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RESEARCH ARTICLE

Solidarity as an Empirical-Ethical Framework for the Analysis of Contact Tracing Apps — a Novel Approach

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Abstract

Digital contact tracing is used in different countries to help contain the COVID-19 pandemic. It raises challenging empirical and ethical questions due to its complexity and widespread effects calling for a broader approach in ethical evaluation. However, existing approaches often fail to include all relevant value perspectives or lack reference to empirical data on the artifact in question. In this paper, we describe the development of an interdisciplinary framework to analyze digital contact tracing from an empirical and ethical perspective. Starting with an analysis of methodological tensions in the attempt to analyze digital contact tracing, we, firstly, set out three methodological premises regarding (a) a specific view of technology, (b) a fruitful normative perspective, and (c) ways to gather empirical knowledge about the object under investigation. Secondly, we inspect consequences of these premises to develop our research methodology. In doing so, we argue for a postphenomenological perspective on technology, solidarity as an important concept to guide the ethical perspective, and an empirical approach based on qualitative social science research and the concept of affordances. We illustrate these considerations by referring to our analysis of the German Corona-Warn-App as an instance of contact tracing based on the Exposure Notification Framework by Google and Apple. We then discuss the implications of using such a framework, including considerations concerning future developments of technologies similar to or inspired by the current concepts of contact tracing.

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Abbreviations

CWA Corona-Warn-App
GAENF Google-Apple Exposure Notification Framework

1 Background

Since the spread of the new coronavirus in December 2019, societies and governments all around the world have been fighting the consequences of the global pandemic. Different measures of varying intensity have been taken to prevent the spread of SARS-CoV-2 (Haug et al., 2020). In addition to traveling and movement-related measures, contact restrictions, and school and workplace closure, these included typical containment measures, such as quarantine, social distancing, self-isolation, vaccination, enhanced focus on hygiene and protection, segregating groups to contain disease spread, and contact tracing (Burns et al., 2020; Liu et al., 2021; Nussbaumer-Streit et al., 2020; Pozo-Martin et al., 2021).

Digital contact tracing apps may contribute significantly to pandemic containment during this crisis (Almagor & Picascia, 2020; Anglemyer et al., 2020). As has become apparent in the initial waves, resources of public health authorities have often been insufficient to allow for complete manual tracing of contacts of infected people. This is due to the comparatively time- and resource-intensive approach of conventional contact tracing, which is countered by the fast spreading rate of SARS-CoV-2 and other adverse factors, such as the increased incidence of asymptomatic infections and long incubation periods (Almagor & Picascia, 2020; Hellewell et al., 2020). Against this background, it is suggested that digital contact tracing may contribute to the identification of a more complete contact history and can reduce crucial delays until information of contacts is received and recorded (Anglemyer et al., 2020; Ranisch et al., 2020). Given that a sufficient rate of users can be reached, digital contact tracing may slow down the development of the pandemic significantly (Kahn, 2020).

Most European countries and several nongovernmental organizations have put respective measures into place (Blasimme et al., 2021; Mossof et al., 2020). However, many of those approaches have disappointingly fallen short of expectations. They are distrusted by the general public, fearing governmental surveillance and loss of autonomy, or there is skepticism about their potential effectiveness (Altmann et al., 2020; O'Callaghan et al., 2020; Williams et al., 2021; Zimmermann et al., 2021). This precaution and skepticism are, among other problems, an expression of a multitude of ethical problems associated with the emergence of the technology which have sparked heated debates, raising questions of ethical acceptability, limits, and boundaries.

From an ethical perspective, one of the most challenging features of the assessment of digital contact tracing is its complexity and wide range of potential effects. It impacts on individuals and on a societal (and potentially global) scale (Kahn, 2020; Ranisch et al., 2020). While positive and negative effects concern individuals as users, for example, regarding their personal autonomy, questions on a more

societal level include the benefits of digital contact tracing as a public health measure, and risks regarding surveillance and its introduction as a kind of social experiment which needs to be balanced against individual gains and losses (Lucivero et al., 2020). In addition, these questions are always related to the effects and properties of a specific technology and cannot be discussed without concrete knowledge about it.

This background calls for a methodologically sound framework for ethical analysis. The latter is especially relevant because contact tracing during the pandemic might only foreshadow developments in medicine and public health technologies in the future, combining the extensive use of health data with very large participant groups, involvement of laypeople and traits of citizen science to fight large-scale health problems (Budd et al., 2020; Wirth et al., 2020). Of course, a variety of different frameworks and tools for the ethical evaluation of technology exist. These include approaches to the evaluation of contact tracing technologies (Klenk & Duijf, 2020; Lo & Sim, 2021; Parker et al., 2020; Ranisch et al., 2020; Schaefer & Ballantyne, 2022) as well as approaches to the evaluation of technology in a more general sense (Brey, 2016; Friedman et al., 2013; Moula & Sandin, 2017; Russo, 2018). Noteworthy in the context of health are frameworks from the spectrum of democratic-deliberative approaches (Buhmann & Fieseler, 2021; Cotton, 2014), frameworks with reference to bioethical principles (Torous & Roberts, 2017), virtue ethics (Hagendorff, 2022), or checklist approaches (Heintz et al., 2015). In addition, there are approaches from the field of value-sensitive design (van Wynsberghe, 2013) and the field of health technology assessment (Bellemare et al., 2018) or concepts focusing on the emergence of new technologies (Floridi & Strait, 2020). In these debates, so-called hard impacts play a major role (Swierstra and te Molder, 2012). Hard impacts approaches can be defined as being based on technological, quantifiable concerns, often related to safety, efficiency, or risk (de Boer & Kudina, 2021; Swierstra and te Molder, 2012). Approaches that broaden their scope beyond those kinds of concerns are still rather rare. Despite the long tradition of interdisciplinary work and empirical investigation in the field of biomedical ethics, empirical research connected to specific technological artifacts (Lo & Sim, 2021) and suitable to inform ethical considerations is still in its infancies (Steerling et al., 2022). In addition, especially approaches related to theories of biomedical ethics have been criticized to follow a limited perspective. As Shaw and Donia (2021) have recently argued, these views tend to accept very narrow boundaries of the ethical discourse. They often rely on concepts of persons as single atomic entities based on the idea of a rational independent actor and health-related actions and decisions as functions of such individuals isolated from relationships with other people and social context (Lupton, 2020; MayKay & Dawson, 2022; Shaw & Donia, 2021). This invites to analyze health technologies with regard to their impact on this individual level (e.g., with regard to individual autonomy, privacy, security, or individual harm) and fits nicely with a focus on quantifiable impacts while it detaches the ethical analysis from more systemic effects that may occur as a result of their entering into specific social arrangements (Lupton, 2020). However, the pandemic itself has made it painfully clear that we may not be as independent as the rational independent actor. In addition, the far-reaching effects of digital contact tracing raise doubt as to whether ethically relevant issues of such technologies can be sufficiently described with a

view on their material effects on persons alone. Instead, these devices present a broader range of issues which is about the mutual dependencies between technologies and the context in which they are embedded and by which they shape how we live, what we experience, and what we do (Shaw & Donia, 2021; Lupton, 2020; Moerenhout et al., 2020; Hämäläinen & Hirvonen, 2020; Blixt et al., 2023; Frittgen & Haltaufderheide, 2022; more general: Verbeek, 2009).

From a perspective of biomedical ethics and health research, it is our understanding that experience and perception of health and healthcare is based in essentially relational practices. One of the cornerstones of medical ethics is to develop an in-depth understanding of such relations as well as to develop sets of claims and obligations to protect moral values or to recommend adequate conduct within these relations. From this perspective — seeing technologies increasingly enter into practices determining experiences and perceptions of health and healthcare — the aim of our work is to provide a framework for the ethical analysis of contact tracing that complements hard impact and individualist approaches with a broader relational perspective. Such an approach has to develop a contextual understanding which means to analyze technologies within but not detached from the context in which they are used. It needs to be able to include and connect ethical considerations on different levels to reach beyond an individualist perspective and, finally, must be able to develop clear-cut recommendations to inform its use and development.

In this paper, we lay out the theoretical outlines of such a framework. Its initial development was based on the German Corona-Warn-App (CWA) which we understand to be an exemplary instance regarding digital contact tracing based on the Exposure Notification Framework set up by Google and Apple (GAENF) (Google, 2021; SAP & Deutsche Telekom 2021). We will begin by considering the premises of an ethical investigation. In particular, these are (1) an adequate concept of technology, (2) the development of a contextual normative perspective, and (3) an empirically informed research methodology to ensure context sensitivity and real-world applicability. Based on our example, we will then illustrate how these premises built up into a research methodology to investigate digital contact tracing apps from an ethical perspective. We will outline three main functions of the CWA to allow for a general understanding of the tracing process. We will, then, show how the CWA can be interpreted as a technology of solidarity that materializes pathways for a coordinated response to a pandemic crisis. With a view to the normative implications, we will, then, investigate where and how the CWA departs from such ideal. Finally, we discuss the implications of such a framework, including possible future developments of digital contact tracing technologies similar to or inspired by the current use.

2 Steps Towards a Research Framework for Digital Contact Tracing

2.1 Tensions in Empirically Informed Ethical Analysis of Technology

As outlined above, this work aims at being able to derive specific recommendations as a result of an ethical analysis. We see this aim in line with the idea of ethical

reflections being applied or practical in a way that it can be said what ought to be done (Hansson, 2017). Besides the methodological tensions of this idea that have been discussed in bioethics and medical ethics for the last decades (Childress, 2009), we note that the endeavor of ethically analyzing digital contact tracing technologies creates additional tensions with this aim that need to be carefully considered (Hansson, 2017). Applied ethics implies judgments to be adequately sensitive to real-world contexts and ensure the applicability and practical relevance of moral judgments (Musschenga, 2005). Düwell calls the development of such judgments "mixed moral judgments" (Düwell, 2009). It requires prescriptive knowledge about the right course of action and descriptive statements about the actual state of the object under investigation. The aim is to conclude whether something that is perceived in a certain way ought to be as it appears. Consequently, ethical judgments have to be normatively justified by reference to some perspective based on a theory of values and have to include factual information about the real world to derive applicable and relevant conclusions.

From a methodological perspective, this means that every ethical framework to be developed has to be explicit about its ethical point of reference and way to derive factual statements about the real world, that is, how to gather and reference relevant empirical knowledge. In addition, the aim of analyzing technology raises the need for further clarification. Ethics is primarily concerned with appropriate actions of morally responsible agents. It is, hence, not obvious how normative considerations regarding the right conduct of responsible agents is linked to technology. The question here is how technology can be included in ethical deliberation given that currently available technological artifacts are not and cannot be moral agents and, hence, cannot be addressed directly.[1] Addressing this question, possible answers depend on the specific view of technology.

With this in mind, we base our framework on three premises concerned with a specific understanding of technology, a normative point of reference, and a method to gather empirical knowledge.

2.2 Adopting a Postphenomenological Perspective of Technology

A classical approach to understanding technology would be to understand digital contact tracing as defined by its intended functionality (Verbeek, 2006). According to this approach, which is still quite common in branches of computer science and engineering, technologies are understood as material objects defined by the purpose for which they are made to serve (Verbeek, 2006). Scholars of this idea define technological artifacts as closed entities with discrete functions to reach a certain end. Accordingly, ethical considerations cannot address technology itself (at least not in a

[1] With this, we are merely assuming that current technologies do not and cannot fulfill the requirements of moral agency. This is not to say that this is not possible in principle or that it cannot make sense to ascribe agency to technologies which is qualitatively different and does not establish moral responsibility. For an insightful discussion, see Nyholm (2020).

strict sense) but focus on the end for which a certain artifact is designed or its effects as a means to this end (Latour & Venn, 2002).

This has the upside of providing a simple answer to the question regarding to what extent technological artifacts can become the object of ethical investigations. However, in its simplicity, it suffers from serious shortcomings, underexposing important connections between human actions and technology. Firstly, it is rather insensitive to the fact that technological artifacts do not exist in a vacuum but are a product of and bound to a social context in which they are created and used. Secondly, it has been noted that actual use might differ drastically as a result of the surrounding context (Verbeek, 2005, 2006). Functionality as a concept, hence, is too limited to be able to represent the role of technology adequately and the relationship to human action.

Referring to this criticism, approaches from postphenomenology have developed a richer understanding of this connection, which we would like to employ here (Brey, 2010; Ihde, 1990; Verbeek, 2005). Postphenomenology stresses the contextual dependency of technology and its mediating capacity (Aydin et al., 2019). To adopt this perspective is to focus on the relationships between human actors and their lifeworld. To understand technology as mediating is to focus on the role technology plays in these relationships (Verbeek, 2006). It is, hence, understood as a contextually defined entity that mediates human experiences, interpretations of reality, and ways in which one can act. Thereby, it does not only transmit but also transform what humans can perceive and how they can present themselves to the world (Ihde, 1990; Verbeek, 2006). This transformative capacity is essential to the postphenomenological understanding of technology relations as something that unfolds between humans and artifacts. It is partly comprised of "what is built in," that is, what tasks, responsibilities, and functions to fulfill are delegated to or what implicit or explicit value assumptions are inscribed in an artifact with its design and creation (Ihde, 1990; Verbeek, 2006). On the other hand, however, this technological intentionality does not determine how an artifact changes perceptions and actions. The transformative capacity is also influenced by the way users actually relate to an artifact and "make sense of it" depending on their context of use. This means that technological artifacts do not offer one but a variety of relations — they are multistable — which each might transform experience in a different way (Verbeek, 2001).

We suggest to use this perspective as one of the many approaches in philosophy of technology which allows to broaden the scope of the discussion and to complement hard impact and individualist approaches which still dominate ethical evaluation of health-related technologies. In addition, we find the relational focus of postphenomenology especially suitable to investigate health and health-related experiences as a relational praxis. With this, we do not want to equate the concept of health as relational praxis with the concept of relations between humans and technology but acknowledge the fact that postphenomenological philosophy provides a useful framework to consider how lived experiences of and in health-related interactions change when new technological artifacts enter the scene.

2.3 Adopting a Normative Perspective

While the postphenomenological view defines how technologies are understood as objects of investigation, we further suggest to capitalize on this view by employing it in a perspective that is based on what is usually called an "ethics of disclosure." Employing this view means to use it as a "theoretical lense" that allows to focus on certain features of technologies and is, hence, instrumental to the development of ethical reflections in line with general aims and goals stated above. As Introna, for example, has argued, ethics of disclosure acknowledges the fact (as does postphenomenology[2]) that the process of creation of technology is a process of closure in which, due to its very nature, technical properties become fixed, design is implemented, and values materialize as a way of producing order (Introna, 2007, 2022). This especially applies with respect to software (algorithms) which increasingly structure the contemporary world but at the same time remain hidden (Berry, 2015; Kitchin, 2011). With regard to transformative capacity, ethics of disclosure aims at describing these effects and processes of producing technical intentionality to hold them accessible for reflection and change. With a view to the multistability of technical objects, however, the task is not to be mistaken as prescribing a preferable single and fixed transformative capacity over others but to suggest technological changes and conditions of use that systematically allow beneficial relations to unfold while decreasing the potential for harmful ones. In combining the idea of ethics of disclosure with a postphenomenological lense, we think that, with digital contact tracing, disclosing how the ability to perceive and to act changes, how this shapes the bandwidth of relations that actually occurs, and, finally, how this contributes to the quality of human relations from an ethical perspective (Verbeek, 2015a) is a worthwhile endeavor.

This requires, however, to also define an ethical perspective content-wise, that is, to find and follow reasonable arguments concerning which values should guide the view and the evaluation. According to Shaw and Donia (2021), analysis of technology from a perspective of bio and health ethics is — compared to other fields — a relatively recent phenomenon. Approaches of bio and health ethics have been dominated by principlist or quasi-principlist accounts as has been biomedical ethics in general for the last decades (Shaw & Donia, 2021). It is, therefore, not surprising that many scholars have suggested to adopt these perspectives in questions of health technologies as well (Perakslis & Stanley, 2021; Schmietow & Marckmann, 2019; Nebeker et al., 2019). We agree, however, with recent criticism regarding this perspective as noted above. The individualist perspective is too narrow and too focused on technology and persons as isolated instances. To our understanding, it is necessary to move beyond the application of commonly accepted lists of principles, rights, and duties or goods worthy of protection based on individualist accounts.

[2] Within the limits of this paper, we cannot argue for this thesis in greater detail. We assume that this overlap can be derived from the roots of Postphenomenology in Science and Technology Studies (Ihde and Malafouris 2019) and is, for example, illustrated by the responsibilities discussed for designers and creators as outlined by Verbeek (2005).

Instead, it is necessary to adopt perspectives that allow to reach beyond the material artifact and the isolated instance of the individual and, hence, allow to reorganize the ethical perspective in a way that also sheds light on the broader implications the use of a technology like digital contact tracing has. It is about to understand the ethical implications of technology in relation to the individuals, communities, and societies that interact with it.

With regard to digital contact tracing and its context, we think that 3 observations might be important to develop a suitable perspective. These observations are concerned with the state of crisis in which digital contact tracing emerges. This crisis evokes unique features of moral responsibility. First, it manifests on the individual level as a threat to values of health and well-being, and calls for their protection. Given the contagious nature of SARS-CoV-2 and its ability to spread through contact, fulfilling these moral responsibilities has, however, drastic implications for each individual and inevitably results in harsh setbacks of personal autonomy and self-determination.

Secondly, as we have painfully learned throughout this crisis, exercising one's individual moral obligations to a degree that actually affects the situation on a larger scale, for example, by reducing personal contacts to near zero, is very difficult and very costly. To take the example of reducing contacts, it would result in heavy losses for everyone regarding their psychological health and well-being. In addition, it would result in indirect negative effects concerning, for example, the economy or society as a whole. Whether this would suffice to significantly slow down the pandemic would, however, still not be certain. Responsibly exercising one's individual moral obligations may simply not be enough. More systematic, effective, and, hence, more coordinated responses are needed which raise questions about coordination and the fair distribution of burdens and benefits.

Finally, although affectedness regarding being at risk applies equally, we note that there are important differences concerning the affectedness of the actual outcome or severity of this risk. Depending on a multitude of factors, such as economic and social status or personal health, no one is actually able to predict to what extent an infection will result in which adverse outcomes. These outcomes may range from asymptomatic courses of the disease over mild symptoms to fatal long-term consequences or death.

Against this background of the values at stake, suboptimal opportunities to exercise individual moral responsibilities, equal affectedness in terms of the scale of the crisis, and unequal distribution in terms of outcomes, the situation has many features that, from an ethical perspective, suggest that acting in solidarity is an imperative and may provide a starting point for the ethical analysis. For the purpose of this paper, we will not elaborate on all of the different meanings of solidarity but will clarify our use regarding two dimensions of the term to set it apart from different notions with which we will not be concerned. Solidarity, according to Prainsack and Buyx (2012), can be understood in a descriptive and a prescriptive meaning. At its core, the descriptive meaning denotes a specific form of action based on the mutual bonds and obligations within a group, directed towards the realization of shared goals (Bayertz, 1998). Solidarity in this understanding is based on the perception of similarity between members of a group, definition of a common goal, subordination

of individual, and particular interest under this goal and contribution to it. It is, hence, a form of two-sided cooperative behavior in which actors tend to carry individual costs and thereby contribute to the realization of a common good, which is then distributed among the members of this group allowing them to participate in its benefits (Prainsack & Buyx, 2012).

In its prescriptive meaning, the term prescribes this way of acting as a moral requirement under certain conditions. In this understanding, similarity among group members refers to morally relevant properties, and proportional distribution of the common good is typically based on further moral considerations, for example, assisting the most vulnerable members of a group, as a way to exercise justice (Dawson & Verweij, 2012).

We admit that there is considerable debate whether and how such prescriptions can be based on reason and rational argument. The empirical fact that one is often bound inevitably and feels obligated to other members of a group does not justify for itself that we should act accordingly (Bobbert, 2007). Some have argued that acting in solidarity is a mere form of prudence based on well informed and well considered self-interest. Solidarity implies individually carrying costs in the short-term which can be outweighed by long-term participation in a realized common good and its benefits (Steinvorth, 1998). However, others have noted that a more substantial concept of justification may apply. In this understanding, solidarity is a coordinated response. It is of instrumental value to satisfy moral requirements in situations where uncoordinated action might not yield respective results (Scholz, 2015). Accordingly, it is often prescribed as a way to exercise obligations to make a just and fair treatment of others. In a third and even stronger way, solidarity is prescribed as a strong moral duty that is based on neither self-interest nor its instrumental value but in being a basic value in itself referring to the interrelatedness of human existence with others (Bobbert, 2007). However, even if one might agree that prescribing solidarity under normal circumstances in one of those ways might be an intellectual challenge, it is, nevertheless, very plausible to assume at least some obligation to act in this way under certain conditions. This applies especially to crises. Given the unique features of the current situation, that is, being equally affected by risk of infection, obliged to protect others, and unable to exercise these responsibilities to a necessary extent, all considerations outlined above seem to be applicable, making it plausible to argue for such an obligation.

Consequently, we determine the normative perspective of a framework for the analysis of digital contact tracing based on the basic values at stake, the context of crisis, and a plausible normative requirement to exercise solidarity towards others.

2.4 Adopting an Empirical Perspective

A third and final presupposition for this framework is to gather empirical knowledge on the artifact under investigation, as one has to derive judgments not only from knowledge on what is actually morally right or wrong but also what pathways for action a technology actually offers, which one user takes, what hurdles and

barriers can be identified, and what risks and benefits may come with the relationship between user and technology.

It is obvious to us that this empirical knowledge cannot be drawn from anecdotal evidence or observations or mere theoretical assumptions alone. Biomedical ethics has a long tradition of combining ethical evaluation and empirical research in which it has been repeatedly argued that empirical evidence of low quality or methodological deficiencies in gathering and analyzing empirical knowledge about a phenomenon under investigation does not only pose problems with regard to scientific quality (Mertz et al., 2014; Singh, 2017). Especially, when such knowledge is used to derive normative recommendations or evaluations, it needs to be gathered and analyzed methodically to ensure validity and reliability (Mertz et al., 2014; Singh, 2017; Holm, 2004; Carminati, 2018). In addition, it needs to be generalizable, that is, it must be possible to explain why respective knowledge derived from the observation of specific instances is suitable to be transferred to instances beyond the research (Carminati, 2018; Williams, 2002). Otherwise any recommendation would only be applicable to the researched instance itself.

In the context of analyzing digital contact tracing applications within our framework, this raises three specific challenges from a methodological perspective. First, the knowledge we seek is based in subjective perception and experience of users within their social context, requiring methods to be able to gather such knowledge. Secondly, the specific relational perspective requires to broaden not only the scope including to be able to address user experiences but also the technological artifact itself as part of the human-technology relation. Finally, the gathered knowledge should be generalizable in the sense outlined above to justify the use in mixed moral judgments beyond those instances that have actually been observed.

Against this background, we deem it necessary to use methods from the spectrum of interpretivist qualitative approaches of social sciences. The strength of qualitative inquiries defined by the interpretivist tradition, as Laura Carminati has argued, is their.

> understanding of how individuals, through their narratives, perceive and experience their lives, constructing meaning within their social and cultural context. […] In this sense, interpretivist research emphasizes the hermeneutics and perception of the social world, and the interactions between individuals and the surrounding context. (Carminati, 2018, p. 2096)

In this regard, researchers act as agentic instruments to collect and analyze data based on the subjective frame of reference of the observed (Carminati, 2018). Generalizability can be ensured by closely observing data and emerging theory about the phenomenon with regard to its saturation. This means that new information is gathered and analyzed until all aspects of the phenomenon have emerged in the reconstruction and it is, hence, deemed unlikely that any new observation will significantly alter existing or add new themes or concepts.

In our case, these considerations lead us to propose a double-sided empirical approach based on qualitative methods to analyze (a) the technological artifact and (b) perceptions of users in a specific context and to synthesize both to reconstruct

what pathways of actions are presented to users, how are they perceived, and which actions can be exercised.

To guide this analysis, we used the concept of affordances (de Boer, 2021; Gibson, 2014). In research of technological artifacts and especially information systems, the idea of affordances has gained increasing attention (Fromm et al., 2020; Klenk, 2020; Tollon, 2022). It is understood to constitute a promising approach to research the materiality of IT structures and their human interpretation while defending a middle ground between technological determinism and social constructivism (Fromm et al., 2020). The term was originally coined in behavioral psychology by Gibson to describe the possibilities for action an environment or object offers a living being (what it affords) (Gibson, 2014). It builds upon the premise that perceiving an object actually precedes interacting with it and, thus, structures the cognitive assessment of what could be done with it. Affordances are, therefore, based on the properties of an object which presents itself to its users, making certain actions more likely by way of its being. Affordances in technology can be based on logical or functional properties of an artifact. However, affordances are more than just the properties on which they are based. They come into existence in relation to interacting agents perceiving these properties as something with which something can be done (Cirucci, 2017). In contrast to other concepts, for example, the scripting approach, which are closely related, affordances do not presuppose technology to have a specified set of actions built in but focus primarily on what is possible from the perspective of the interacting agent. Affordances are, thus, relational properties, defined by the artifact and the context in which a user perceives these properties. Accordingly, affordances of a technology are part of the social and contextual practices which can become the object of empirical and especially qualitative social science research. We, therefore, propose to gather empirical knowledge with a focus on the interplay between users and artifact to develop an instance-specific understanding how relationships to this artifact shapes pathways of perceiving and acting.

Regarding the CWA, we conducted the first step of empirical analysis by way of a qualitatively oriented analysis of the source code, the technical documentation, and the design elements and specifications of the graphical user interface. Starting with the program code, we developed a model of discrete functions accessible for the user and distinguished those from other functions, such as background operations or server tasks. Building upon these functions, we analyzed the existing technical documents, paying special attention to explanations of these functions and their intended use to develop a description of their operation. In a final step, we reviewed the graphical user interface based on our interpretations to understand how these were presented to the users. In our own analysis, this approach highlighted how specific functionalities of regulating one's own behavior and contributing to a common good are presented to users as something that can be done with the CWA.

Following the idea of affordances as relational properties defined by technical materiality and user perception in context, it is, however, necessary to also include user perspective as a counterpart of the relationship. Including this perspective serves three distinctive purposes within this methodology. Firstly, it can be used to

learn more about the actual context of the use of digital contact tracing technologies. Secondly, it yields important insights into actual perceptions of the technological artifact under investigation. Thirdly, it can be used to broaden the normative perspective including those dimensions of which researchers are not necessarily aware.

In our case with the German CWA, we used expert interviews to inform our approach. Nineteen interviews were conducted in total to explore the topic of digital contact tracing with the CWA. Sixteen interviews were conducted in German and three in English. Due to the restrictions during the pandemic, all interviews were conducted remotely via "Zoom." The length of the interviews ranged from 21 to 81 min. The data was analyzed using the principles of grounded theory methodology (Corbin & Strauss, 2015). The sample included medical doctors, ethicists, lawyers, computer scientists, sociologists, and an internet journalist. We understand these experts not only to be equipped with certain knowledge and skills but also as representatives of different societal discourses on digital contact tracing. A discourse is understood as set of meanings and representations that exists besides other particular sets of meanings and representations to "produce" a specific way to talk and think about a phenomenon (Burr, 1995; Clarke, 2005). In this view, language and its use in discourse formations is seen as constructive for social contexts. We hypothesized that by interviewing experts from different fields — each familiar with specific discourses — we would be able to learn more about the different particular sets of meaning and representation with which the individual experience of contact tracing can be constructed as part of a social reality. Discourses are, hence, understood as repertoires individuals can draw on to make sense of something and expert interviewees as potential informants which are familiar with these repertoires as well as with structuring their thinking very explicit within such formations. Our semi-structured questionnaire comprised four main topics. The first included questions regarding the perception of information giving and information transparency. We were interested in the experts' opinion as to what information is processed in their understanding, what information is accessible to the user, and what informational imbalances between different parties involved may exist. In the second part, we focused on questions concerning the privacy of users. These questions were mainly designed to steer reflections towards issues of the use of data and data protection and towards different technical architectures. The third topic included questions to broaden the interview perspective regarding societal issues, such as perceptions of participation and barriers and hurdles to it. Questions in the fourth topic were concerned with perceptions of the epidemiological goal of a reduction of infections and the participants' perception and evaluation of it. In addition to asking interviewees to reflect on factual issues, the participants were also asked to include their normative perspective in each field and give an impression of their understanding of potential ethical issues connected to the respective fields.

As a result of these methodological considerations, we propose an approach to the analysis of digital contact tracing apps that is guided by a postphenomenological perspective of technology and an interdisciplinary framework of normative and empirical analysis, as indicated in Fig. 1.

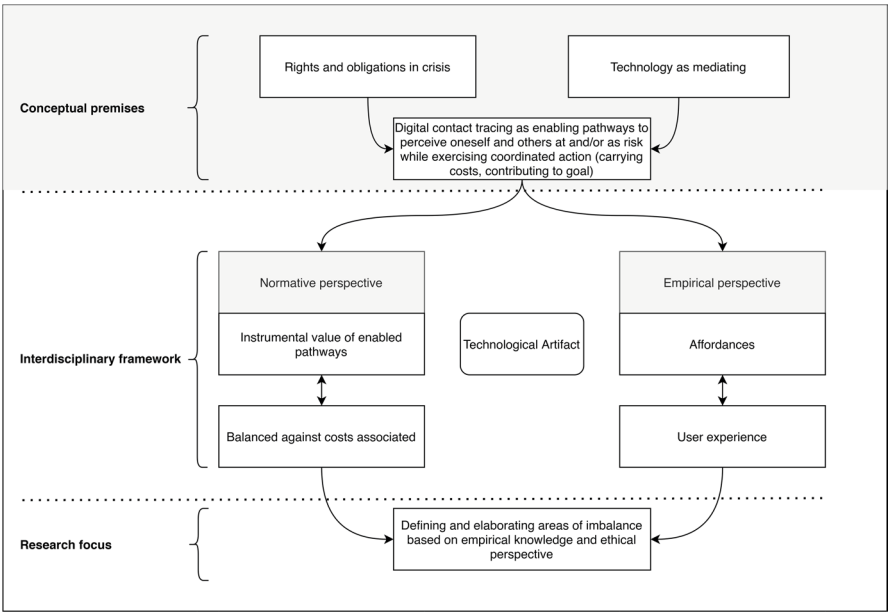

Fig. 1 Graphical representation of the feedback loop

3 Proof of Concept

3.1 The GAENF and CWA as Exemplary Points of Departure

The CWA is the German version of a digital contact tracing app based on the GAEFN. It was published by the German federal government and has been available since June 2020. The GAENF provides three basic functions which are used by the respective systems to instantiate digital contact tracing. Firstly, it allows Smartphone Apps for Apple and Android devices access to data on timing, duration, and Bluetooth signal attenuation in case intersecting signal cones with other users of the system are detected. This enables apps to store these data in addition to a temporary identifier transmitted by the counterpart. The device then regularly checks on information regarding these identifiers in a database on a server. Secondly, the GAENF provides functions to share and upload information on the user's status. This includes positive testing results (of different kinds) and additional information that can be used to estimate the infectivity or risk of transmission of an infected person. This, finally, allows the app to match identifiers with information on their infection status and enables the calculation of different scores regarding the risk of a single encounter and a summary score covering the estimated risk over a longer period of time. In the case of the CWA, Bluetooth signal attenuation is used to define a radius of 8 m and a contact duration period of 15 min in which every contact is recorded and stored. Information from testing laboratories can be uploaded to a server system to inform users about their results and enable them to decide on sharing. After

consent has been given, the result is uploaded and a numerical value is assigned to each of the last 14 days to allow for an estimation of the transmission risk to be made. These data combined with information on the distance, duration, and time since exposure are used to generate a score for each encounter and an overall risk for the period of time in which infections might be possible (e.g., 14 days).[3] Users can then be notified about changes in their risk status which is visualized in reference to certain thresholds (unclear, low, high) indicating the severity of the exposures, the number of risky contacts, and further recommendations for action. These include guidance regarding general rules of hygiene, recommendations for preventive self-isolation, and recommendations to seek testing or medical attention if deemed necessary.

Starting from our premises, we think it is fruitful to define technologies of digital contact tracing not only as a mere technical arrangement consisting of a back-end (e.g., the server-system) and a frontend (e.g., the app on the smartphone) but also as a complex social environmental phenomenon based on digital data. With this term, we draw on the works of Verbeek (2015b) and Aydin et al. (2019) to describe recent changes in the texture of digital technologies that can be applied to understand how the CWA works (Aydin et al., 2019; Verbeek, 2015b). Both works — using slightly different vocabulary — note an increasing intelligification of the material world achieved through the embedding of information technology in all kinds of material objects in our surroundings and pockets. This gives rise to smart environments, that is, technology is becoming part of the environment but at the same time does not constitute a mute and stable background but has an active capacity and directedness at humans. As Verbeek has argued, such technologies allow for complex immersive relations consisting in two parallel circuits. They do not only add an extra layer to our perception but also offer a new representation of the world (Verbeek, 2015b). In this understanding and based on our analysis of the coding of the German CWA, we understand digital contact tracing to create a joint social sphere of information exchange within the context of an immediate health threat. Access to this sphere is not determined by factors such as the physical proximity or familiarity with other members but by the ability to make sense of the binary code used to process the information. Within this sphere, a representation of each user and a constant retrospective feedback loop is created. This loop is fed by information on the users' encounters with other members of the sphere in the past and users' decisions to inform others about positive testing results. These are calculated as a "risk score" that can be interpreted as information about recent health risk impositions that may call for a further intervention (e.g., change of behavior, quarantine, and testing) or an adaption of recent behavior. The CWA, hence, adds an extra layer of information by allowing to perceive oneself based on ones' relation to others within the feedback loop, that is as an individual being at risk and being a risk to others. This mechanics creates an

[3] We want to be clear that all exact numerical given here can (and have been) subject to revision and, hence, can change with every update that is rolled out. These values are taken from version 2.6.1 of the CWA and only serve to illustrate the mechanics of the CWA.

extension of our ability to perceive risks and offers a representation of the life-world in terms of health risk impositions.

The risk score is central to the creation of the feedback loop. This became especially apparent in our analysis of the more visible layers of the CWA. On the one hand, the system invites users to check their risk status regularly. As this risk status is framed as being a measure of the user's behavior in the past, certain risks are connected with recommendations for further action. These include remembering and being aware of basic rules of hygiene, recommendations regarding preventive self-isolation, and the seeking of medical attention. By the connection of risk status and behavior, the user is invited to adapt their behavior according to the parameters of the risk score as outlined above. In this regard, specific design elements, such as system-wide notifications, color, and graphical elements, can be shown to highlight this functionality. On the other hand, the system presents functions that visualize and contextualize the information currently available in the system. These include, for example, an overview of epidemiological measures over time, current developments, or how many positive and negative results have been processed by the system. As these functions mostly reference information that is not directly connected to the user, they allow them to develop an understanding of the overall mechanics of the system and the dynamic of the pandemic. In principle, this allows the user to connect their contribution to the production of a common good that is created by all users, that is, contributing to the lowering of infection rates, preventing fatalities, and — in the end — lowering one's own personal risk. Online Resource 1 gives an exemplary overview of the analysis of the "risk calculation" function.

In result, the feedback loop allows users to share information about infections publicly but, nevertheless, anonymously within the sphere and to warn others, thereby contributing to a common good (e.g., the decrease of risk of infection) created by all members. At the same time, it allows the regulation of one's own behavior according to the information received by perceiving social contacts as possible risk impositions. Figure 2 includes a graphical representation of this approach.

Viewed from a normative angle and adding to the postphenomenological premise of technology as transforming relationships to the world, the CWA's feedback loop can be understood as a technologically materialized way that — in principle — provides all means to afford pathways for exercising solidarity by coordinating and connecting members of a group. It allows one to perceive necessary information (to view others and oneself as and at risk) and to exercise the two-sided set of actions by carrying individual costs (regulating one's own behavior) and contributing to a shared goal (reducing infections and protecting health and well-being). It can, therefore, be evaluated from an ethical perspective by assessing whether and to what extent a certain instance of such a technology is suitable to fulfill this purpose, and it can be assessed whether and to what extent the actual pathways to action, perceptions that are created, and costs associated align with the promotion of solidary acting or fall short of this ideal by materializing and affording different, less favorable pathways.

In this regard, our analysis of the German CWA revealed at least three important dimensions for ethical consideration which became apparent during our expert interviews in which stakeholder representatives were asked about their

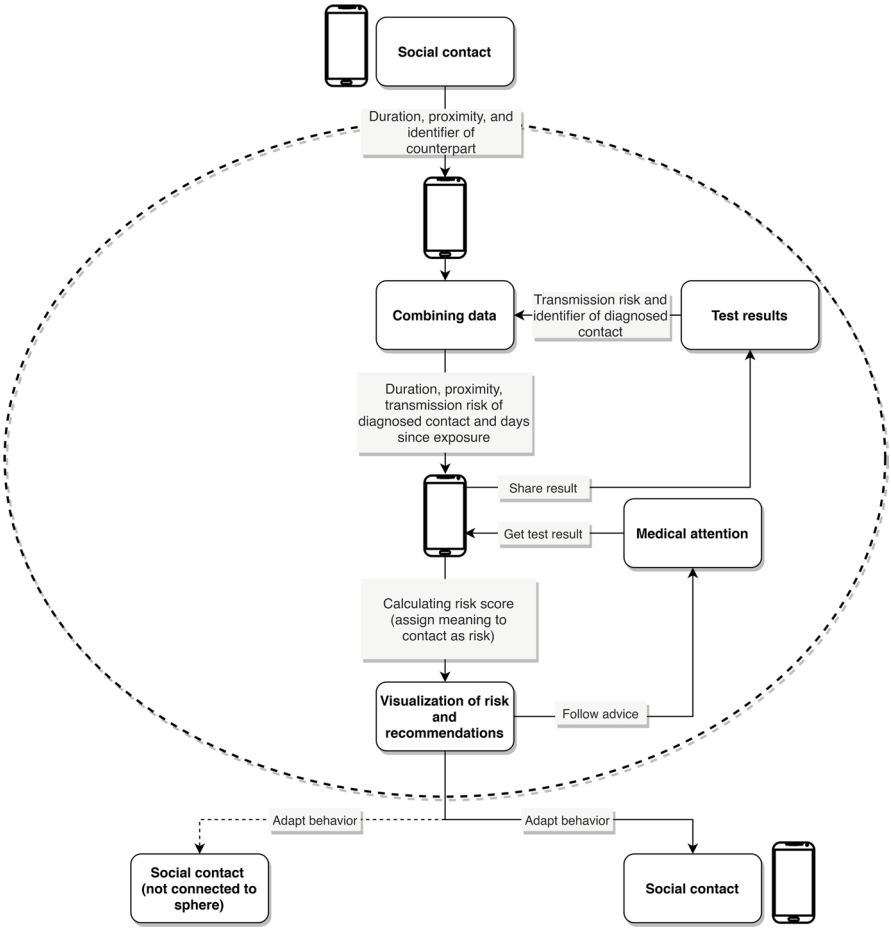

Fig. 2 Framework for the analysis of digital contact tracing

impression of the CWA. The first dimension of concern is regarding a user's ability to participate in digital contact tracing, that is, to relate to the feedback loop at all. Accessibility to the sphere requires respective devices, technical skills, and an understanding of information. With these factors, access is, however, bound to socioeconomic factors of resources and knowledge. It seems to be of special importance as the occurrence of barriers to access typically coincides with factors for higher risks of severe outcomes of infections and, thus, might lead to an exclusion of the most vulnerable.

The second dimension refers to ethical questions concerning the transformation of information, perception, and action through the CWA. As outlined above, solidarity requires a two-sided form of acting to be performed. However, we noted a worrying imbalance in the amplification of information affording self-regulation, while information concerning benefits and contribution to a shared goal are

underrepresented. In addition, the transformation of social contacts to risks might be a further issue to consider. Although it might be necessary to create this common metric to coordinate users, it, nevertheless, has to be noted that it comes with a specific structure of amplification and reduction. While it amplifies the perception of social contacts in terms of the consequences for health, it reduces and does not represent other perceptions of a social contact. Finally, we found evidence that using this technical arrangement requires a user to process very complex information to be able to make self-determined and informed choices with it. Given that this includes permeating the complex mechanics of digital contact tracing, it seems to be questionable that the processes of information giving and consent used suffice to satisfy this requirement.

In result, the CWA does offer the ability to perceive social contacts as well as oneself as a health risk, hence allowing to coordinate with others in the way described above. However, the analysis also reveals it might be selective with regard to the question who is able to participate in these relations and might run the risk of reproducing socioeconomic injustices of its context running counter to the concept of solidarity. This raises further questions concerning who should bear the costs for getting access and whether an unequal distribution of access actually leads to an unequal distribution of benefits. Secondly, its current use seems to run the risk of favoring self-regulation over a balanced distribution of benefits and burdens and a perception of sociality as (potentially harmful) health risk imposition. The latter stands in sharp contrast to, for example, social contacts as a necessary prerequisite of democratic and pluralistic societies. To our understanding, this shift has to be considered very carefully and only seems to be acceptable under the constraint of being a way to prevent greater harm. Finally, while these concerns are directed at the way how persons can relate to their environment *through* the feedback loop, we note that its current configuration may not provide a sufficient way to relate *to* it, that is, to relate to the artifact as an object of inquiry that makes itself comprehensible and understandable to allow for informed decision-making. Entering free-willingly into the solidary calculus and not being persuaded — maybe without understanding and noticing — is, however, a prerequisite of every concept of solidarity.

4 Discussion

While these areas of concern warrant further research and in-depth inspection, they mainly serve to illustrate the fruitfulness of our approach. Firstly, it shows how ethical analysis of digital contact tracing may arrive at a broader and contextually informed normative perspective which can be grounded in our methodological premises. In this context, the normative perspective of solidarity proves to be particularly helpful. On the one hand, it is able to take up plausible intuitions about the conflict of health, well-being, and autonomy which are connected to digital contact tracing as possible areas of concern. On the other hand, it contextualizes the normative requirements in the horizon of crisis, as outlined above. The idea of solidarity as a coordinated response connects individual levels of ethical considerations with more societal ones, allowing for a structured investigation of the trade-offs between

those two. It allows, for example, issues to be raised regarding the fairness of distribution of individual losses and common benefits. Connecting this framework to actual empirical knowledge on a specific artifact, as outlined above, finally proves to be particularly helpful to the specific shape of user relationships emerging as a result of interacting with a certain artifact. The approach can, therefore, be used to "locate" ethical areas of concern within a specific design and from a relational perspective as well as to develop recommendations for adaption.

In addition, the interpretation of digital contact tracing as a technology of solidarity offers another starting point for a better understanding of similar technologies in general. Creating a joint information sphere against the background of a jointly experienced problem to allow for coordination exemplifies a mechanism based on digital data which is highly scalable and adaptable. In the future, technologies that develop approaches for treating major health problems based on individual user data will play an increasing role. These apps may not only aim to monitor specific infectious diseases but also target various widespread health problems, such as heart diseases, diabetes, dementia-related changes, or other forms of health problems. It is expected that these technologies will employ similar mechanisms, although they might use different data. This could include the monitoring of body data of a specific group of patients affected by a certain disease or the monitoring of parameters to develop a new understanding of risk factors. In all of these cases, similar ethical questions would arise in which an individual contribution (e.g., via the donation of body or movement data) may be connected to certain individual costs regarding privacy or autonomy, or a user's perception of themselves and others, but, at the same time, could lead to additional benefits for all individuals who participate and which may not be realizable in other ways. Here, too, the task of ethical analysis is to place the proportionality of individual risks and restrictions when using of such technologies in relation to a jointly generated benefit and examine this in terms of a morally acceptable balance. Accordingly, our framework might provide a starting point to be adapted for further analysis.

We have to admit, however, that at this point, our approach comes with several caveats and limitations that need to be addressed and indicate the need for further development. With regard to the exemplary results presented here, we want to be clear that these results mainly serve to illustrate the fruitfulness of our approach. A detailed ethical evaluation surely would have to include a consideration in greater depth which is beyond the scope of this paper. With regard to our methodology, it is important to understand the interdisciplinary challenge that comes with this framework. As it includes both normative and empirical perspectives, it requires a suitable account of connecting these perspectives. For the sake of clarity, our presentation might give the impression of a linear research process. We want to be clear, however, that this work requires iterative work resulting in a dialog of perspectives to inform each other. The advantage is a fruitful methodology; possible risks regarding blurring the lines between different perspectives have to be carefully accounted for. Concerning our normative perspective, it has to be noted that solidarity is a very complex normative concept. Within the limits of this paper, we are not able to address all issues arising from this term. As has been noted more than once, defining

an adequate concept of solidarity beyond the basic sketch we have delivered here is a challenge in which more research is needed.

A third limitation applies to our approach of contextualization. We used the CWA to illustrate our considerations. As most of its technical functions are derived from the GAENF, our approach might be suitable to similar products. However, adopting a perspective including a social context always comes at the cost of limits regarding the generalizability of the approach. Application to other contexts (e.g., other cultural environments or other technical architectures) may not be possible without careful adaption. Finally, it has to be noted that our empirical methodology comes with certain limitations. Combining knowledge on technological artifacts with knowledge about the user perspectives and analyzing it from a normative perspective is a complex endeavor that needs a careful inspection of methodological implications. It is important to understand that our empirical approach is exploratory in nature and, therefore, does not allow one to infer representative statements on the use of digital contact tracing technologies in general but is designed to give an account of the underlying mechanisms and connect these to the specific occurrence of an artifact.

5 Conclusion

A consideration of these limitations indicates the need for further research regarding this approach. However, to the best of our knowledge, our framework provides a first and comprehensive, empirically informed framework to an ethical analysis of contact tracing apps that bridges theoretical tensions in analyzing digital contact tracing technology and proposes a respective framework. We have argued that current perspectives of biomedical ethics usually follow a narrow perspective that relies on an instrumental understanding of technology and an individualist value approach that favors analysis of hard impacts. Against the background of the limitations that come with this approach, we have suggested a broader framework that focuses on technologies as complex social phenomena within a certain social context. To our understanding, postphenomenological philosophy can provide a richer understanding and allows to view digital contact tracing technologies with regard to their mediating capacities. We suggested to put this view to use within an ethics of disclosure. Putting to use in this respect means to employ postphenomenology as a theoretical lense and aiming to reveal how the technological directedness and intentionality is created and to suggest conditions of use and technological refinement that enables beneficial relations with technology. Given the unique features of the pandemic crisis, we have furthermore argued that an important hallmark of such beneficial relations could be derived from the concept of solidarity as a favorable course of action. The ethical analysis can, hence, be guided by the questions how digital contact tracing changes ways of perceiving and acting and to what extent these changes create technologically mediated pathways to act in solidarity. We have suggested to supplement these theoretical premises with a proposal as to how specific technological artifacts could be researched. Our approach is based on the interpretive spectrum of

qualitative social science research that allows to include the artifact as well as narratives and perceptions of use to develop in in-depth understanding of how specific instances of digital contact tracing work. In conclusion, our proof of concept with the German CWA highlights how this framework can be put to use and provides a foundation for further investigation and refinement.

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Data Availability The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request. Restrictions apply to protect anonymity of participants.

Declarations

Ethics Approval and Consent to Participate The empirical part of this study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Ruhr-University Bochum, Germany (14.10.2020/20–7061-BR). Informed consent was obtained from all individual participants included in the study.

Consent for Publication This manuscript does not contain any individual persons' data. All participants consented to the use of anonymized quotations from their interviews.

Competing Interests The authors declare no competing interests.

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