



What are socially disruptive technologies?

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ABSTRACT

Scholarly discourse on “disruptive technologies” has been strongly influenced by disruptive innovation theory. This theory is tailored for analyzing disruptions in markets and business. It is of limited use, however, in analyzing the broader social, moral and existential dynamics of technosocial disruption. Yet these broader dynamics should be of great scholarly concern, both in coming to terms with technological disruptions of the past and those of our current age. Technologies can disrupt social relations, institutions, epistemic paradigms, foundational concepts, values, and even the nature of human cognition and experience – domains of disruption that are largely neglected in existing discourse on disruptive technologies. Accordingly, this paper seeks to reorient scholarly discussion around a broader notion of technosocial disruption. This broader notion raises three foundational questions. First, how can technosocial disruption be conceptualized in a way that clearly sets it apart from the disruptive innovation framework? Secondly, how does the notion of technosocial disruption relate to the concordant notions of “disruptor” and “disruptiveness”? Thirdly, can we advance criteria to assess the “degree of social disruptiveness” of different technologies? The paper clarifies these questions and proposes an answer to each of them. In doing so, it advances “technosocial disruption” as a key *analysandum* for future scholarship on the interactions between technology and society.

1. Introduction

Clayton Christensen's [1,2] disruptive innovation theory has had a strong influence on the way that “disruptive technologies” are conceptualized, both in colloquial and scholarly discourse. On Christensen's account, novel technologies can prompt the destruction of existing supply chains and business models, thereby disrupting markets and industries. While Christensen's theoretical framework is still prevalent in economics and business studies, recent scholars have voiced calls for a more encompassing understanding of disruptive technologies [3–7]. With its focus on processes of market disruption, disruptive innovation theory does little to illuminate the broader dynamics of social transformation engendered by new technologies. Yet understanding these broader dynamics is of substantial scholarly importance, as is apparent from the societal promises and anxieties surrounding emerging technologies that are often characterized as “disruptive”, such as AI, genome editing, synthetic biology, robotics, smart sensors, 3D-printing, big data analytics, virtual reality, and many more (e.g. [8–10]).

Going beyond disruptive innovation theory, an understanding of technological disruption is needed that is not limited to markets and business, but that also serves to illuminate how technologies can disrupt social relations, institutions, epistemic paradigms, foundational concepts, values, and the very nature of human cognition and experience.¹ In order to clearly disentangle this broader understanding from Christensen's account, in this article I refer to technological disruption in this broad sense as “technosocial disruption”, and to technologies that play a major role in the dynamics of technosocial disruption as “socially disruptive technologies” (SDTs). The aim of the paper is to clarify these notions and to develop the conceptual framework associated with them, to arrive at a better understanding of the interactions between technology and society.

Prior to doing so, let me highlight a few more considerations to strengthen the case for reorienting discourse on disruption along said lines. I discern five interlocking reasons for why doing so is an important undertaking. First, “disruption” and its cognates “disruptor”, “disruptee” and “disruptiveness” have proven to be a helpful vocabulary to describe

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¹ In using the concept of “Socially Disruptive Technologies” (SDTs) as a catch-all label for technologies that are disruptive in a broadly social sense, I follow the research programme outlined by Brey et al. [27]. Note that in this paper the qualifier “Social” should be understood generically: “SDTs” are meant to be domain-general, rather than being tied to the social sphere in a strict sense. That is, in the context of this paper technosocial disruption need not necessarily pertain to distinctly social practices and relations; it may also pertain, for instance, to the cognition or sensory experience of individuals.

and analyze the interactions between technology and society. This has been recognized by previous scholars [5,11] and is evidenced by the fact that colloquial discourse on technosocial disruption is becoming increasingly prevalent, suggesting a natural affinity between the language of disruption and attempts to conceptualize the interactions between technology and society. Secondly, these processes are high on the radar of ethicists as well as those of policymakers (e.g. [12], who often grapple with effective means of governance in the face of technosocial disruption. The societal relevance of the topic warrants scholarly engagement. Thirdly, extant discourse has clear limitations: Christensen's operationalization of disruptive technologies has several peculiarities, which do not easily mash with a more encompassing notion of SDTs (see section 2). Fourthly, as of yet this broader notion has not been singled out as a self-standing topic of scholarly analysis (see section 3). Plausibly, scholarly work on the topic has been inhibited by the omnipresence of disruptive innovation theory, which may have served as a limiting example and hampered efforts to theorize about technological disruption beyond the spheres of market and business. Fifthly, to the extent that scholars *have* engaged with the topic of technosocial disruption, they have not supplied it with clear conceptual foundations. The authors of a recent typology of disruption in the legal sphere even contend that what makes something disruptive "is never going to be precisely definable" [7].

I argue to the contrary. Technosocial disruption may be a complex notion, but its multidimensionality and cross-disciplinary application should not discourage attempts to define it. Not only is it *possible* to come up with an integrative definition, but there is much to gain from doing so. An overarching notion of technosocial disruption can serve to unify scholarly understanding, bridging the dispersed analyses of technological disruption that have emerged in the wake of Christensen's theory (e.g. [3,6,7]). Furthermore, it can stimulate theoretical and conceptual progress, by generating an appropriate conceptual toolkit to analyze salient dynamics of technosocial change.

One might object that a conceptual focus on *disruption* is not strictly required to analyze these dynamics. They can also be analyzed in terms of the related notion of *transformation* [13,14], or perhaps by adopting a different vocabulary altogether. Be that as it may, I maintain that the defensive move of conceding all the "disruptive technology" terminology to disruptive innovation theory, while adopting an altogether different conceptual framework for disruptions beyond the domains of markets and business, is inadequate. As noted above, this concessive move is being put under pressure by colloquial discourse, in which disruptive technologies are commonly associated with exactly the kind of "technosocial disruptions" that this paper addresses, but that are peripheral to disruptive innovation theory. Therefore, the concession is likely to lead to confusion, as it results in the failure to articulate a conceptual framework that can vindicate colloquial appeals to technological disruption. Furthermore, it leaves us intellectually impoverished, as it results in a failure to develop and integrate existing discourses. For instance, it blocks the prospect of differentiating between the nuances of "technosocial transformation" on the one hand and "technosocial disruption" on the other (see section 4). Therefore, even if the conceptual toolkit of "disruption" is not the *only* means to conceptualize the dynamics of technosocial change, there is good reason to develop this toolkit nonetheless.

In terms of conceptual approach, two general pressures will affect the course of the ensuing analysis. On the one hand, I take it that a fruitful account of technosocial disruption should align fairly closely with colloquial discourse: the technical term should not stray too far from ordinary connotations of "technology" and "disruption". Capturing shared public opinion may not be the only *desideratum* when engineering scholarly concepts, but *if* a technical term can be brought in line with ordinary language and colloquial intuitions, then all the better for it. Arguably, this is precisely what Christensen has failed to do, thereby inhibiting the promise of his theory in coming to terms with processes of disruption in general [15]. On the other hand, a fruitful

conceptualization of SDTs should be conducive to further theorizing, for instance by weeding out inconsistencies that may be present in colloquial accounts, and by explicitly positioning itself in relation to existing theoretical frameworks.

I proceed as follows. Section 2 provides an overview of how disruptive technologies are commonly understood, and how the concept has been developed in the context of disruptive innovation theory. Section 3 points to shortcomings of this framework and its successors, highlighting important dimensions of technosocial disruption that are not captured by existing theories. Section 4 prepares the conceptual groundwork for a broader notion of "technosocial disruption", thereby clarifying the relation between "disruption", "transformation" and "change". Section 5 outlines seven key criteria for assessing the degree of a technology's "social disruptiveness". Section 6 concludes by stressing the promise of further research on SDTs.

2. Etymological and theoretical roots: disruptive technologies and disruptive innovation theory

The term "disruption" has its roots in the Latin verb *disrumpere*, which was originally used as a medical term, referring to the process of breaking (*rumpere*) apart (*dis*). In classifying wounds of different kinds, the 16th century surgeon Thomas Gale, who authored the first book on surgery in English, made mention of "a wounde disrupted or broken", as distinct from a mere cut [16]; p. 100). The semantic field widened in the centuries thereafter, taking on ecclesiastical connotations among others: "The Great Disruption" of 1843 was a landmark event in Scottish church history. It was not until halfway the 20th century, however, that "disrupt" and "disruption" became part of the daily lexicon. Google Ngram reveals that mention of disruption and its cognates became common in written works during the postwar decades. The concept of "disruptive technology" was very rarely used up until the 1990s, when Christensen popularized the term.

In the wake of Christensen's influential theorizing, definitions of disruption have bifurcated into a colloquial and a technical counterpart. On dictionary definitions, the meaning of the verb "to disrupt" can be spelled out as follows:

- *To prevent something, especially a system, process, or event, from continuing as usual or as expected* (Cambridge dictionary);
- *To break apart; to throw into disorder; to interrupt the normal course or unity of; to cause upheaval in* (Merriam-Webster dictionary).

Hence, in common parlance disruption is strongly associated with disturbance, disorder, turmoil and destruction. As such, disruptive processes are often negatively evaluated. A further feature that has been pointed out is that disruptions are typically prompted by external stimuli [12]. Disruptive change does not come from within the system but is forced upon it.

The technical notion of disruption, as advanced by Christensen, diverges from this colloquial concept in several respects. First, it does so by being theory-laden: disruption, on a technical understanding, is strongly associated with disruptive innovation theory. Secondly, its application is restricted to the domains of market and business. Thirdly, disruption *sensu* Christensen has developed a decidedly positive connotation [4]. In contemporary business circles – and especially among Big Tech companies – disruptive technologies, and the associated notion of "creative destruction" [17], are hailed as aspirations. For instance, up until 2014 "move fast and break things" was the internal motto used by Facebook, reflected in its drive to overturn antiquated business models, as well as social and legal norms [12].

The roots of Christensen's use of the term disruption go back to his PhD-thesis (1992) [45], but in his writings over the subsequent two decades he has further developed, refined and somewhat altered his terminology. This happened partly in response to criticisms that his terminology was insufficiently precise, inconsistent, and invited

	Sustaining technologies / innovations	Disruptive technologies / innovations
Description	Innovations that sustain a historical trajectory of performance improvement, aligning with what customers in mainstream markets already value.	Innovations that create an entirely new market through the introduction of a new kind of product or service, which is initially judged to be worse on the basis of the performance metrics that mainstream customers value.
Examples	<ul style="list-style-type: none"> The first automobiles did not disrupt the market of horse-drawn vehicles in the late 19th century. Instead, they were a sustaining innovation in luxury transportation. Uber established a position in the mainstream taxi market by improving on existing taxi services. 	<ul style="list-style-type: none"> Amazon.com has been disruptive with respect to the business model of traditional bookstores. Google has been disruptive with respect to the Yellow Pages.

Fig. 1. The distinction between disruptive and sustaining technologies according to Christensen's disruptive innovation theory. Examples i.a. from [2,22].

confusion [15,18–20]. At a conceptual level, the most consequential change in Christensen's work has been a shift from his initial emphasis on disruptive *technology* to a later emphasis on disruptive *innovation* [2, 5]. While the latter concept better captures Christensen's theoretical focus, the original concept [21] has – somewhat unfortunately – stuck with many commentators.

Christensen contrasts disruptive technologies with sustaining technologies (see Fig. 1). Sustaining technologies, *sensu* Christensen, derive their market-success from incrementally improving attributes of products or services that customers already value. Disruptive technologies, by contrast, introduce new attributes that initially appeal only to a fringe market, but are eventually key to its success. This is the counterintuitive thesis at the core of Christensen's theory: disruptive innovations do not start with introducing better products in existing markets. By contrast, existing customers initially judge the products of disruptive market entrants to be *worse*. But while incumbent firms focus on serving pre-existing consumer needs, new entrants can quickly capture a large market share by serving needs that did not previously exist. Subsequently, this allows successful new entrants to challenge incumbents, typically by offering products that are cheaper, simpler, smaller and more convenient to use. Christensen's example of choice is the evolution of the floppy disk. Although not initially delivering superior performance, small floppy disks acquired an increasing market share and eventually exceeded the demands of the original market [21]. What counts as a disruptive innovation, then, is relative to the historical trajectory of a given product, market, or business context: the fact that a new service or product is an initial outlier is part of what makes its subsequent success disruptive.

Two observations about Christensen's account and his influence on scholarly discourse are particularly relevant for present purposes. First, on Christensen's understanding, disruption should be understood in a rather restricted sense. The criteria to be classified as a disruptor *sensu* Christensen are stringent, and often conflict with ordinary uses of term. For instance, colloquial ascriptions notwithstanding, Christensen et al. [22] explicitly argue that the influence of Uber on the taxi market does *not* qualify as a genuinely disruptive technology, since the services Uber provides are largely consonant with those of the traditional taxi business (but see [23]). Secondly, it is clear that even though Christensen made the first claim to the concept of “disruptive technology”, the theoretical toolkit he provides is not specifically tailored for articulating this notion beyond the domains of market and business. To come to terms with the broader dynamics of technosocial disruption a different theoretical framework is called for.

3. Towards a broader account of disruptive technologies

Various phenomena that are colloquially described as instances of technological disruption are not designated as such by disruptive innovation theory, since they do not pertain to disruptions of markets and industries, but to other domains of human existence and social life. Consider the emerging practice of teleworking enabled by video

conferencing software, the new ways in which people maintain friendships in the online sphere, or the changing styles of political communication afforded by social media [24]. What is disrupted, here, are not merely products or services, but daily human routines and basic social and political practices. Accordingly, dissatisfied with its limitations of scope, a few theorists have sought to extend the notion of disruptive technology beyond the confines of Christensen's work, specifically by looking at disruptions in the digital sphere.

Some of the broader dynamics of technosocial disruption – specifically those that pertain to the legal sphere – are addressed by Liu et al. [7], who present a two-phase model for understanding the legal disruption precipitated by AI. The first phase is constituted by what they call the “disruptive moment”, which comes about when technologies generate, reveal or unlock new affordances, when such affordances are acted upon, and when the resulting behaviour is deemed a legal problem or hazard. The second phase involves the ensuing process of legal development, displacement, or destruction. For instance, with regard to legal development, AI might generate legal gaps that require new legal rules; it might lead to legal uncertainty; it might lead to existing laws having a wrong scope of application; or it might lead to obsolescence of existing legal provisions (*idem*, p. 104; see also [25]). The authors offer a rich conceptual framework for analysing legal disruption as a standalone phenomenon. However, their account does not provide much clarification of the concept of disruption itself, which the authors take to be too fuzzy and context-dependent to be analysable.

The most comprehensive account of technosocial disruption to date is formulated by Schuelke-Leech [3]. Schuelke-Leech ties her work to disruptive innovation theory by distinguishing between two levels of technological disruption. A first-order disruption is a localized change within a market or industry – disruption in Christensen's sense. Second-order disruptions affect a much broader range of societal norms and operations, including social relationships, organizational structures, institutions, public policies and the physical environment. Schuelke-Leech (p. 270) outlines four characteristics of technologies that qualify as second-order disruptive:

1. [They] are non-localized, dynamic developments of fundamental technologies, often combining numerous individual technologies;
2. [They] have wide-spread applications in different industries;
3. [They] restructure, reorganize, disrupt current social and institutional norms and standards, operations, production, trends, not limited to a particular market or industry;
4. [They] do not drive economy-wide growth (...), [but] may combine resulting in a Kondratieff long wave.

One of the virtues of Schuelke-Leech's analysis that it clearly positions itself in relation to the earlier work of Christensen, as well as that of Schumpeter [17], who coined the term “Kondratieff long wave” (see also [26]). Yet her account still overlooks some of the most interesting – and understudied – aspects of technosocial change: the way in which technologies disrupt human knowledge and cognition, moral norms and

values, as well as fundamental concepts and categories of thought [27].

Emerging technologies have a potential to disrupt human nature, social life, and nature itself at a fundamental level. “Deep technologies” reach down into the very nature of things to refigure them for human purposes [47,48]. Established natural boundaries and entrenched social categories are thereby challenged. This is not altogether new: technology has also exerted such pressures in the past. Writing, for instance, has changed how we think; the printing press marked a new era in human’s cognitive evolution. Yet the variety of currently emerging deep technologies certainly makes deep disruptions, which put into question what were previously held as “fixed points” about human nature, human society, and the natural world, a topic of specific current concern. Synthetic biology allows for the creation of organisms that, for the first time in billions of years, have not been created through Darwinian evolution but human intelligence. Neurotechnology implants hold promise to fundamentally alter modes of experience and cognition, while AI is challenging various epistemic practices. And just like technologies can change our epistemic outlook, they can also change moral norms, values, identities and agency (e.g. [30,31]).

Or consider the disruption of fundamental categories and concepts of thought. The dichotomy between being “dead” and “alive” comprises a fundamental distinction along such lines, which was put under pressure by the mechanical ventilator [32–34] – just like the distinction between “surviving” and “extinct” is currently being put under pressure by de-extinction technologies. Gene-technology creates hybrid “monsters” that cross settled basic ontological boundaries (e.g. [35]) and force us to rethink our classifications. AI and machine learning technologies put pressure on fundamental concepts, such as human agency, personhood, autonomy and creativity. Socially constructed kinds, including human identities and human nature, are being challenged by technologies. This foundational aspect of technosocial disruption is also one of its least studied aspects.

Disruption, here, manifests itself in the overturning of stably entrenched norms, practices, as well as concepts. These examples of technosocial disruption go much deeper than both Christensen and more recent theorists of disruption have allowed for. Yet a good case can be made that deep disruptions, which instigate processes of fundamentally remaking our society and ourselves, should take center stage in future scholarship, especially since deep disruptions raise issues that ethicists are grappling with and that are of clear societal importance. Arguably, interest in these disruptions should be all the greater because of the foundational theoretical challenges SDTs provoke, and their challenge to extant methods and approaches for analyzing the interplay between technology and society [27]. Disruptive technologies make us lose our normative, theoretical and conceptual bearings. They generate theoretical uncertainty, similar to what Gardiner [36] describes as the “theoretical storm” that haunts the ethics of climate change. Even our best moral theories face severe difficulties conceptualizing basic issues regarding the problems of long-term climate change. Similarly, even our best theories in the philosophy and ethics of technology have trouble to come to terms with SDTs.

Consider, once more, processes of conceptual disruption. Several currently emerging technologies challenge basic concepts of ethical and philosophical discourse, such as “autonomy”, “agency”, “identity” and “reality”. They put pressure on dichotomies like “natural vs. artificial”, “self vs. other”, “organism vs. artefact”. These concepts and dichotomies, in turn, are deeply engrained in ethical and philosophical discourse. Reassessing their meaning in the face of technological pressures involves a reassessment of basic building blocks of ethical theorizing, and indeed, of human sense-making and self-understanding. Analyzing these “deep disruptions” transcends previous work on disruptive technologies. Furthermore, it calls for renewed analysis of the notion of disruption itself. How to conceptualize the phenomenon of disruption, in a way that is conducive to further theorizing in this field?

4. Socially disruptive technologies: A new conceptual framework

As Schuelke-Leech [3] points out, one of the challenges in conceptualizing disruptive technologies is to pinpoint where the disruption really begins. Novel techniques, procedures, artifacts and applications might instigate a process of disruption, but so might new ideas or societal challenges. Consider the most prominent socially disruptive event of the recent past: the Covid-19 pandemic. Here social disruption was not instigated by new technologies, but by a pandemic. Much of the societal response to this social disruption, however, has been strongly technology-driven, including the search for medical treatment and vaccines, the introduction of contact tracing apps and the widespread adoption of video-conferencing software to facilitate online collaboration [12]. Indeed, the pandemic has initiated a global experiment in smart living [37]. Even in disruptive processes that were not initially triggered by technologies, SDTs might nonetheless play an important part in the subsequent dynamics. Indeed, the dynamics between technology and society are typically tightly interwoven when it comes to processes of disruption. Causal schemas which strictly distinguish between technological and non-technological agents may be of limited use. Instead, the entangled sociotechnical dynamics should be the core focus of interest.

A first conceptual lesson, then, is that technosocial disruption is a contextual notion. Not only is it bound to sociohistorical contexts, but also to specific industries, business sectors, and groups in society. A technology might be disruptive for some, but not for others. Smart organs-on-a-chip may positively disrupt the lives of vulnerable health groups, whereas they do not provide any specific support to the population at large. Advanced battery storage technologies may serve to relieve power shortages in the Global South, which do not exist in the Global North.

Additionally, note that disruption is never intrinsic to the technology itself. Instead, it depends on the complex interplay between a technology and a given social context. That said, the disruptiveness of archetypical SDTs will typically be invariant to a great many of social contexts. Consider deepfakes, health care robots or artificial meat. In communities of many kinds these emerging technologies are likely to engender noticeable social disruptions. Their disruptive potential manifests itself in conditions that are fairly basic to society and entrenched in social structures.

4.1. Disruptors and disrutees

Adopting Christensen’s terminology, processes of disruption involve both a “disruptor” and a “disruptee”. Mindful of this distinction, note that there is a subtle difference between the notions “disruptive technologies” and “technological disruption”. The former notion foregrounds technology as the driver of disruption, whereas the latter notion leaves open whether technology acts as a disruptor or is being disrupted. For apart from being agents of disruption, technologies can also be disrupted themselves: new technologies can overtake existing ones, change fields of industry and engineering, converge with related – or unrelated – technologies, transform into general purpose technologies, and make existing artifacts, procedures, and applications obsolete.

Paradigmatic SDTs bring along disruptions at the level of technology as well as society. Nuclear technology is an example here: its deployment of techniques for the fission of atomic nuclei led to an entirely new field of engineering, but the emergence of nuclear technology also had a transformative impact on warfare and international politics. In principle, however, technosocial disruption may have a pronounced social component, while only barely influencing existing fields of technology and industry. Carlsen et al. [11] give the development of airplanes as an example. Energy efficient airliners, incrementally improving in capacity, speed, and cost-efficiency, have given rise to major changes in society. The techniques of industrial production, however, did not involve

any radical alterations, but evolved along a path of incremental technological improvement.

Conversely, technological disruption can also occur mostly the level of industry, while having only moderate social implications. Carlsen et al. [11] present anti-lock brakes and the self-supporting body in the automobile industry as an example. Their development in the 1970s involved radical technology changes to the automobile industry, but did not lead to a corresponding change in user experience or have substantial societal implications.

4.2. Disruption, transformation, innovation and revolution

Disruption and transformation can be regarded as modalities of change. While all processes of social disruption involve dramatic social change (cf. [38]), not all processes of social change are equally disruptive. Social transformations are typically regarded as structural and systemic, affecting foundational structures of society. Their formative nature implies that transformations cannot easily be reversed or be made undone, as Gruetzemacher and Whittlestone [13] underscore: transformation engenders irreversibility. Contrasted with the notion of transformation, the notion of disruption foregrounds the reactive mode in the face of change. Disruptions are more likely to be rapid, unanticipated, causing rupture and uncertainty. Rather than a change of form, it describes a mode of change in which the form is not yet settled (cf [34]).

The relation between disruption and transformation may be operationalized in context-specific ways. For instance, in the context of organizational transitions, Suarez and Oliva [39] outline a typology of environmental change, where disruptive change has the specific attributes of being infrequent, developing gradually and having high intensity effects (see also [40]). As discussed, the qualifier “disruptive” is also frequently used to describe processes of innovation. “Innovation” and “technology” are distinct concepts, however, and there are good reasons to dissociate them [41]. For instance, innovation discourse has the process level as its point of departure, whereas technology discourse is tilted towards the product level. This provides further reason to analyze the nature of disruptive technologies beyond the bounds of disruptive innovation theory. It also suggests a tension in the concept of “disruptive technology”, understood as a process-qualification attributed to a product-notion.

Another mode of change with which disruption may be contrasted is that of revolution. In his recent work on moral revolutions, Baker [42] underscores the elements of intentionality, agency, and activism that underly moral revolutions. Moral disruptions, by contrast, need not be intentionally driven. To complicate matters, technologies do often play a prominent role in radical social change, including revolutionary changes driven by social activism [46]. To the extent that an autonomous dynamic of technological forces is regarded as a key driver of radical social change, this is naturally couched in terms of social disruption. If goal-intended human agency is the main driver of radical change, it is naturally couched in terms of revolution.

4.3. Disruptors good and bad

As noted, on Christensen’s understanding disruption is hailed as an aspiration of incumbent firms: market disruption has decidedly positive connotations. By contrast, in its recent legislative proposal for an Artificial Intelligence Act [43], the European Commission uses the term “disruption” to refer to societal risks that warrant caution. The valence of technosocial disruption, it appears, is context-bound. There is no conceptual constraint on whether technosocial disruption should be evaluated in positive or negative terms. Technosocial disruption may either be regarded as desirable or undesirable – and depending on context, its evaluation might also be mixed or changeable. For as said, different groups can be affected by SDTs, both in space and time.

The ‘goodness’ of market disruptions is prudential, rather than moral. In fact, market disruptions are not typically evaluated in moral

terms. Technosocial disruptions, by contrast, often invite ethical reflection. This has to do, in part, with the foundational nature of technosocial disruption: if technologies touch upon the very essence of politics, social life, human experience and human nature, then ethical reflection is called for. Moreover, technosocial disruptions may come along with an unequal distribution of costs, benefits, and risks, thereby raising issues of justice. These unequal divisions typically befall on specific groups, creating a schism, for instance, between young and old, healthy and ill, rich and poor, employed and unemployed, lowly and highly skilled, and current and future generations.

4.4. Disruption and disruptiveness

SDTs can be identified either on the basis of their *potential* or their *actual* impact. Naturally, SDTs that have been operative in history can be pinpointed with greater confidence than currently emerging disruptive technologies. How socially disruptive the dynamics of currently emerging technologies will turn out to be is difficult to predict. Foresight analysis may accidentally serve to hype the potential of certain SDTs, while the potential of others is overlooked. That said, technologies of which the disruptive potential has not yet been actualized should not be excluded from a definition of SDTs. Doing so would make an analysis of SDTs a merely historical exercise, with limited relevance for understanding present-day societal dynamics.

The distinction between actual and potential impact is mirrored in uses of the terms *disruption* and *disruptiveness*. When speaking of the social disruption of a given technology, we denote an actual change the technology has made in a given social constellation. Social disruption can be understood as the breaking down of a stable societal equilibrium or entrenched state-of-affairs, for instance with regard to social norms and institutions, or with regard to concepts, values, practices and relations. But when speaking of the social disruptiveness of a given technology, we typically refer to the technology’s *potential* to disrupt. Analyzing this potential can be a useful tool for theorizing, especially in reflecting on emerging technologies of which the disruptive potential can be estimated, but which have not left historical traces that allow for an assessment of their concrete impact. For purposes of ethically assessing emerging technologies, therefore, it may be most fruitful to focus on the concept of disruptiveness.

4.5. SDTs versus SSTs

As said, the actual disruption of a technology might be understood in terms of a historical status quo, a stable developmental trajectory, or an equilibrium regarding a society’s social and normative structure, which technosocial dynamics serve to upset. An apparent counterexample to this characterization comes from technologies which have a major influence on society, but simultaneously serve to sustain, rather than disrupt, an existing status quo. Consider green energy technologies. *Prima facie*, these constitute a plausible candidate to be designated as SDTs. However, the societal influence they exert is in an important sense that of *sustaining* existing practices, rather than disrupting them. After all, green energy technologies facilitate a continuation of living energy-intensive lifestyles, and of doing so without substantially altering the global carbon cycle. But if green energy technologies serve to sustain the status quo, then how can they be designated as SDTs?

The answer to this puzzle is that the status quo alluded to is a contextual notion. SDTs do not serve to disrupt each and every stable societal constellation. To the contrary, for each SDT there will inevitably be certain practices that it serves to sustain. But this does not preclude the qualification of a technology as SDT, as long as there is *some* important equilibrium that its dynamics serve to alter. Consider that another status quo of human societies, at least since the Industrial Revolution, has been to generate energy from non-renewable resources. This is a status quo that green energy technologies do serve to upset, fueling the intuition that they should be classified as SDT.

This analysis foregrounds that the disruption of a technology cannot be equated with its causal influence on society. It might well be the case that a given technology has major causal influence, such that if the technology did not exist, social structures would be radically different. But if this causal influence predominantly serves to sustain existing practices, then the technology should not be regarded as disruptive. Consider wastewater treatment technology, which has not radically altered over the last century, but is very important to sustaining many contemporary social practices. In our present era, we are unlikely to regard this as an SDT, even if we heavily rely on it. Instead, since the technology consolidates a significant status quo, it is more aptly described as a *Socially Sustaining Technology* (SST).

5. What grounds technosocial disruptiveness? Seven criteria

I have covered various basic conceptual distinctions that pertain to SDTs and technosocial disruption, which clarify what makes technologies socially disruptive. My method has been to analyze and integrate extant colloquial and technical discourses on disruption, with the aim of arriving at an understanding of disruption that advances scholarly understanding of technology's social implications. Taking one step further in the direction of conceptual engineering, I will now distil from the foregoing analysis seven criteria that ground a technology's technosocial disruptiveness, with the aim of generating a quasi-technical concept of "SDTs".

As a preliminary, let me outline how these criteria should be understood. First, it should be acknowledged that social disruptiveness is not an all or nothing affair. Some technologies are more socially disruptive than others. The seven criteria outlined below do not constitute a set of necessary conditions, but a set of contributing factors: not *all* of them have to be fulfilled for a technology to be classified as an SDT, though *some* certainly do. Secondly, different technologies can be disruptive in different ways. Accordingly, the criteria on which a given SDT scores particularly high may differ per technology. The more criteria are fulfilled, and the higher the degree to which they are, the more disruptive we may take a technology to be. Thirdly, not all criteria outlined below may be equally important. For instance, depth of impacts (a) is undoubtedly a core criterion of SDTs; reversibility (f) is arguably a subsidiary, or derivative, criterion. Yet, in other respects the respective contribution of a-g to a technology's disruptiveness is still up for debate. Fourthly, the set of criteria outlined below is not meant to be comprehensive. There may be further criteria relevant to designating a technology as socially disruptive, and outlining them will be an important task for future work on SDTs. What the set below does aspire to capture are some of the core criteria that *paradigm SDTs* should satisfy.

5.1. Depth of impacts

Depth of impacts denotes the extent to which SDTs affect deeply held beliefs, values, social norms, and basic human capacities. Paradigmatic SDTs challenge basic categories and concepts of thought, such the distinction between virtual and real, natural and artificial, or dead and alive. They affect basic human practices, fundamental concepts, ontological distinctions, and go to the heart of our human self-understanding. For instance, AI challenges notions like agency, responsibility, intelligence, and reasoning, which have long been believed to be uniquely human. Genome editing raises foundational questions about human enhancement, human finitude, species boundaries, hybridization and (de-)extinction. Robotics puts pressure on views about basic moral and legal status. All of these are instances of "deep disruption", whereby fundamental values and previously held certainties are challenged.

Deep disruptions may be contrasted with disruptions whose implications only scratch the surface of entrenched social structures, or do not affect basic concepts. Consider the floppy disk, which was hailed as a paradigm disruptive innovation by Bower and Christensen [21]. While

floppy disks have certainly proved disruptive to industry and consumers, they did not challenge fundamental concepts, or overturn basic practices of social interaction, nor did they alter the nature of work, or affect political structures.

5.2. Range of impacts

The social impact of technologies can be more or less extensive. Some technologies are very disruptive in a given domain (e.g. the domain of politics, medicine, or the military), but do not seem to have substantial impact beyond that domain. They are, with Schuelke-Leech's [3] term, first-order disruptions. For instance, exoskeleton technologies may serve to strengthen the endurance and fighting capabilities of soldiers and could have a disruptive impact on the way that military operations are organized. However, at least at present, the promise of using exoskeletons in non-military settings is less obvious; plausibly, the impact of this emerging technology will be restricted to the military domain. By contrast, blockchain is an emerging technology of which the anticipated impacts range across several domains, including finance, government administration and industrial production. Hence, blockchain has clear potential to be second-order disruptive. The variety of domains affected counts towards the disruptiveness of a technology: the more ubiquitous its domains of impact, the more disruptive we may take a technology to be.

5.3. Valence of impacts

What matters for the disruptiveness of technologies, too, is the valence ascribed to their impacts. Paradigmatic SDTs compromise a state-of-affairs that is regarded as significant, because it touches upon matters that are valued in society. Indeed, paradigmatic SDTs affect key determinants of the quality of society, nature, and human life. Consider the artificial womb, with its potential to disrupt existing family structures and gender roles. These phenomena are dear to many people; their disruption is likely to provoke strong sentiments and to be regarded as either very good or very bad. By contrast, innovations in battery technology are unlikely to provoke similarly strong sentiments, even if batteries are omnipresent in technical artifacts and their improvement constitutes a major innovation, as seen through the lens of R&D. The intensity of the affective disturbance provoked by a given technosocial disruption might be taken as a measure of disruptiveness.

5.4. Ethical salience of impacts

Paradigmatic SDTs do not only trigger strong emotional responses, but also have impacts that are morally significant. They raise ethical dilemmas, create value conflicts, provoke moral confusion and uncertainty, and bring issues to the fore that current systems of ethics are not well equipped to handle. To name just a few examples, genome editing provokes heated moral debates over human enhancement. Big data analytics raises issues of privacy that challenge current legal and moral frameworks. The algorithmic bias produced by AI systems is widely regarded as a cause for ethical concern. Sex robots create moral confusion regarding the moral permissibility of sexual practices involving them. In each of these cases SDTs foreground unresolved ethical issues. The amount of ethical reflection an emerging technology invites can be regarded as an indicator of the technology's disruptiveness.

While all technologies that are described as "disruptive" are likely to be associated with *some* ethical issues, these issues may be more or less pronounced. Consider single serve plastic coffee capsules, which disrupted the coffee market in the 1990s. This technology had effects on the labor market and on plastic waste production, which are related to social and ethical values such as well-being and sustainability. That said, the ease of preparing coffee is not a strong determinant of the quality of society. The ethical component of disruptions provoked by paradigmatic SDTs is much more salient.

5.5. Extent of uncertainty

The impacts of SDTs are typically sudden, surprising, and difficult to anticipate. New technologies get entangled with sociohistorical trends and recombine with other emerging technologies, mutually transforming each other in the ensuing process. The uncertainty engendered by the lack of foreseeability of this process adds to the technology's disruptiveness. Generally speaking, the more difficult it is to anticipate its ensuing technosocial dynamics, the more disruptive we may take a technology to be. Moreover, apart from predictive uncertainty, SDTs also provoke other kinds of uncertainty, such as conceptual ambiguity and contestation, moral confusion, and moral disagreement [33,34]. These species of moral uncertainty, too, are characteristic of technosocial disruption. Deep disruptions destabilize social, institutional, and moral practices. They take away our epistemic and moral bearings – and the greater the extent they do so, the more disruptive we may take them to be. Furthermore, contrary to paradigmatic moral revolutions [42], moral disruptions may not be intentionally driven. They are likely to be associated with greater uncertainty, and specific efforts at sense-making and settling into new routines, while engaging with new social practices.

5.6. Pace of change

A defining aspect of disruption as a mode of change is its pace. Technologies may serve to inhibit, or to accelerate social change. SDTs are on the side of acceleration: disruptions typically occur rapidly. This accords with common usage: disruptions are often regarded as the counterpart of gradual change. For instance, Boucher et al. [12] describe disruption as “a specific form of change which occurs relatively quickly or dramatically.” In this respect, disruptive change can be partly opposed to transformative change, which also subsumes incremental, slow-moving processes. While transformation foregrounds the structural nature of change, disruption foregrounds its speediness, suddenness, and disorderliness. Conceptually, the more rapidly the technosocial change it engenders occurs, the more disruptive an SDT may be taken to be.

5.7. Reversibility of impacts

A final determinant of social disruptiveness is the reversibility of impacts: the more irreversible and permanent the impacts of SDTs, the more disruptive they may be taken to be. Conceptually, irreversibility has an even stronger link with the notion of transformation. Indeed, in their recent work on Transformative AI (TAI), Gruetzmacher and Whittlestone [13] argue that irreversibility is the hallmark of transformative change, and characterize transformation as the practically irreversible change in trajectories of human life and progress. Yet paradigmatic technosocial disruptions, too, are associated with changes that cannot be easily made undone. Think of “deep disruptions” regarding our human nature, which transform fundamental modes of human sensemaking and being-in-the-world. Or think of technologies – such as solar radiation management – that hold to promise to drastically alter our planetary environment in ways that cannot easily be made undone, and have the potential to alter the trajectory of human civilization for centuries to come. Irreversibility has ethical significance: the extent to which impacts are reversible is an important determinant of their ethical evaluation. Accordingly, irreversible changes will be typically regarded as more ethically salient (d).

A-g are interlocking criteria: they constitute different facets that can be integrated in the complex concept of “SDT”. Highlighting these criteria serves to illuminate how this concept differs from “disruption” as it has been understood in earlier discourses. Furthermore, it helps to understand why disentangling these concepts is important for future scholarship. Disruption is high on the agenda of policymakers (e.g. [43], whose cautionary approach with attempts at regulation clearly differs from how disruptive innovators approach the phenomenon.

Furthermore, it is high on the agenda of ethicists, especially those with an interest in emerging technologies. As Floridi and Strait [44]: 79) note, periods of disruption pertain to “rapid changes in both the technology’s development and uncertainty from society about how a technology or artefact should be used. This is the period of time when interpretive flexibility, or the capability of relevant social groups to impart different meanings, expectations, and uses of a technological artefact, is at its highest.” Such uncertainty and flexibility poses a challenge to ethical foresight methodologies. To improve these ethical methods, thoroughgoing engagement with technology’s disruptiveness, understood in terms of the conceptual framework outlined here, is called for.

6. Conclusion

Combining the criteria (a-g) we may characterize archetypical SDTs as technologies that have deep, important, ethically salient and wide-ranging impacts, that occur rapidly, provoke uncertainty and cannot be easily reversed. Several technologies that have historically become entrenched in society, such as the printing press, electric lighting and the internet fit these criteria to a substantial degree and may therefore be justifiably typified as historical SDTs. But as noted, SDTs can also be identified on the basis of their potential. For several currently emerging technologies, such as AI, machine learning, CRISPR-Cas9, the artificial womb and various others, a good case can be made that they satisfy the abovementioned criteria to a substantial degree and can thus be justifiably regarded as emerging SDTs.

The present article has made first steps towards articulating a conceptual framework that can be used to further analyze SDTs and reflect on the nature of technosocial disruption. It has done so by relating SDTs to the existing framework of disruption advanced by disruptive innovation theory, and subsequently by clarifying several of the features and conceptual intricacies of the broader notion of “technosocial disruption”, such as the differences between the concepts of “disruption”, “deep disruption” “transformation”, “disruptor”, “disruptee”, and “disruptiveness”. Of course, this is merely conceptual groundwork; the philosophical and ethical meat on the bones must come from case-studies of technosocial disruption. Such analyses hold great promise for future scholarship in the philosophy of technology.²

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