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Abstract: The political, societal or economic impact of algorithms is seen as one of the most debated issues in recent history. In this introduction to the special issue Algorithms and Communication, we elaborate on the importance of algorithms as research objects for communication science. We discuss why algorithms are such an intensively discussed topic. We describe different kinds of "communicating algorithms" that affect processes of political, social and interpersonal communication. In this context, we elaborate on new research questions for communication sciences that arise out of the importance of algorithms. Finally, we conclude with a call for a transformation of traditional models of mass communication. Particularly, we highlight the necessity to systematically describe and define the role of algorithms as "autonomous" senders in communication processes.

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Algorithms as Research Objects for Communication Science

1 Introduction

The political, societal or economic impact of algorithms is seen as one of the most debated issues in recent history. In his popular scientific book "Homo Deus," historian Yuval Noah Harari defines an algorithm as "*...a methodical set of steps that can be used to make calculations, resolve problems and reach decisions. An algorithm isn't a particular calculation, but the method followed when making the calculation*" (Harari, 2015, p. 97). As such, elementary school children already learn basic algorithms applied in basic arithmetic operations, such as addition or multiplication – even if they are not aware they are using an algorithm to solve their problem. With this in mind, the meaning of a more computer-scientific-based definition becomes clear. Cormen and colleagues (2009) state that an algorithm is "*...any well-defined computational procedure that takes some value, or set of values, as input and produces some value, or set of values, as output. An algorithm is thus a sequence of computational steps that transform the input into the output*" (Cormen et al., 2009, p. 5). This input-output relation can be straightforward, such as sorting five random numbers in a list from lowest to highest.

Algorithms have accompanied humankind from the early days. In 300 B.C., the Greek mathematician Euclid developed the so-called Euclidean Algorithm to compute the greatest common divisor of two numbers (Honerkamp, 2012). Given that algorithms are not a new phenomenon and can be so simple that elementary

school children understand their basic principles, how can so many discussions currently surround this topic? And why – and how far – is this relevant for communication science?

Maybe the key to understanding this lies in combining three aspects: First, algorithms nowadays significantly impact many facets of our daily lives. Second, algorithms still operate to a high share as "black boxes." As such, we do not know much about *how* they intervene in our daily lives. Third, while we do not know much about them, they can "know" much about us, leading to an imbalance in transparency. Turning to the first aspect, progress in computer sciences has made it possible for algorithms to be tasked with solving problems or reaching decisions in almost every single layer of individual, societal, political, and economic life. In other words, algorithms are inevitable (Rainie & Anderson, 2017). Many of these layers are closely entangled with the core research fields of communication science or related research fields, such as media psychology. Algorithms help us find needed information on the internet, remain informed about current affairs, tailor advertising to our interests, make proposals for potential life partners, and even forecast an influenza pandemic. In many cases, algorithms can help to solve problems that are beyond the capabilities of humans. For example, no human can find an excellent solution to an internet search query about maintaining a healthy lifestyle within a second or two, but a search engine algorithm can. As such, algorithms make our lives easier in many ways, having gained a foothold in society. Some might say that our current model of society may even collapse without them.

However, given this huge impact, there is still a lack of transparency in their working principles that regularly calls the attention of politicians, legislators, regulators, or digital activists. This lack of transparency particularly touches communication scientists' expertise when algorithms affect public affairs fields, such as information or news dissemination or privacy violation (Wendelin, 2020). In this context, the argument is that we must know more about *how* algorithms shape these fields. However, since these algorithms are linked to enormous economic interests, it is against the interests of companies to increase transparency. Indeed, the operating principles of their algorithms are considered some of the best kept – and probably lucrative – secrets in the world (Hildebrandt et al., 2015). In addition, progress in deep learning and neural networks enables algorithms to improve and further develop autonomously without the aid of humans. In a deep learning approach, humans only provide learning materials for the algorithm. The analysis of the material and the deduction of

related decisions and conclusions are placed in the "hands" of the self-learning algorithm (Christin et al., 2019). Therefore, the question of how the algorithm concludes might even become a black box for coders and developers (Luber & Litzel, 2017).

While there is this lack of transparency in what we know about algorithms, there is also a glut in transparency in what – at least certain types of – algorithms "know" about us, particularly when a big data approach is applied to analyze "human data": It is well-known that the data traces we leave online while visiting websites, online shopping, be- or unfriending and interacting on social media are stored and analyzed to tailor content and advertisements according to our assumed personal interests and profiles. While this might be helpful in some areas, it potentially hinders others. In particular, when it comes to political communication, the discussions on filter bubbles (Pariser, 2012) and echo chambers (Sunstein, 2001), as well as the "famous" scandal surrounding the role of Cambridge Analytica in the U.S. election from 2016 and the Brexit vote being two prominent testimonies of resulting problems.

In this area of conflict between growing societal impact, lack of transparency, and a glut of transparency, various arguments about the benefit and threads of the "age of algorithms" (Abiteboul & Doewk, 2020) are discussed. These range from praise for a more productive, creative, fair, and efficient future to concerns about a loss of human autonomy and humanity in society: problems stemming from potential algorithmic biases deepening divides in society, and even unemployment (Rainie & Anderson, 2017). Considering Melvin Kranzberg's famous first law of technology:

> Technology is neither good nor bad; nor is it neutral... technology`s interaction with the social ecology is such that technical developments frequently have environmental, social, and human consequences that go far beyond the immediate purposes of the technical devices and practices themselves. (Kranzberg, 1986, S. 545)

Thus, we should analyze, understand, and shape the role of this technology in our society. With this special issue, we aim to contribute to the knowledge about the role of algorithms for (public) communication.

For this, we start by describing the different types of algorithms currently the most prevalent in shaping communication processes. Second, we identify and describe several research fields that require refinement and new thinking. Finally, we set our sights on the future and argue that, with the future developments of algorithms, particularly in artificial intelligence and deep learning, we face even more substantial re-orientation of the basic models that define communication science.

2 Communicating algorithms

The algorithmic selection of information is a central function of various online formats, including social media. It is the technical-functional core of a plethora of applications that increasingly affect processes of social information, communication, and transactions (Saurwein et al., 2017) – applications such as search engines, information aggregators, recommendation systems, scoring systems, monitoring, and forecasting applications, automated content production (algorithmic journalism), and allocation applications such as algorithmically set advertising (computational advertising) or algorithm-based trading (algo trading) highly shape communication processes (Latzer et al., 2016). As such, it is of crucial relevance for research and evaluation of their potential benefits or risks for individuals and society to differentiate between different operation modes on various platforms. In the following, we describe four basic functions of "communicating algorithms." In doing so, we do not map the entire range of algorithms that intervene in communication processes but instead focus on the most prevalent ones.

First is the filtering of information which is widespread in the online world. Here, information that does not meet certain formal criteria is removed. These criteria can be different and refer to various aspects. They are either defined by a user or determined automatically (Haim et al., 2018). Search engines are one example of where users rely on algorithmic filtering procedures (Lewandowski, 2015). Second, and also often used in various online services, is the prioritization of information, which includes creating ranking lists. This can be based on chronological order (presenting the newest information first), as well as on specific ranking factors which account for the (assumed) relevance of information for the users (Lewandowski & Spree, 2011). Third, algorithms can be implemented for classification processes to assign information to specific categories, such as different music styles. Fourth, algorithms can apply associate methods and identify relationships between individual elements. Here, the information is compared by aspects they have in common (content-based filtering) or by reactions of users with similar profiles (collaborative filtering), for example, in online shops ('others who have bought this item were interested in') (Senecal & Nantel, 2004).

Different information sources such as news articles, websites or videos, can be the object of these four methods of algorithmic selection. The different methods

are based on different requirements regarding the nature of the underlying information and its database. A sufficient amount and variety of data and metadata are needed to ensure it results at a satisfying quality level (Lewandowski & Höchstötter, 2008). Moreover, several ethical concerns about how algorithms make sense out of the underlying data are discussed, such as the possibility for unfair outcomes (for an overview, see Mittelstadt et al., 2016).

In addition to the "hidden" information selectors, algorithms come into play as more "visible" communicators. The so-called "social bots" have garnered much attention lately (Stieglitz et al., 2017a). Bots are defined as "...software designed to act in ways that are similar to how a person would act in the social space" (Abokhodair et al., 2015, p. 840). They can disrupt or influence online discourse in many ways (e.g., spreading spam or astroturfing) (Stieglitz et al., 2017b). Different kinds of social bots can be differentiated. Two distinctions are commonly made in the literature (Stieglitz et al., 2017a) by distinguishing them into benign and malicious bots (Ferrara et al., 2016). Benign bots aggregate content, respond automatically, and perform other useful services. Malicious bots, in contrast, are designed with a purpose to harm. A lot of discussion and concern on manipulation have been triggered due to the existence of algorithmic actors in opinion-shaping environments. There is indeed research that reveals the involvement of social bots in online discussions about current political events, such as the armed conflict between Ukraine and Russia, and the war in Syria, by spamming the discussion with one-sided arguments or unrelated content to distract participants (Abokhodair et al., 2015).

3 Researching algorithms – from new research questions to a reorientation in communication science

Coming from this brief and by no means comprehensive overview of different types of algorithms, we now turn to the question about the extent to which they already shape traditional fields of communication research and what new research questions have been investigated. Again, we cannot mirror the whole spectrum of research fields and questions but instead focus on those we see as particularly important for communication scholars.

3.1 Perceptions of algorithms

Having highlighted the lack of transparency of algorithms, it becomes even more important to focus on the perspective of recipients interacting with them. Are users aware of algorithmic processes, and how do they perceive and evaluate them?

In essence, research has identified effects termed "machine heuristic" (Sundar & Kim, 2019). This describes a general belief that machines are impartial and objective in their information selection compared to humans. This was also found in the context of algorithmic authorship in journalism (Tandoc et al., 2020). Auto-written news stories were rated as less biased than human-written news (Jung et al., 2017; Wu, 2020). In contrast, it was identified that people often exhibit an 'algorithm aversion' (Dietvorst et al., 2015). Whilst it has been shown that the vast majority of forecasting tasks see algorithmic forecasts being more accurate than human forecasts, people often remain resistant to using algorithms and prefer human forecasts to algorithm forecasts (Eastwood et al., 2012). People seem to trust human input more than algorithmic input (Önkal et al., 2009; Promberger & Baron, 2006).

To perceive and evaluate algorithmic content, recipients must be – at least to some extent – aware of algorithmic communicators. However, based on their literature review, Hargittai and colleagues (2020) conclude that a high share of people are still unaware of algorithmic actors, particularly in social media or search engines. This is insofar remarkable because extracting information from these platforms shapes an inherent part of the information diet of many people. From a political point of view, citizens need a minimum amount of knowledge about news production and distribution to evaluate information and make informed decisions. As such, we see that a certain level of so-called code or algorithmic literacy among the populace is crucial for the future of democracies. The expertise of communication scholars can contribute here to defining, analyzing, and discussing concepts of code literacy and making proposals of how to implement these in modern societies. (For more information, see the paper by Dogruel in this special issue).

3.2 Algorithmic impact on the informed public

Public communication is at the core of communication science. As algorithms nowadays play a crucial role in information selection or dissemination, communication scholars have begun to scrutinize their role in this context. Closely related to that are the concerns that content curating algorithms could enclose citizens in so-called filter bubbles (Pariser, 2012) or echo chambers (Sunstein, 2001). In addition, concerns have been expressed that they play an active role in circulating fake news and misinformation. For the first, worries about the decreased likelihood of contacting counter-attitudinal political positions and an increase in ideological segregation in modern societies have been raised (for an overview, see Spohr, 2017). In line with that, manifold problems for the functioning of modern democracies have been discussed (Bozdag & van den Hoven, 2015). However, more and more studies – either empirical or literature reviews – conclude that the problem of algorithms causing filter bubbles is not as severe as initially believed (Bruns, 2019; Möller et al., 2018). Indeed, selective exposure mechanisms or tendencies to place oneself in homophilic networks are not recent phenomena of the algorithmic age. Moreover, under certain conditions, algorithmically curated content might even see citizens encounter more information from the opposing political spectrum (Flaxman et al., 2016). Future studies should look in more detail around the interplay between human selective exposure mechanisms and algorithmic content curation. For the latter, a more differentiated consideration of various types of algorithms and how they might foster or "hinder" the emergence of filter bubbles, as proposed by Berman and Katona (2020), will be necessary. In this context, the analysis of the discrete output of algorithmically curated content can also serve as a gateway for a better understanding of how algorithms shape information dissemination in modern societies. The study by Becker in this special issue proposes an approach for realizing a content analysis of news aggregators' output.

Second, communication scholars have started to address the role algorithms play in disseminating fake news or misinformation, particularly as these often circulate through algorithmic-driven social media platforms. Research in this area is still in its infancy, but initial insights on Twitter and Facebook suppose that algorithms might "privilege" fake news over actual news. Fernández and colleagues (2021) provide an overview of the mechanisms behind this, such as an algorithm's

preference for emotional "news" (see Borges & Gambarato, 2019) or an algorithm's popularity bias, meaning that recommender algorithms promote trending information on the platform. As fake news often operates with emotions and as they were found to circulate faster and reach more people (Vosoughi et al., 2018) – in other words, become trends – algorithms may accelerate the dissemination of fake news. In addition, algorithms, especially social bots, can be purposively used as autonomous agents to spread false information and/or manipulate citizens to serve the interests of certain actors (Michael, 2017), something that is also called computational propaganda (Woolley & Howard, 2016). However, in contrast to this "harming" role of algorithms for fake news dissemination, they might also be used to mitigate the problem. Algorithms are trained to detect and monitor false news (Fletcher et al., 2020; Hunt et al., 2020; Singh et al., 2021). Therefore, future research will need to scrutinize if and how such attempts can help curb the problem of fake news traveling through wide circles of the population.

3.3 Algorithms and media regulation. Algorithms as media regulators

Communicating algorithms have also called the attention of media regulators, particularly in the context of social media and search engines. Companies often underline that they are "simply" commercial, governmental and public pressure increasingly force them to accept a hybrid role. While initially not intended, they nowadays play a significant role in citizens' information diet about public affairs (Iosifidis & Andrews, 2020).

The list of aspects that principally fall under the responsibility of media regulation or governance is long and ranges from issues of data protection (particularly against the misuse by companies such as in the famous Cambridge Analytica data scandal) and monopolistic concentration tendencies, over hate speech, and the circulation of fake news (Iosifidis & Andrews, 2020). This also includes calls to make the operating principles of the algorithms more transparent (for some pros and cons, see Hosanagar & Jair, 2018). Given that variety of aspects, the question of how a (or several) regulatory framework(s) should look is a challenging one, and detailed consideration of existing models and the related status of academic research would exceed the scope of this paper. Therefore, for a more comprehensive overview about the different principles

of regulation, potential actors, or applied instruments, we have to direct the interested reader to recent publications such as the one by Iosifidis and Andrews (2020) or – more centered on the European context – de Blasio and Selva (2021). However, from the various attempts, we see that the algorithms themselves undertaking the role of regulator or governor will need further scientific consideration by communication scholars. Behind this so-called algorithmic governance (Katzenbach & Ulbricht, 2019) stands the idea of applying technical solutions to complex governance questions (Gorwa et al., 2020). Algorithmic content moderation, for example, should regulate the emergence of hate or antidemocratic speech on social media. Also, the aforementioned algorithmic fake news detection falls into this category. In addition to the more technical question of how good these algorithmic systems work, several concerns are currently discussed from a media regulation perspective. Gorwa and colleagues (2020) emphasize an increased non-transparency in poorly understood processes (see Coglianese & Lehr, 2019), doubts about how fair and objective such systems are, and a de-politicization of a political sphere.

3.4 Algorithms in communication research: A look into the future

Given the various research fields of communication science that are affected by algorithmic "intervention," Schäfer and Wessler (2020) even call for a re-orientation of the discipline. They underline the necessity to systematically focus and integrate socio-technological innovations for (public) communication in the research process. Indeed, the impact of technology for communication processes at its best plays a marginal role in the classical and basic models of mass-communication science that lay the foundation of the discipline. Through the lens of communication scholars, it is essential to locate algorithms in the communication process and to apply a finer granulation of functional algorithms that can play within the process.

Looking into the future, we see the necessity for a substantial transformation of traditional models of mass communication. This process had already started when the original sender-, mediator- and receiver-approach was adopted by considering the computer as a mediator (the tradition of computer-mediated-communication research) and, more recently, as a sender (human-computer-interaction research). In the future, we argue that communication science needs an even

more comprehensive interpretation of the sender involving algorithms. Notably, we must consider the vast developments in artificial intelligence that will impact communication processes. Guzman and Lewis (2020) introduce a Human–Machine Communication research agenda, Hancock and colleagues (2020) argue for the introduction of AI-mediated communication (AI-MC) research. Here, AI is referred to as "... computational systems that involve algorithms, machine learning methods, natural language processing, and other techniques that operate on behalf of an individual to improve a communication outcome" (Hancock et al., 2020, p. 90). However, 'communicative robots' (Hepp, 2020) enable further algorithmic-based functionalities – often but not always on the basis of artificial intelligence. The paper by Zeller on algorithmic machines, social robots, and Human-Robot-Interaction in this special issue encourages many existing and future perspectives in this research field.

4 The special format of a special issue in the open-access book series "Digital Communication Research"

In addition to the comparably "new" research area of algorithms in communication science, there are several specifics regarding this special issue. First, we decided to make use of the possibilities the online and open access format that the DCR Digital Communication Research series offers. Initially, DCR was conceptualized as a book series and was introduced as "... the official book series of the "Digital Communication" section of the German Communication Association (DGPuK). The book series publishes conference proceedings, edited volumes as well as dissertations and other monographs dealing with digital communication" (see digitalcommunicationresearch.de; translation by authors). In DCR, every chapter (or entire book) undergoes a rigorous peer-review process, and all edited volume chapters or conference proceedings receive a doi of their own. This is a clear testimony that the lines between books and journal publications become blurry when publishing online and that new forms and formats of academic publications are possible. In this respect, we did not feel bound by the format of a book, such as the traditional anthology, when designing this special issue as a somewhat hybrid format: A publication that is published in an open access book series but one that resembles the format of a special issue as known in journal publications.

Second, we noticed – both ourselves and through many discussions in the world of academia – an urgent need for overview articles that bring together different reflections of research and that systematize and elaborate in more detail on research fields than an empirical paper. We assume it is fruitful for the academic world to have such work not only in handbooks and student manuals. As such, we call for a higher entanglement of empirical and theoretical-/meta-analytical research in established academic publication series. Consequently, the present special issue contains both: empirical work and overview articles. However, we are aware of the challenges in publishing such overview articles because they must be well-balanced between an overview and report of the status quo and a novelty value. This is relevant for the authors during the writing process and for the reviewers and editors during the evaluation process.

Third, this special issue was produced during the COVID-19-pandemic. This was (and is) a challenging time for the researchers (and for all other people as well). Many scholars faced serious difficulties in finding the time and cognitive capacity for their research and publication work given the increased demands in teaching as well as caretaking, homeschooling, and other duties during lockdowns. These challenges have affected everyone – editors, authors, and reviewers – as well as those who would have been authors of this special issue but who had to withdraw. Though the entire publication process took considerably longer due to the pandemic, we are proud of ourselves. We have great respect for the authors who managed to bring their contribution to the finish line despite the adverse conditions. We look forward to other opportunities to work with them – and of course, the non-authors. In the sense of this special issue: Scientists are also just human beings, not algorithms.

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