Strong et al., 2014). This means that affordances are not viewed as properties of the artefact nor the actor but as possible actions that arise in the actor–artefact relation (Chemero, 2003; Majchrzak & Markus, 2013). However, what this relation implies and what needs to be in place for the relation to lead to affordance perception is not specified in detail. Researchers have suggested that factors such as context (e.g., Bernardi et al., 2019; Lehrer et al., 2018; Seidel et al., 2013), culture (e.g., Leonardi, 2011a; Rico & Xia, 2018; Thapa & Sein, 2018) and norms (e.g., Costall, 2012; Essén & Värlander, 2019; Faik et al., 2020) may influence affordance perception. However, these perspectives focus on actors working in isolation and interacting with artefacts to achieve their goal, while in reality, we would argue the actors are already embedded in the context and perceive in everyday practice. While IS researchers have provided valuable insight into processes of affordance *actualisation* (e.g., Burton-Jones & Volkoff, 2017; Leidner et al., 2018; Li et al., 2020; Strong et al., 2014; Thapa & Sein, 2018), the relational aspect of affordance *perception* remains unclear (Lanamäki et al., 2016; Seidel et al., 2013). To better understand how actors perceive affordances, we need a more holistic understanding of the relational aspect of affordances.

Following Lanamäki et al. (2015), who suggested that the affordance concept be supplemented with new concepts to increase granularity and specificity, we set out to explore whether perspectives from the *Heideggerian philosophy* might help increase our understanding of the relational aspect of affordances and perception. We found the perspectives of Martin Heidegger in his *Being and Time* (1962) to be suitable for this endeavour because of his fundamental focus on ontological inseparability (Riemer & Johnston, 2017), moving away from the dualistic view of actors and artefacts as separate entities. Instead of considering *artefacts*, Heidegger distinguishes between *objects* and *equipment*, where the latter refers to entities of practical means encountered in everyday use. For a human actor, equipment is *what it is for* and its practical use depends on a chain of references and involvements with other equipment within a *world*. According to Heidegger, humans are thrown into a ‘world’ (e.g., a workplace) with a series of possibilities available to them in encountering and interacting with equipment (Critchley, 2020). And in a world, the ideas of *familiarity* and *referential totality* are essential. *Familiarity* can be described as a background understanding of this world in which humans need to deal with the world and equipment in a non-deliberate way, which is embedded in know-how, related to specific contexts, and accumulated over time through practice or experience (Heidegger, 1962; Riemer & Johnston, 2017). It is only on the basis of familiarity that an actor can encounter any equipment, and, in that the way, an actor's understanding of equipment is always an ‘interpretation on the basis of this precognitive, background understanding [(i.e., familiarity)]’ (Riemer & Johnston, 2017, p. 1063). Regarding *referential totality*, Heidegger stated that humans always encounter equipment in reference to themselves and other equipment, and that equipment always serves to enact a purpose and an identity (Heidegger, 1962; Turner, 2005). In other words, the referential totality of equipment involves the everyday, practical use of the equipment (i.e., the task one could perform with it), as well as the purposes of the tasks and the identity the human could assume in doing so.

We believe the thinking of Heidegger can help improve our understanding of the actor–artefact relation (a relationship we later on refer to as the actor-equipment relation), which is needed to better understand affordance perception. Hence, the objective of this work is to explore *how the Heideggerian concepts of familiarity and referential totality help specify and increase our understanding of the relational aspects of affordance perception*. To do so, we conducted a case study of a digital twin project in an incumbent firm in Norway; GridCo, one of the largest and oldest grid companies in Norway which provides electricity to more than 240 000 customers through over 27 000 kilometres of aerial power lines and underground power cables. The digital twin project concerned the development of a digital twin of GridCo's electricity grid network. A digital twin is a virtual representation of a physical object (Grieves, 2014), allowing the user to digitally mirror and manage the object through its life cycle (Dietz & Pernul, 2020), and it can potentially be of great value for organisations in transforming their business (Seidel & Berente, 2020). However, the question of how increasingly complex digital entities, such as digital twins, are understood in the workplace still needs to be answered (Meske et al., 2021). Loaded with accurate and real-time data on grid network structure, configuration and electricity consumption, in our case, the digital twin, replicates the grid infrastructure in a digital space and redefines relationships between organisational actors and the physical counterpart of the twin. Being susceptible to almost any kind of data from its physical counterpart (Dietz & Pernul, 2020; Grieves & Vickers, 2017; Madni et al., 2019), the digital twin offers users a wide array of potential action possibilities (i.e., affordances) – which are likely to evolve even further as data and features are added. Against this backdrop, the GridCo digital twin serves as a valuable case to explore the relational aspects and how potential users at GridCo came to perceive digital twin affordances.

Following the digital twin project over time, we were able to collect rich data, which we analysed to understand how and why the users perceived digital twin affordances, through a Heideggerian lens. We found that the users perceived digital twin affordances because they developed a familiarity with the referential totality of the digital twin. Based on our findings and the theoretical foundations, we developed a theoretical model in which we specified the relational aspect of affordance perception through familiarity with the equipment totality. With our model, we suggest that the relation leading to affordance perception is not as simple as an actor–artefact relation; rather, affordance perception is possible if the actor is familiar with the totality of the equipment as its practical means, and we explain mechanisms which could enhance this familiarity. Hence, we contribute to affordance theory through specifying and expanding the relational aspect of affordances and offering a nuanced perspective on affordance perception. Further, as research on digital twins is still nascent (Meske et al., 2021), we contribute to practice and to the IS field by exploring how such complex digital entities are understood and applied by users in specific context, and how affordances of digital twins can play an important part in incumbent firms' digital transformations.

In this article, we proceed by first presenting the status quo on the affordance discourse in IS research and highlighting the specific research gap regarding the relational aspects of affordance perception. We then present Heideggerian thinking and the concepts of familiarity and referential totality. This is followed by the research design and context of the empirical study. Following that, we present the results from our empirical study. Based on our findings and the theoretical backgrounds, we develop an enriched theoretical model based on Heideggerian concepts of familiarity and referential totality and discuss the implications of our model, before we conclude the article.

2 | THEORETICAL BACKGROUND

In this section, we present the theoretical perspectives underlying our research. First, we cover affordance theory and present existing views on the relational aspect of affordance perception in IS research. Thereafter, we introduce the Heideggerian concepts of familiarity and referential totality as an alternate view to understand relation.

2.1 | Perceiving affordances in actor–artefact relations

The term affordances was introduced by ecological psychologist James J. Gibson (1904–1979) in his study of animals' perceptions of their surroundings. Gibson believed that humans directly perceive what an artefact in their environment will enable them to do – that the artefact, in relation to the human, holds affordances, that is, what is offered, provided or furnished to someone or something by an object (Gibson, 1986; Strong et al., 2014). Within the IS field, affordances are broadly viewed as possibilities of actions that arise in the relation between an IT artefact and a goal-directed actor (Leidner et al., 2018; Markus & Silver, 2008; Strong et al., 2014; Volkoff & Strong, 2013). The affordance perspective enables IS researchers to study how technology and social actors interact (Strong et al., 2014) and takes a socio-technical view, allowing researchers to be specific about the technology, while, at the same time, incorporating social and contextual aspects (Volkoff & Strong, 2017). Accordingly, IS researchers have typically applied affordance theory to theorise socio-technical phenomena (Leonardi, 2013; Markus & Silver, 2008; Meske & Amojo, 2020) and to understand IT-associated organisational change (e.g., Strong et al., 2014; Tim et al., 2020), IT implementation and adoption (e.g., Du et al., 2019; Porter & van den Hooff, 2020; Volkoff & Strong, 2017), effects of IT artefact applications (e.g., Klecun et al., 2016; Leidner et al., 2018; Verstegen et al., 2019) and IT design (e.g., Bardram & Houben, 2018; Benbunan-Fich, 2019; Klecun et al., 2016; Maier & Fadel, 2009).

While Gibson believed that affordances exist naturally in the environment (Gibson, 1986; Lanamäki et al., 2015), with time, the understanding of the nature of affordances has taken different directions within IS research (Lanamäki et al., 2016). Where some posit that affordances are designed into an artefact (designed affordances) (e.g., Benbunan-Fich, 2019; Majchrzak & Markus, 2013), others argue that affordances arise as they are acted upon (enactive affordances) (e.g., Zheng & Yu, 2016). Some researchers view affordances as canonical, meaning that affordances are independent of particular artefacts, but rather reside within wider social frameworks (canonical affordances) (e.g., Costall, 2012; Fayard & Weeks, 2014). The most common perspective, however, is that affordances are ever-present potentials for actions (e.g., Strong et al., 2014; Thapa & Sein, 2018) – they are latent and exist without and before actual users' perceptions of them (potential affordances) (Lanamäki et al., 2016).

In this article, following the most common view of *potential affordances* (Lanamäki et al., 2016), affordance perception regards the process where the actor interprets and recognises the action possibilities offered to them in relation to an artefact. Further, taking the view that affordances need to be perceived in order to be acted upon (Bernhard et al., 2013), perception is generally understood as occurring in the actor–artefact relation and relying on the features or properties of the artefact and the capabilities and goals of the actor (Bernhard et al., 2013; Pozzi et al., 2014). The artefact holds some features and properties, providing the actor with information about the action possibilities offered to them—enabling the actor to interpret and, hence, perceive the affordances (Bernhard et al., 2013) (Figure 1).

In the IS literature, perception has also been portrayed as being subject to influence from factors such as context, culture and norms. For instance, some researchers posit that affordance perception is influenced by *sociocultural and organisational contexts* (Bernardi et al., 2019; Lanamäki et al., 2016; Seidel et al., 2013). Leonardi (2011b) explained how ‘technologies have material properties, but those material properties afford different possibilities for action based on the contexts in which they are used’ (p. 153). For example, Strong et al. (2014) found that electronic healthcare records (EHRs) provided a capable physician (e.g., with the skills for creating electronic notes) with the affordance of capturing and archiving digital data about patients (among other affordances). The authors suggested that the physician's perception of this affordance was influenced by an organisational context characterised by a

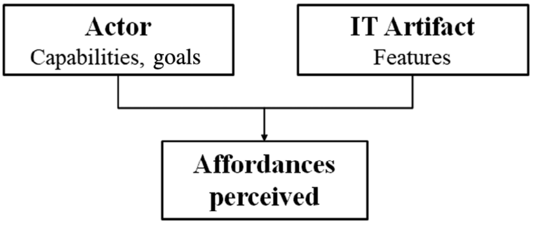

FIGURE 1 Traditional perspective on affordance perception (inspired by Pozzi et al., 2014 and Lanamäki et al., 2016)

culture that supported patient data as a clinic resource. However, as Thapa and Sein (2018) emphasised, if the context were different, other affordances might have been revealed. For instance, Lehrer et al. (2018) suggested that contextual factors such as 'strategies, customers, competitive environment, values, and regulations' (p. 430) might influence which affordances are perceived by the actor. Others have argued that affordances are designed into the artefact and that affordance perception is based on conformity, meaning that the designers based on anticipated interpretation embed the affordances in the artefact through intuitive design (Lanamäki et al., 2016). As such, the design of an artefact should ensure that affordances are easily perceptible by imagined users (Leonardi, 2011b). However, the organisational *culture* (Rico & Xia, 2018) or individual cultural background of the user (Leonardi, 2011a) has the potential to influence affordance perception, which can lead to non-conformity gaps between affordances designed in the artefact and the perceived use of the artefact. It has been further suggested that affordance perception is influenced by social and cultural *norms* (Fayard & Weeks, 2007), that is, the historical and social narratives of the context may affect which affordances arise from the actor–artefact relation (Essén & Värlander, 2019; Thapa & Sein, 2018). For instance, Faik et al. (2020) suggested that which affordances are perceived by an actor would depend on the institutional logics and societal norms within the societal order or context in which the actor and artefact reside. Hence, affordance perception should perhaps be considered within wider social frameworks (Costall, 2012).

The variety of perspectives on both the nature of affordances as well as on which factors influence affordance perception and how, illustrates the inconclusiveness of the relational aspect of affordance theory. To move past this confusion of affordance theory, we suggest moving beyond a dualistic view of the actor-artefact relation to instead consider the relational aspect as one of the actor and equipment in 'totality', where affordance perception occurs in everyday practice (Heidegger, 1962).

2.2 | Perceiving affordances in actor–equipment relations

Martin Heidegger (1889–1976) was a German philosopher and seminal thinker, most known for his contributions to phenomenology (i.e., the study of experience). In his most prominent work, *Being and Time* (1962), first published in 1927, Heidegger presented his ontological focus in explaining the meaning of *being* (*Dasein*), as well as the so-called Heideggerian equipment analysis (Harman, 2010; Riemer & Johnston, 2017). A well-known expression of Heidegger is *being in the world* (Feenberg, 2019), which can be translated to the most basic condition of humans: to already be in the world prior to any experience (Riemer & Johnston, 2017). A world, for Heidegger, is made of 'practices, equipment, and skills shared by a specific community' (Van de Walle et al., 2003, p. 2) and can be multiple, local worlds – such as a family, a workplace, an industry or society in general (Riemer & Johnston, 2017). As such, every human being is part of some world (a broader, encompassing context; Dreyfus, 1998), which contemplates a particular culture or established ways of life (Riemer & Johnston, 2017). Human existence in this world is, according to Heidegger, defined by time – human beings exist with a past, move through a presence and have available to them a series of possibilities, which they can seize hold of, or not (Critchley, 2020), whereas *existence* (engagement in practices; Riemer & Johnston, 2011, 2014) denotes the way of being of humans, Heidegger distinguished between two types of being of other entities in the world: *presence-at-hand* (the way of being of objects) and *readiness-to-hand* (the way of being of what Heidegger refers to as *equipment*) (Riemer & Johnston, 2014, 2017), where the latter concept was the most important to Heidegger. Equipment are entities of practical means (Harnesk & Thapa, 2016), encountered in fluent use (Riemer & Johnston, 2017), and according to Heidegger, the most frequent way humans encounter and deal with equipment is by taking them for granted as items in everyday use, rather than having them in consciousness (Harman, 2010). To fully integrate Heidegerian thinking we adopt the notion of *equipment* in our study. Considering IT as equipment implies understanding IT as interwoven with other equipment, user practices and identities, which allows us to focus on the holistic view of *technologies in practice* (Riemer & Johnston, 2011, 2014).

Heidegger's philosophical thinking is complex and rather difficult to grasp (Critchley, 2020; Horrigan-Kelly et al., 2016); however; his contributions are highly recognised in research, in general and within the IS field (Lanamäki et al., 2015; Riemer & Johnston, 2017). In this article, our aim is not to go into detail into Heidegger's thinking. Rather, following our research interests, we explore how the concepts of *familiarity* and *referential totality* from Heidegger's *Being and Time* (1962) may help increase our understanding of the relational aspects of affordance perception. Heidegger's terminology is relevant for understanding IT entities and their use (Riemer & Johnston, 2014) and enables us to explore an actor's engagement in a social and material world (Riemer & Johnston, 2017). By drawing on Heidegger's notion of equipment as practical means and the concepts of familiarity and referential totality, we offer a nuanced perspective on relation, moving beyond the dualistic view of an actor in relation to an artefact, to consider the actor and equipment as integrated in a context through everyday practice.

2.2.1 | Familiarity

According to Heidegger, actors possess familiarity with themselves, others, entities and their interrelatedness in a world, which shapes their self-understanding (Teal, 2009) and enables them to cope with situations and equipment (Turner, 2005). Familiarity is a background understanding that actors need to deal with the world and equipment in an absorbed and non-deliberate way (Riemer & Johnston, 2017), embedded in know-how (Riemer & Johnston, 2014), related to specific contexts and accumulated through practice or experience. Actors rely on familiarity, for instance, when brushing their teeth or mastering an instrument, where knowledge to conduct the activity is enacted and not actively thought (Teal, 2009). As such, actors require some individual learning to acquire sufficient familiarity with an entity to encounter it in a practical and unreflective way (Riemer & Johnston, 2014). Van de Walle et al. (2003) identified three ideas underlying an actor's familiarity with the world. First, the actor is *involved* in the world, which provides a feeling of being-at-home. Second, to relate to the world, the actor has an *understanding* of themselves and the world, which, according to Heidegger, is not merely related to knowledge, but skill and capacity to do something, manifested through taking part in activities in the world. Third, familiarity implies a *unity of self and world*, meaning that the actor in being involved in and understanding the world understands themselves as integrated in the world. Familiarity itself is not observable; however, outcomes of familiarity are observable by which an actor conducts themselves in performing activities with, for instance, easiness, confidence and success (Van de Walle et al., 2003). Translated to our study, we understand familiarity as an actor's background understanding, involvement and engagement in a world, making the actor ready to cope with equipment within this world. Using GridCo as an example, familiarity could, for instance, regard an actor at GridCo's understanding of, involvement in, and prior engagement in practices in the grid company and grid sector in general, which would prepare the actor to come to consider a 'new' artefact as equipment and cope with this equipment within this same 'world'.

2.2.2 | Totality

Heidegger referred to the world as a totality of referential totalities and explained how equipment always belongs to a totality of equipment. Equipment is essentially something *in-order-to* something (Heidegger, 1962), what Heidegger referred to as *readiness-to-hand*. An actor does not encounter equipment as objects with properties, but as practical or handy means: in-order-to's (Riemer & Johnston, 2017). Accordingly, equipment is always viewed in terms of its belonging to other equipment (Critchley, 2020). For instance, a hammer is encountered as in-order-to hammer something; thus, it is not meaningful to consider a hammer without reference to other equipment such as nails and wood. The totality of equipment depends on three interrelated elements. First is what Heidegger referred to as the *for-which* (i.e., for which task the equipment is used) (Riemer & Johnston, 2014, 2017). In other words, the character and tasks of equipment in reference to other equipment (e.g., the shape and construction of the hammer in relation to nails and wood, implies hammering) (Turner, 2005). Second is the *toward-which* (i.e., towards which purpose) (Riemer & Johnston, 2014, 2017), meaning the set of purposes or use practices (Riemer & Johnston, 2014) to which performing these tasks are put (e.g., building a wall or a house) (Turner, 2005). Third is the *for-the-sake-of-which* (i.e., the bearing equipment has on an actor) (Riemer & Johnston, 2014, 2017). For Heidegger, equipment always serves to enact an identity, in that an actor assumes a particular identity in performing the purposed tasks with the equipment (e.g., the identity of a carpenter) (Turner, 2005). Translated to our study, we understand totality as the artefact's referential whole; the tasks the actor could perform with the equipment (in relation to other equipment), the purpose(s) of the actor performing these tasks and the identity the actor could assume in doing so. Using digital twins as an example (e.g., a digital twin of a manufacturing asset), the referential totality of the digital twin would involve the tasks one could perform with the digital twin (e.g., schedule maintenance on the asset) in relation to the physical asset and other entities as well as the purpose of performing the tasks (e.g., to prevent damage to the asset) and the identity the actor could assume in doing so (e.g., contributor to prolonged life cycle of the asset) (Table 1).

3 | RESEARCH DESIGN OF THE EMPIRICAL STUDY

To explore how the concepts of familiarity and totality could help specify the relational aspects of affordance perception, we conducted a case study (Creswell, 2012) of a digital twin project in a large Norwegian grid company, referred to as GridCo.

3.1 | Case description

GridCo is one of the largest grid companies in Norway, responsible for building, operating and maintaining the regional and local grid network in a specific geographic area to distribute electricity to customers. The company was founded in 1920, has approximately 500 employees, and has a long tradition of fulfilling its obligation to provide electricity to its 240 000 customers. The purpose of the DigitalGrid project is to develop a digital twin of the grid network in Norway. DigitalCo is the project owner and responsible for developing the digital twin – building on its experience with digital twin development in other industries. GridCo represents the main user partner in the project. It is involved in the development and design of the digital twin, and the digital twin is based on GridCo's grid network data and processes. In addition to GridCo, the project partners consist of two other grid companies, two research institutes and one software company. The project started in February 2018 and has a projected duration of approximately 3 years. Within the project duration, DigitalCo aims to have developed a minimum viable product (MVP): a digital twin prototype that

TABLE 1 Summary of Heideggerian concepts applied in this study

	Core elements	Relational description
Familiarity	The actor is *involved* in the world The actor has *understanding* of themselves and the world There is a *unity of self and world*	An actor's background understanding, involvement, and engagement in a world, enabling the actor to consider artefacts as equipment and cope with the equipment in this world.
Totality	*For-which* (i.e., for which task the equipment is used) *Toward-which* (i.e., toward which purpose) *For-the-sake-of-which* (i.e., the bearing equipment has on an actor)	The equipment's referential whole; the tasks the actor could perform with the equipment (in relation to other equipment), the purpose(s) of the actor performing these tasks and the identity the actor could assume in doing so.

illustrates sufficient value for GridCo and other grid companies for them to want to acquire a full solution from DigitalCo. This article addresses the digital twin prototype, hereinafter referred to as the *digital twin* or *twin*.

A digital twin is a virtual representation of a physical asset or object, which allows a company to digitally mirror and manage this asset through its life cycle (Dietz & Pernul, 2020). In general terms, a digital twin consists of three main components: (1) a physical object in real space, which can be tangible or intangible; (2) a virtual object in virtual space (e.g., in the cloud) and (3) connections between the virtual and the physical space, consisting of data and information tying the physical and virtual together (Grieves, 2014). All kinds of data (e.g., performance data, health data, maintenance data; Madni et al., 2019) can be extracted from the physical object to the virtual object to replicate the reality, providing the user with information on the physical object's condition and state (Dietz & Pernul, 2020).

In our case, the digital twin is a digital twin of the grid network in Norway – the twin is a georeferenced digital representation of how the grid network is laid out in reality, based on GridCo's grid network data. The twin is available in a map-based application, where the users are presented with a map of the grid network area. The map shows all components in the grid network in their exact location (e.g., house branch lines, distribution cabinets, feeder cables, grid substations, cable lines, substation departures and substations) and accompanying information on each component (e.g., voltage level, type of cable, length of cable, electrical properties, alarms and warnings). Predefined rules based on grid sector standards underlie the graphical presentation of the grid network components. If a component has a yellow colour, it is reaching its loading capacity (80% of nominal current), whereas a red colour indicates the component is overloaded (over 100% of nominal current). In Figure 2, we have included some screenshots from the first version of the digital twin.

The idea is that, in the future, the digital twin will be able to incorporate and combine data from additional internal sources and external sources. In addition to being designed based on standardised rules and an open information model, the digital twin consists of four feature categories:

- *Insight*: Showing an actual, modelled and predicted state of the grid. Includes features such as visualisation, topology processing, forecasting and time machine.
- *Planner*: Planning grid operations in the short-term and grid investments in the longer term, where the users get decision support from scenario-based simulations. Includes features such as capacity calculator, investment calculator, grid templates and scenario analyser.

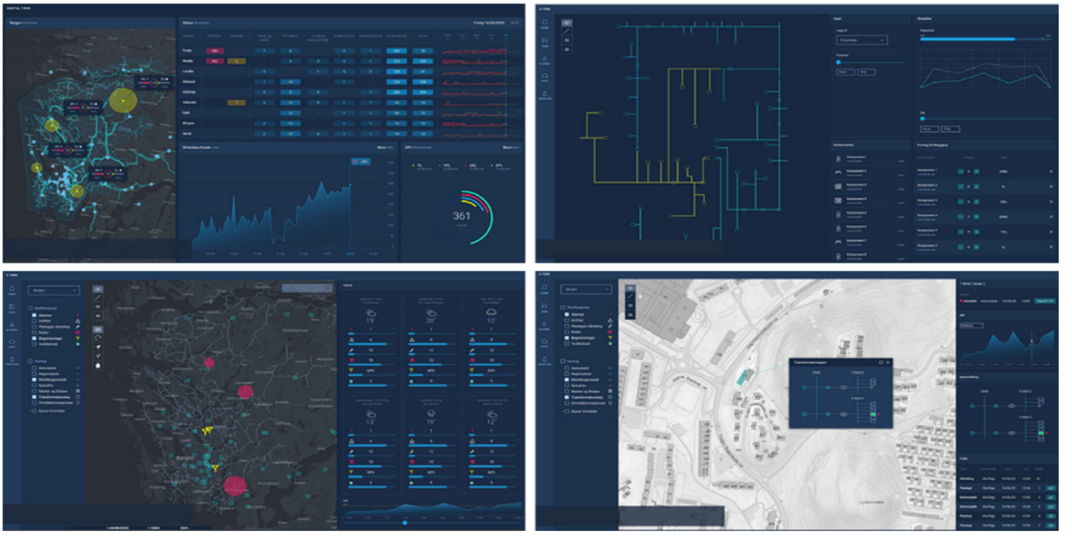

FIGURE 2 Digital twin screenshots

- *Optimiser*: Providing optimal asset utilisation, both technical and economic. The features help the users in balancing investments with operational measures, such as voltage regulation, flexibility and topology changes. Includes features such as optimal grid configuration, optimal power flow, optimal scheduling and micro grid operation.
- *Health*: Providing consolidated risk exposure of operation and investments. This involves risks related to condition, health, safety and environment (HSE), outages, overinvestments and quality of supply. Includes features such as risk forecasting (condition monitoring), dashboards and portability.

3.2 | Data collection

We relied on three sources of data over the course of three phases of the DigitalGrid project: interviews, observations and archival data; however, the interviews served as our main data source. Table 2 illustrates the different data sources.

We conducted 27 interviews with 22 respondents during the three phases. Some respondents were interviewed more than once. Each interview lasted from 40 to 90 min. With the respondents' consent, the interviews were recorded and transcribed verbatim. In the first two phases (2018 and 2019), 18 interviews were conducted with respondents working in a variety of positions and departments in GridCo, some of whom were more directly involved in the DigitalGrid project than others. In addition, interviews non-related to the DigitalGrid project were conducted with 28 respondents from GridCo during this period, which served as a foundation for gaining a rich understanding of GridCo and the Norwegian grid sector. In the third phase (2020), we focussed our interviews more directly on those involved in the DigitalGrid project, supplementing with interviews from respondents from the developing company, DigitalCo. In total, nine semi-structured interviews were conducted in the third phase: seven interviews with GridCo respondents and two interviews with DigitalCo respondents. The interview guide from the third phase is available in Appendix A.

Observation was another important data source, enabling us to view the organisation and project from an insider perspective (Jorgensen, 1989). One author spent 1–3 days a week with GridCo for almost 2 years, participating in meetings, seminars and workshops. Working side-by-side with DigitalGrid project members and attending demonstrations of the different versions of the digital twin provided rich insight into the project and the twin. Observations were documented in over 100 pages of field notes, constituting a valuable data source and foundation for data analysis. Our study also included extensive archival data. We accessed both formal and internal project documentation, including presentations, budgets and plans, from the project members and their collaboration platforms. In addition, we were able to access strategic documents and intracompany information regarding the DigitalGrid project through the grid company's document archival system and internal communication platform.

3.3 | Data analysis

We applied thematic analysis to analyse our data, a useful and flexible method for identifying, analysing and reporting patterns across qualitative data (Braun & Clarke, 2006). *Themes* refer to abstract constructs identified by researchers before, during and after analysis to capture important aspects of the data according to the aim of the research. We chose a theoretical approach to our thematic analysis; our analysis was driven by our theoretical interests and research objectives. We followed six steps in analysing the data, inspired by the phases of thematic analysis presented by Braun and Clarke (2006) (Table 3).

In the first step, interviews were transcribed verbatim and translated from Norwegian to English to enable all researchers to engage in further data analysis. The translated transcripts, observational field notes and archival documents were read and reread. This step enabled us to familiarise ourselves with the data, resulting in ideas for subsequent steps of analysis and a thorough understanding of the case and the phases of the DigitalGrid project (Figure 3). In the second step, we generated themes for further data analysis driven by our research objectives. We

TABLE 2 Data sources

	Role	Phase 1 (2018)			Phase 2 (2019)			Phase 3 (2020)		
		No. of interviews	Respondent ID	Duration	No. of interviews	Respondent ID	Duration	No. of interviews	Respondent ID	Duration
Interviews	*DigitalGrid project member (GridCo)*	4	1;2;3;6	278 min	1	8	47 min	7	1;3;6;8;19; 22	501 min
	Manager (GridCo)	1	5	55 min	2	10;12	114 min			
	Employee (GridCo)	2	4;7	112 min	8	9;11;13;14;15;16;17;18	378 min			
	DigitalGrid developer (DigitalCo)							2	20;21	126 min
	In total	7		445 min/7.4 h	11		539 min/9.0 h	9		627 min/10.5 h
Observation	Working side-by-side project members and other organisational members 1–3 days per week Daily conversations with project members Participation in weekly and monthly meetings, seminars and workshops Three demonstrations of the digital twin versions 1, 2 and 3 Participation in four sprint demonstrations >100 pages of written field notes									
Archival data	Formal project documentation Internal project documentation (GridCo) Strategic documents (GridCo) Other relevant documents									

wanted to capture the digital twin affordances, and accordingly, we generated the theme *affordances*. Further, following our objective to explore how the two concepts of Heidegger could help explain and specify affordance perception, *familiarity* and *totality* were also chosen as themes for our data analysis.

The third step involved generating initial codes within each theme. The generated codes represented features of the data that appeared interesting and relevant to our research objective (Braun & Clarke, 2006), based on the literature and pre-understanding we developed through familiarising ourselves with the data. For instance, codes could represent potential digital twin affordances, or they could be linked to the underlying ideas of familiarity and totality. Then, in the fourth step, we coded the data. Coding implies organising the data into meaningful groups (Braun & Clarke, 2006) and collating data extracts into relevant codes. During the coding process, we also identified additional affordances than those we initially had considered, which generated new codes.

TABLE 3 Data analysis steps (inspired by Braun & Clarke, 2006)

Step	Description	Outcome
1. Familiarising ourselves with the data	Transcribing data, translating transcripts, reading and rereading transcripts, making notes on initial ideas	Case description Phases of DigitalGrid project (Figure 3) Ideas for subsequent steps
2. Generating themes	Themes chosen based on theoretical perspectives	Themes: affordances, familiarity, totality
3. Generating initial codes	Codes generated and assigned to relevant themes, based on literature and previous steps	Initial codes for each theme
4. Coding data extracts	Coding relevant and interesting features across the entire data set and adding new codes	Additional codes Coded data extracts
5a. Analysing themes: *Familiarity and Totality*	Collating codes into themes, gathering data relevant to each theme; focussing on links among familiarity, totality and affordance perceptions	Codes connected to themes Activities leading to familiarity and totality Links among familiarity, totality and affordance perception (Table 4)
5b. Analysing theme: *Affordances*	Cycle 1: Identifying affordances from codes and data extracts Cycle 2: Checking codes against data extracts, combining affordances	Codes connected to theme Digital twin affordances (figure A1 in Appendix B and table A1 in Appendix C)
6. Producing report and developing theoretical model	Reviewing and validating; selecting extracts, illustrating findings, relating back to research objectives; integrating the concepts of familiarity and totality in developing an enriched theoretical model of the relational aspect of affordance perception	Theoretical model (Figure 4)

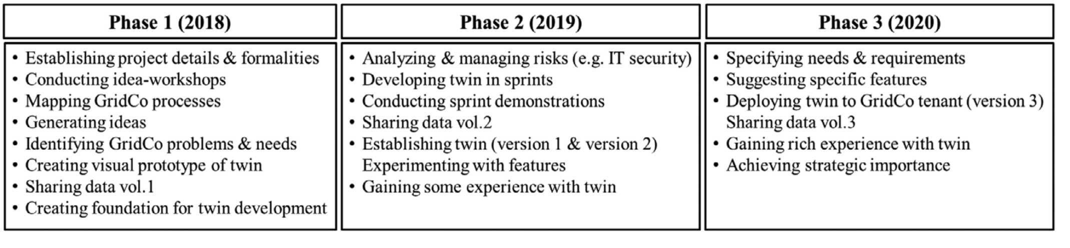

FIGURE 3 DigitalGrid project evolution through three phases

Regarding the fifth step, we chose different approaches to analyse the familiarity and totality themes and the affordance theme in parallel. For the familiarity and totality themes (step 5a), we first gathered and organised all coded data extracts for each code and accompanying theme. Our analytical focus here considered capturing relevant links between the digital twin totality and the users' familiarity and linking these to affordance perception. We reviewed the data extracts and codes for each theme several times with constant comparison among the data, codes and themes to ensure we had captured the full essence of both themes. Based on this step, we were able to determine how users came to perceive digital twin affordances and link these insights to the users' familiarity and digital twin totality (Table 4). The affordance theme (step 5b) was analysed in two cycles (see Appendix B). First, we identified candidate affordances based on the codes and data extracts underlying the theme. Second, we reviewed and

TABLE 4 Mechanisms for perceiving digital twin affordances

Perceived digital twin affordance	Familiarity of digital twin tasks based on features	Which was developed through	And familiarity of purposes (developed through challenging)	And familiarity of identity (developed through mapping)
Collatability	Open information model	Leveraging experience Involving users Standardising design	GridCo challenges and user issues	Improved operations Improved development
Monitorability	Insight Health	Leveraging experience Involving users Visualising Testing Standardising design	GridCo challenges and user issues	Improved operations Improved development
Operatability	Planner	Leveraging experience Involving users Visualising Testing Standardising design	GridCo challenges and user issues	Improved operations
Developability	Planner Optimiser Health	Leveraging experience Involving users Visualising Testing	GridCo challenges and user issues	Improved development
Simulatability	Open information model Planner Optimiser	Leveraging experience Involving users Visualising Testing	GridCo challenges and user issues	Improved Operations Improved Development
Decision supportability	Open information model Insight Planner Optimiser Health	Leveraging experience Involving users Visualising Testing	GridCo challenges and user issues	Improved operations Improved development
Automatability	Planner Optimiser Health	Leveraging experience Involving users Visualising Testing	GridCo challenges and user issues	Improved operations Improved development
Customer improvability	Insight Planner Optimiser Health	Leveraging experience Involving users Visualising Testing	GridCo challenges and user issues	Improved operations Improved development

again checked the codes against the data extracts to combine and refine digital twin affordances. The affordances identified are described in detail in Section 4.3 and summarised in table A1 in Appendix C.

In the sixth and final step, we again studied the coded data extracts and themes in detail. Extracts, codes and themes were reviewed and validated and sometimes renamed or recombined. We then wrote down the story the data told. We chose relevant data extracts to include to capture the points we wanted to demonstrate, presented our findings with logical illustrations, revised these illustrations, and related the findings to our research objectives (Braun & Clarke, 2006), and in so doing, we integrated the concepts of familiarity and totality in an enriched theoretical model of the relational aspect of affordance perception.

4 | RESULTS OF THE EMPIRICAL STUDY

In this section, we present the results of our empirical study. First, we present the evolution of the DigitalGrid project through three phases, which represented a learning and maturing process for GridCo. Second, we show how this learning involved GridCo users developing a familiarity with the digital twin totality, which evolved through mechanisms in the interplay between the users (GridCo) and developers (DigitalCo). This, in turn, enabled the users to perceive eight digital twin affordances, which are presented in the third subsection.

4.1 | Evolution of the DigitalGrid project

The DigitalGrid project began in early 2018 with a 3-year projected duration. From the interviews and project documentation, we identified three main phases of the project evolution as summarised in Figure 3.

The official kickoff of the project was on February 1, 2018; since then, the DigitalGrid project has evolved incrementally over time. In the first phase, when all formalities and project details were in place, DigitalCo engaged an agency to facilitate idea workshops with GridCo users to map processes, generate ideas and identify the problems and needs of GridCo. Four workshops were conducted, which generated a broad list of requirements for the digital twin and the project. In the beginning of the second phase, GridCo was focussed on dealing with IT security and finding viable solutions for sharing increased amounts of data with the twin. This was of particular importance because the energy sector in Norway is subject to regulations from the Energy Act to protect sensitive power system information. Once security measures were in place and risks were under control, the development of the digital twin could start. The developers at DigitalCo worked in 2-week sprints, where the latest status and updates on the digital twin were presented to GridCo users in sprint demonstrations on a monthly basis. The development approach in the second phase was explorative, characterised by experimentation and idea testing. Based on the list generated in phase one and feedback from GridCo users, DigitalCo added features to the digital twin on a continuous basis. The third phase was characterised by increased user-centricity, in that GridCo users became more specific in expressing their needs and requirements for the further development of the digital twin, which DigitalCo accommodated. As one GridCo respondent commented, '*It's kind of a way for us to take more control in the project, basically, and get the most out of the project. We just want our needs to be met*' (Respondent 1). Accordingly, driven by a fear of ending up with '*something that is fun, but not useful*' (Respondent 1), the GridCo users took a more active role in phase three, to ensure that the digital twin would in fact have features that could accommodate their problems. During the third phase, the digital twin was transferred to GridCo's tenant, allowing GridCo to expand the scale and scope of the data extracted to the twin without exposing sensitive power system information. During the third phase, the DigitalGrid project also received increasing attention from GridCo on a strategic level, with the top management pointing to the digital twin as an essential building block in GridCo's digital transformation.

During the project, valuable learning enabled GridCo users to more actively specify their needs for the digital twin along the way. One respondent from GridCo explained, '*I can only evaluate the functionality against my* *understanding. And the understanding has evolved during the project. And I also evaluate the functionality against our own needs. And the more I have talked to our people, and the longer I have worked in GridCo, the more I understand our needs. So it's an evaluation of our needs versus the twin's functionality'* (Respondent 1). The increased understanding also enabled GridCo users to gradually realise the value of a digital twin of the grid network: '*I would say that the understanding of 'what this is' has increased. And we realize more and more how things cohere, which we did not realize in the beginning at all. And we didn't know that we needed [a digital twin] when we started this project. So that is an understanding that has evolved over time'* (Respondent 6).

4.2 | Familiarity with referential totality to enable the perception of affordances

Building on Heideggerian thought, we found that affordance perception was possible because GridCo users developed a familiarity with not only the digital twin and its features, but the totality of the digital twin. By this we mean that, over time, GridCo users came to understand the digital twin as practical means (i.e., equipment), embedded in their know-how and related to contexts specific for GridCo and the grid sector, providing the user with a familiarity of the digital twin in relation to themselves and other equipment in the same 'world'. In our case, familiarity with the digital twin totality implies the GridCo user's familiarity with three interrelated components of the digital twin: the tasks the user could perform with the twin in relation to other equipment, the purposes behind applying the digital twin and the identity the user could assume in this application. In this section, we present the mechanisms throughout the project and in the interplay between GridCo and DigitalCo that enabled GridCo users to develop familiarity with the totality of the digital twin, and how this, in turn, influenced the perception of digital twin affordances.

4.2.1 | Leveraging experience

Building on experience from developing digital twins in other industries, DigitalCo transferred knowledge, methodology and frameworks to the DigitalGrid project and the grid sector. As one representative from DigitalCo explained, '*We draw from synergies regarding technology and methodology from other industries or other domains, such as oil and gas and the maritime sector. So we build on coding-related and methodological elements from other parts of our organization*' (Respondent 20). DigitalCo illustrated what they had accomplished with digital twins in other industries, which helped GridCo users imagine for what purposes a digital twin of the grid network could potentially be applied.

4.2.2 | Involving users

DigitalCo consistently involved GridCo users in the development and design of the digital twin. The users who were involved in the DigitalGrid project mainly represented employees from departments for which the digital twin had the greatest potential of application: the Operations (i.e., those working on operating and maintaining the grid network in the short term) and Development (i.e., those working on maintaining and developing the grid network over the long term) departments. In addition, some employees from the Innovation and IT departments were part of the project team. As such, 'GridCo users' consist of employees who have extensive experience with and knowledge about the grid network structure and data, as well as grid company processes. As such, the users represent actors that were integrated in the same 'world' as the physical grid network and who thereby already had developed a familiarity with the physical counterpart of the digital twin. For DigitalCo, user involvement was crucial to ensure they developed something of value and utility for GridCo. In addition to regular meetings and continuous dialogue, DigitalCo involved GridCo users in the development and design of the digital twin in three ways. First, the users were actively involved in the idea workshops in the first phase. Here, GridCo's '*problems and needs for the short and long term*' (Respondent 3) were identified, which became the guide for the development of the digital twin. Second, GridCo shared relevant grid network data with DigitalCo to develop the digital twin. Third, GridCo users attended the sprint demonstrations where DigitalCo presented the status of the digital twin development and where GridCo users provided feedback and input. Heavy involvement enabled the users to develop an understanding of the digital twin as integrated in the same world as themselves and in their practical work context. Or as one GridCo respondent reflected, it allowed them to '*see the digital twin in relation to other things, other work and projects in the company'* (Respondent 3).

4.2.3 | Visualising

Through different types of visualisations, DigitalCo was able to show GridCo users for what purposes the digital twin could be applied. In the beginning, visualisation was mainly done through pictures and slideshows. Later in the project, however, DigitalCo could show the actual digital twin solution to the GridCo users, which made it easier for the users to imagine what the digital twin could be used for and provide relevant input to the developers. According to GridCo, visualisation was essential: '*In the beginning everything was just on paper. And then DigitalCo made some sort of mockup, which made it more realistic. And the more functionality we can see, the easier it is to relate to the twin and other possibilities. It's hard to only discuss with words. It's easier for the users to see, and provide feedback on adjustments, when there is something concrete to relate to*' (Respondent 22).

4.2.4 | Testing

Eventually, GridCo users obtained the access to test and use the digital twin during the project period, as the different versions of the digital twin were released. This access was groundbreaking for GridCo, as it increased the users' '*knowledge of the twin's areas of application*' (Respondent 8). Accordingly, the opportunity to test and '*play around*' (Respondent 19) with the twin increased GridCo users' familiarity with the digital twin's potential areas of application within their work context and in relation to other equipment. As one respondent explained, '*There's something that happens when you get to click inside the digital twin and start a process. And that's when we start asking questions regarding data quality, whether calculations are correct, or if we could add "this and that"*' (Respondent 1).

4.2.5 | Standardising design

The digital twin is a georeferenced, digital representation of the grid network in GridCo's concession area. Through a map-based application, GridCo users can recognise their entire grid network, digitally, with all its components and properties. This was possible for two specific reasons. First, the digital twin is based on GridCo's data and grid network. Second, DigitalCo developed and refined the graphical user interface of the digital twin based on feedback from GridCo users and grid sector standards. As one GridCo respondent explained, the digital twin was built on '*a standardized information model where voltage is voltage, and electricity is electricity – so that you can compare apples with apples and bananas with bananas*' (Respondent 1). Further, the digital twin features in the insight, planner, optimiser and health categories are readily available for GridCo users with familiar tools and logical graphical interfaces; thus, they could develop a familiarity with the tasks possible to perform with the digital twin in relation to other equipment and within their work context.

4.2.6 | Challenging

The tasks GridCo users could perform with the digital twin are linked to a set of purposes to which these tasks could be put. In our case, familiarity with the purpose component of the totality evolved as GridCo users came to understand how the digital twin could be applied in their work context to accommodate the issues they had in their daily practice and the challenges GridCo faced as a grid company. Although GridCo perhaps was aware of these challenges and issues, DigitalCo was able to emphasise the severity and imminency of these challenges and also demonstrate to GridCo users how they could apply the twin to accommodate them. As one respondent from GridCo explained: '*We need to know which means we can use to ensure our customers' needs are fulfilled, and at the same time sustain the balance in the grid network. So we need to look at all these means, and how we apply them to always ensure that our customers are satisfied and they get their electricity at the right quality. That voltage levels are sustained. And to do so, we need the digital twin*' (Respondent 8).

4.2.7 | Mapping

The final component of the totality is the identity GridCo users could assume in applying the digital twin to perform purposed tasks in their daily work practice. In this case, this implied the identity of the main user groups at GridCo who would potentially apply the digital twin: operations and development. Familiarity with the identity evolved through GridCo and DigitalCo making efforts to identify and map the tasks and processes of the user groups. Considering existing processes and how they could be improved to get where they wanted to be, GridCo users developed a familiarity with the identities of *improved operations* and *improved development* that they could assume in performing tasks with the digital twin in their work context and in relation themselves and other equipment. Accordingly, familiarity with the identity component of the digital twin evolved through an understanding of how the digital twin could improve the operations and development processes and tasks.

To summarise, through leveraging experience, involving users, visualising, testing and standardising design, the project enabled GridCo users to develop familiarity with the digital twin and its potential application in their daily work practice and in relation to themselves and other equipment within the same context. Application of the digital twin was further linked to the purpose behind GridCo users applying the twin and the identity they could assume in doing so, which evolved through DigitalCo challenging them and extensive mapping of tasks and processes.

4.3 | Digital twin affordances

Eight digital twin affordances were identified in this study as perceived by GridCo users, each of which are formulated as an '*ability*' because they represented action possibilities offered to users in relation to the digital twin. A summary of the digital twin affordances is provided in table A1 in Appendix C.

Collatability refers to the possibility for GridCo users to use the digital twin to collate and combine data from several sources. One GridCo respondent explained that, with the digital twin, they were '*able to collate different types of data, and get insight into things that are not possible in our traditional professional systems, where we only have one perspective*' (Respondent 22). He continued, '*with the digital twin, we can link several perspectives, and feed the twin with different input, to get more accurate answers*' (Respondent 22).

Monitorability regards the possibility for GridCo users to apply the digital twin to monitor the grid network and its health status and identify bottlenecks and voltage discrepancies. One GridCo respondent explained, '*[The digital twin is] able to always update us on the level of risk in the grid network, based on ongoing work on the grid, weather and wind, and condition evaluations in the grid network.… We can monitor which areas of the grid network are most critical today, regarding outages and incidents*' (Respondent 3).

Operatability refers to GridCo users' possibility to operate the grid network through the digital twin, supporting planning and maintenance in the short term. Being fed with relevant and real-time data from sensors in the grid network and other data sources, the digital twin is able to present the grid network with all its components in an understandable and accurate way, which makes the digital twin '*central as a tool for operational support*' (Respondent 1). This affordance is mainly actualised by the Operations user group, that is, '*those who have a need for insight into how the grid is going to behave 48 hours ahead in time*' (Respondent 1).

Developability concerns GridCo users' possibility to develop the grid network through the digital twin, supporting planning and investments in the grid in the long term. This affordance is mainly actualised by the Development user group, that is, '*those who are supposed to have control over our grid network*' (Respondent 19). In the digital twin, the users can analyse consequences of changes in the grid network, and based on the output from the twin, they can evaluate the best viable option for further grid development.

Simulatability refers to the possibility for GridCo users to apply the digital twin to simulate different scenarios in the grid network. Feeding the twin with relevant and real-time data from several sources improves its simulation capacity. As one DigitalCo employee pointed out, '*the whole magic in this is what you feed it with, and how you orchestrate it, basically*' (Respondent 21). Accordingly, the digital twin can be used to simulate almost any scenario the users wish, as long as the twin has the necessary data available to do so. According to GridCo, this affordance is particularly important because of the aforementioned changes in the grid sector, with new consumption and production patterns predicted to come in the future.

Decision supportability regards the possibility for GridCo users to use the digital twin for support in decisions regarding the grid, where the digital twin suggests solutions for handling issues in the grid network. Again, the more data the digital twin is fed, the better the decision support: '*When you are making decisions; the more information you feed it with, the more perspectives you get, and the better decisions you can make*' (Respondent 8). The digital twin can support GridCo users in decisions in both the short and long term, that is, in operating the grid on a daily basis (Operations) and in developing the grid network (Development).

Automatability refers to the possibility for GridCo users to apply the digital twin to automate tasks, processes and decisions. As one person at GridCo noted, the dream is, put bluntly, that '*everything is automated*' (Respondent 19). One respondent from GridCo explained how they '*do a whole lot of manual processing around here, which I believe the digital twin could relieve through automation*' (Respondent 22). He continued, '*It's not enough that data flows one way only. The digital twin will have to be able to make automatic reconnections, or make adjustments in the real world to solve the problems that the digital twin finds. This has to happen, or else we'll just get a new warning lamp somewhere, and we'll have to go into a different system to fix it*'.

Customer improvability refers to the possibility for GridCo users to use the digital twin to improve the customer interface and the way they approach the customers by simplifying and automating customer interactions and processes, integrating digital twin applications with the customer interfaces, and even '*provid[ing] the customers with self-service solutions*' (Respondent 1). By doing so, GridCo users argued, they could rely on fewer actors in the customer processes, respond to customers more quickly and reduce costs.

Table 4 illustrates the perceived affordances and how GridCo users developed familiarity (i.e., based on which features [see Section 3.1] and through which mechanisms) with each of the different elements of the totality of the digital twin (i.e., tasks, purpose and identity).

In sum, familiarity with the digital twin totality enabled GridCo users to perceive eight digital twin affordances. Without familiarity, these digital twin affordances could have remained latent or hidden for the users. In fact, the users who developed a familiarity with the digital twin totality were those who were involved in the development of the digital twin. Other employees at GridCo who were not involved in the DigitalGrid project lacked this familiarity and did not perceive the digital twin affordances. For any user (existing or new) to consider the digital twin as an equipment as part of a totality, they need to develop familiarity with the totality, which could be developed through the mechanisms as presented in Section 4.2 and in Table 4. This is also illustrated by how familiarity with the digital twin totality was something that evolved for GridCo users with time, which eventually enabled them to perceive

FIGURE 4 Nuanced perspective on relational aspect of affordance perception

digital twin affordances: '*the first time I saw [the digital twin], it was very Greek for me. But as you work a bit with it and start to understand it, it's not that hard*' (Respondent 1). Further, DigitalCo talked of a ninth digital twin affordance – *Flexibility Manageability* – the possibility of managing flexibility solutions in solving capacity challenges from an operational perspective. According to a DigitalCo respondent, this was the affordance they '*actually have the most faith in*' (Respondent 20); however, they acknowledged that GridCo users had not developed enough familiarity with the digital twin totality, particularly with the potential purposes behind applying the digital twin, for them to perceive this affordance.

5 | DISCUSSION

Our study started with the objective of unfolding the relational view of affordances and how this would influence the perception of affordances. To do so, we applied the Heideggerian notions of familiarity and referential totality. From a Heideggerian perspective, affordance perception does not happen in isolation; rather, actors are 'being in the world'; they have familiarity with equipment based on their everyday engagement in the world. They perceive the action possibilities of equipment in its familiar referential totality. In the previous section, we discussed how our empirical study of GridCo enhanced our understanding in this regard. In the following section, we first present an enriched theoretical model of the relational aspect of affordance perception and then discuss implications of our research and model to affordance theory in particular and contributions to practice and the IS field more generally.

5.1 | A nuanced perspective of the relational aspect of affordance perception

Our study showed that, through the project evolution and interplay between the users (GridCo) and designers (DigitalCo), the users developed familiarity with the digital twin totality and were able to perceive eight digital twin affordances. Drawing on these insights, we developed an enriched theoretical model integrating the concepts of familiarity and referential totality to present a nuanced perspective to specify the relational aspect of affordance perception (see Figure 4).

In our model (Figure 4), the actor and IT equipment are placed as part of the same 'world', where the actor becomes familiar with the referential totality of the equipment and through that perceives affordances. A shared world increases familiarity of the referential totality, which alters the actor's understanding of their involvement with the equipment as experience (Harnesk & Thapa, 2016) and in this world, allowing the actor to perceive affordances in co-presence. Taken together, we posit that an actor perceives affordances through being part of the same world as the equipment, and that affordances themselves are embedded inside the referential totality in which equipment exists in interrelation with actors and other equipment.

In other words, with this model we posit that an actor perceives affordances in relation to an equipment if the actor is familiar with the totality of the equipment. This implies that the actor, for one, is familiar with the everyday use of the equipment (rather than just the characteristics and features of an artefact) and which tasks the actor could perform with the equipment (i.e., with how the equipment reveals itself in practice and in connection to other equipment). Second, the actor is familiar with and understands some purposes to which these tasks can be put, and third, which identity the actor could assume in performing them.

Without familiarity of the equipment totality, users would not have perceived the affordances offered in relation with the digital twin (i.e., affordances would remain latent), as would have been the case for other GridCo employees who were not involved in the development of the twin, did not get the opportunity to test the digital twin prototype, had not thought through the grid company's challenges, were not engaged in process mapping and improvement and so on. In other words, new users approaching the digital twin for the very first time would likely find themselves in a *breakdown situation* (Lanamäki et al., 2015). Despite that Heidegger himself did not use the term ‘breakdown’ in his writing, the term is associated with situations when ongoing, non-reflective practice is interrupted (Dreyfus, 1998; Koschmann et al., 1998). In such situations, actors would lack familiarity with the referential totality and would not view the digital twin as equipment (readiness-to-hand), but rather as objects (presence-at-hand) (Koschmann et al., 1998; Lanamäki et al., 2015). Instead of considering the practical application of the digital twin in relation to other equipment in the given context, the actor would likely consider the digital twin as a collection of separate components that do not make any practical sense to them. Take the hammer example again; in a breakdown situation, one would typically consider the hammer as an object as it is present at hand – as a heavy metal blob on a wooden shank, for instance – rather than ‘something-to-hammer-something’ (Riemer & Johnston, 2014). For any user (new or old) to consider the digital twin as an equipment as part of a totality, they need to develop familiarity with the totality, which could be developed through the mechanisms as presented in Section 4.2 and in Table 4.

5.2 | Implications for affordance theory

With our model (Figure 4), we continue the general perspective that affordance perception requires an actor with capabilities and goals (Leidner et al., 2018; Markus & Silver, 2008; Strong et al., 2014); however, by integrating Heideggerian concepts, we seek to illustrate that the relation in which affordances arise is not as simple as the relation between the actor (with capabilities and goals) and an artefact (with features), which has been the common view within affordance theory (Bernhard et al., 2013; Pozzi et al., 2014). Rather, affordances arise from the familiarity of capable and goal-directed actors with equipment in totality (since every equipment is part of a larger totality). In other words, affordances can only be perceived within the referential totality or the world in which the equipment and actor exist in co-presence.

Through applying the idea of familiarity, we integrate both the ideas of context (Leonardi, 2011b), cultural background (Leonardi, 2011a) and norms (Fayard & Weeks, 2007), in that the actor perceives affordances based on their background understanding and everyday know-how in relation to an equipment in a particular situation in a given context. Familiarity, as such, represents a shared background understanding of a shared world – a phenomenon containing any contextual element of practical everyday life (Dreyfus, 1998). Hence, an actor's familiarity with the equipment in its referential totality can enable the actor to perceive affordances.

Drawing on the thinking of Heidegger, we consider the relation between an actor and an entity, not as a two-way relation, but rather as a totality, a shared world. As such, integrating a Heideggerian perspective on affordance perception (Lanamäki et al., 2015) allows us to move beyond the dualistic view of relation (Riemer & Johnston, 2017), where much of the confusion regarding the nature and influences of affordance perception seems to reside. Instead of delving into discussions on the nature and properties of the relation of an actor and an entity influencing affordance perception (i.e., different stances of affordance perception; Lanamäki et al., 2016), Heidegger was concerned with the totality and shared world of an actor, other actors and equipment (Dreyfus, 1998; Riemer &

Johnston, 2017). This holistic view is also, so we argue, more in line with the original conception of Gibson; considering affordances as environment-provided (Gibson, 1986; Lanamäki et al., 2015), rather than merely residing in a two-way relation between an actor and an artefact.

With our study, we not only expand and specify the relational aspect of affordance perception through integrating the Heideggerian concepts of familiarity and totality; we also explain the mechanisms which should be in place for users to develop familiarity with the artefact totality (Table 4). Our findings also show that the users of digital twins, unlike the physical structure (grid network), need two levels (physical and virtual) of familiarity and pre-understanding of the totality to perceive its affordances. This understanding also addresses the confusion of the relational aspect of the theory of affordances. The relation in existing research has been interpreted in different ways (Lanamäki et al., 2016). We argue that the relation should not be understood through interaction and reflections but through engagement and action based on familiarity with the totality. That comes from our everyday engagement in the world.

5.3 | Contributions to practice and the IS field

Digital twin is an emerging phenomenon, and research on it is still nascent (Kritzinger et al., 2018; Meske et al., 2021). Our work contributes to practice and IS research in exploring how such complex digital entities are understood and applied by users in specific contexts. Similar to Treem and Leonardi (2013) who identified generalised functional affordances of social media; in our study, we revealed affordances of digital twins that can be helpful for both researchers studying digital twins and digital transformation, as well as practitioners engaging in or considering engaging in digital twin projects. Specifically, we identified eight digital twin affordances perceived by the users: collectability, monitorability, operatability, developability, simulatability, decision supportability, automatability and customer improvability. Some of these affordances are in line with the predictions of digital twins enabling companies to operate, monitor and develop their physical counterparts as well as serving as valuable tools for simulation and decision support (Enders & Hoßbach, 2019; Madni et al., 2019). However, for any of these affordances to become a reality and the potential of a digital twin to avoid remaining untapped, the users of a digital twin need to become familiar with the features and tasks to perform with it, the purposes behind performing these tasks and the identity they could assume in doing so. In other words, users (new or old) and their digital twins need to be in the same 'world' to become familiar with the referential totality of the digital twin. To achieve this, and avoid breakdown situations (Koschmann et al., 1998; Lanamäki et al., 2015), we have illustrated and explained mechanisms which should be in place for users to develop familiarity with complex digital entities in their referential totality (Table 4). Future research should explore breakdown situations in more detail, to increase our understanding of why breakdown situations occur and what could be done to avoid them.

Our study further confirms the important role a digital twin can play in firms' digital transformation (Sarraco, 2019), through enabling organisations to gain rich, in-depth understanding of their physical counterparts. This is arguably especially valuable for established, asset centric firms, where data typically exist in separate organisational silos, which can be combined in a digital twin, and for organisations who operate critical infrastructures (Dietz & Pernul, 2020), such as GridCo. In our study, we illustrate how digital twins can serve as helpful tools in collating dispersed and increasing amounts of data in the physical counterpart's environment, automate tasks and processes and improve customer support, all of which are valuable for incumbent firms' digital transformation and to stay competitive and relevant in the digital era (Vial, 2019).

In our study we also observed that, as GridCo users' familiarity with the referential totality of the digital twin increased, they gradually came to experience the application of the digital twin as being of significance (Heidegger, 1962; Riemer & Johnston, 2014) and contributing to achieving GridCo's digital transformation goal to optimise resources and increase customer satisfaction. This was also reflected in GridCo management's gradually increasing devoted attention to the digital twin and DigitalGrid project on a strategic level. This significance was further reinforced through DigitalCo actively trying to engage GridCo users in understanding the sense-of-urgency of grid sector challenges and the relevance of the digital twin to accommodate these challenges. Particularly, the affordance regarding automation of tasks, processes and decisions (i.e., automatability) was perceived by the GridCo users and was considered as technically possible to act upon; however, the users did not yet evaluate this affordance as significant enough for them to actualise it. Hence, this suggests that, for a final digital twin to be rolled out as a company-wide digital solution, it must be clearly linked to the digital transformation goal of the company, so that the general employee would evaluate their application of the twin in their everyday practice as of significance (Heidegger, 1962; Riemer & Johnston, 2014). Otherwise, the digital twin's potential would remain untapped. Future research should explore the notion of significance from Heidegger's thinking further and in relation to affordance actualisation. Moreover, the digital twin affordances identified in this study could all (except one; customer improvability) be characterised as functional affordances (Thapa & Sein, 2018). We have not investigated whether a higher level of digital twin affordances might arise as functional affordances are actualised, or whether there exist any dependencies (Strong et al., 2014) among identified digital twin affordances, which represent fruitful avenues for future research.

Although we mainly focussed on the actor–equipment relation in this article, our empirical study also revealed that, in cases of high levels of user involvement in developing and designing IT, the designer can play an important part in influencing the user's familiarity with the totality of the equipment. As such, the designer can contribute to the user's perception (and potential actualisation) of affordances, not only through design (i.e., designed affordances; Lanamäki et al., 2016), but also through interacting with the user throughout the development period. By involving intended users throughout the development and design of the digital entity, the users and designers can build a common understanding of the equipment and its potential applications. Put differently: if the designer and actor are part of the same 'world', this increases the likelihood of affordance perception (Lanamäki et al., 2015; Turner, 2005). This was evident in our study where DigitalCo's engagement with GridCo users over time led them to sharing the same world which influenced their understanding of the referential totality of the digital twin. Future research should investigate further the role of the designer in influencing affordance perception and actualisation as being part of the same 'world' as potential users.

6 | CONCLUSION

In this article, we addressed the relational aspect of affordances and sought to specify and expand our common understanding of how actors come to perceive affordances. Existing views of affordance perception are diversified and unclear and seem to consider actors as working in isolation and interacting with artefacts to achieve their goal. Building on Heidegger's philosophical thinking, we have developed an enriched theoretical model and argued that actors are already embedded in the 'world' with equipment and perceive affordances in everyday practice. In this world, the actor becomes familiar with the equipment totality, which enables them to perceive affordances. This implies that the actor, in being in the world, develops an understanding of the features and tasks to perform with the equipment, the purpose of performing these tasks and the identity the actor could assume in doing so. In our case study, we showed how GridCo users over time developed this familiarity with the digital twin totality, which enabled them to perceive digital twin affordances.

As with every study, our work also has limitations. For instance, we borrowed the concepts familiarity and totality. We acknowledge that Heidegger's philosophy and thinking are complex, and that the complexity of the concepts is greater than how we have portrayed them in this article. However, understanding and explaining all of Heidegger in detail would require an entirely different study. We believe we have captured the essence of familiarity and totality through our application of the concepts. Moreover, to achieve high reliability and to exclude confounding variables introduced by the heterogeneity of organisational contexts, we focussed on one case only. In that sense, we bought internal consistency at the expense of generalisability. Our theoretical model should be further tested in other domains and with varying types of actors and digital entities to explore its tenability. Also, the digital twin in our empirical study is currently only a prototype and part of a research and development (R&D) project involving DigitalCo, GridCo and other partner companies. The full digital twin solution will only be available for GridCo and other grid companies if they choose to acquire the solution when the project ends, which is most likely but not certain.

DATA AVAILABILITY STATEMENT

Data is available on request from the authors.

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APPENDIX A: INTERVIEW GUIDE EXAMPLE

Introduction (our research interests)

The respondent's role in the DigitalGrid project (if applicable)

- Could you specify your role in the project?
- How and when were you introduced to the project?
- What are your main tasks related to the project?
- Have your tasks or role changed during the project?

Phases of the DigitalGrid project

- GridCo respondents:
    - How has the DigitalGrid project evolved over time?
    - My impression is that the DigitalGrid project has evolved over time through different phases: In 2018, the focus was on generating ideas, in 2019, the focus was on experimenting and exploring functionality of the digital twin, and in 2020, the focus has been on specifying the needs of GridCo and functionality of the twin more concretely. Does this perception relate to your understanding of the development of the DigitalGrid project?
        - If yes/no: Could you elaborate?
    - Specification of different project phases:
        - What are the outcomes of each phase?
        - What have you learned from each phase?
        - Have your requirements to the digital twin changed during these phases?

- DigitalCo respondents:
    - How has the DigitalGrid project evolved over time?
    - Is it correct to infer that the DigitalGrid project evolution can be characterised by three different phases: In 2018, the focus was on idea generation, in 2019, the focus was on experimentation and explorative development of functionalities, and in 2020, the development will be more focussed towards the grid companies' direct needs and specifications?
        - If yes/no: Could you elaborate?
    - Specification of different project phases:
        - What are the outcomes of each phase?
        - What have you learned from each phase?
        - Have your intentions with the digital twin changed during these phases?
    - Has the effort DigitalCo has put down in the project varied during the course of the project?
        - If yes, when and how has it changed?

Functionalities of the digital twin over time

- GridCo respondents:
    - What are the most important functionalities of the twin, in your perception?
    - Have your requirements to the functionality of the twin (what the twin is able to do) changed
        - If yes; why and what has changed?
    - What are the main drivers behind the requirements/functionalities of the digital twin?
    - Are your requirements of the functionalities of the twin in line with DigitalCo's intention of the digital twin?
- DigitalCo respondents:
    - What are the most important functionalities of the twin, in your perception?
    - Have your intentions of the digital twin and its functionalities changed during the course of the project?
        - If yes; why and what has changed?
    - What are the main drivers behind the functionalities and design of the digital twin?
    - Are your intentions of the digital twin functionalities in line with the grid companies' perceptions?

User-involvement

- GridCo respondents:
    - How much are you as a grid company and potential user of the digital twin involved in the development and design of the twin?
    - What are the main benefits of participating in the development and design of the twin?
    - Are there any challenges with being involved in the design and development of the twin?
- DigitalCo respondents:
    - What is the intention behind involving grid companies, like GridCo, in the development of the twin?
    - Has GridCo been involved at different degrees during the project? Or has their involvement been the same over time?
    - What are the benefits of involving the grid companies in the design and development of the digital twin?
    - Are there any challenges of involving potential users to this degree?

DigitalGrid objectives

- The project end date is set to 01.01.2021. What do you hope to have achieved by this date?
- What are the next steps after this date?
- What are the main objectives of participating in the DigitalGrid project?

APPENDIX B: DATA ANALYSIS AFFORDANCE THEME

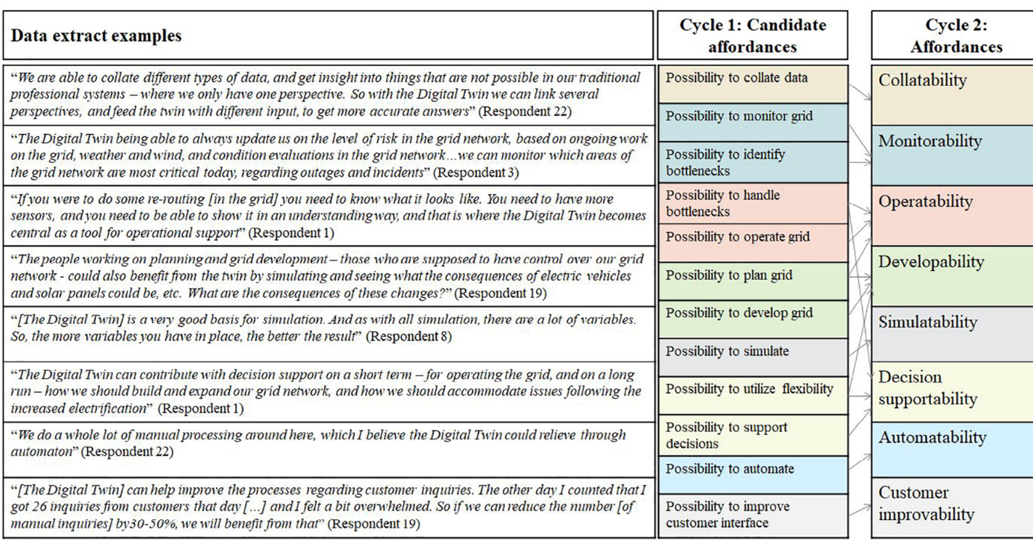

FIGURE A1 Data analysis affordance theme

APPENDIX C: SUMMARY OF DIGITAL TWIN AFFORDANCES

TABLE A1 Digital twin affordances summary

Affordance	Description
Collatability	Possibility to collate and combine data from different sources (internal and external)
Monitorability	Possibility to monitor the grid network and its health status and identify bottlenecks
Operatability	Possibility to operate the grid network and support planning and maintenance on a short term
Developability	Possibility to develop the grid network and support planning and newbuilds on a long term
Simulatability	Possibility to simulate for different scenarios in the grid network
Decision supportability	Possibility to support decisions regarding the grid, suggesting solutions for handling issues in the grid
Automatability	Possibility to automate tasks, processes and decisions
Customer improvability	Possibility to improve the customer interface and approach by simplifying and automating customer interactions and inquiries