What is Algorithm Literacy? A Conceptualization and Challenges Regarding its Empirical Measurement

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Abstract: While communication research has been particularly focused on examining the effects of algorithms on (public) communication processes, less attention has been dedicated to studying media users' understanding and perceptions of algorithms in online contexts. This contribution provides a first step into studying Internet users' competences in navigating algorithmically curated environments by proposing a theoretical concept on (lay) Internet users' algorithm literacy. Based on existing concepts in media literacy research, we present theory-driven dimensions to address algorithm literacy among Internet users. This is complemented by suggestions for an operationalization of these dimensions informed by findings from qualitative interviews with Internet users. As a result, the proposed concept of algorithm literacy comprises two cognitive dimensions, namely awareness & knowledge and the (critical) evaluation of algorithms, and two behavior-related dimensions, addressing individuals' coping behaviors and abilities for creation and design in terms of the use of algorithms.

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What is Algorithm Literacy?

A Conceptualization and Challenges Regarding its Empirical Measurement

1 Introduction

The automated processing of data based on certain rules shapes almost all information and communication situations and particularly those, in which we navigate digital, networked environments. Algorithms play a crucial role in the selection, prioritization, categorization, and presentation of information and communication and, thus, have a critical impact on our perception of the world as well as on our decision-making (Gillespie, 2014; Kitchin, 2017; Pasquale, 2015). While communication research has been particularly focused on examining the effects of algorithms on (public) communication processes, for example, opinion formation and the (possible) effects of audience fragmentation (e.g., Bakshy et al., 2015; Bodó et al., 2019), less attention has been dedicated to studying media users' understanding and perceptions of algorithms in online contexts (e.g., Rader & Gray, 2015). Public surveys inquiring into Germans' or Europeans' general awareness of and attitudes towards algorithms in society (Fischer & Petersen, 2018) point to a lack of awareness and understanding of algorithms in general. A more in-depth analysis of the public's level of understanding of and competence to cope with algorithmic-curated online environments is however

scarce (Hargittai et al., 2020). This is contrasted by a call for algorithmic, or more broadly speaking, code competent citizens – as demanded in public and policy discourses (e.g., Dreyer et al., 2014).

Given this background, this contribution sets out to develop a concept to study (lay) Internet users' algorithm literacy. We hereby focus on algorithms employed in online environments to encompass those that Internet users generally encounter. This includes algorithms used in online activities, such as in the provision of (personalized) news, in information searches, during online shopping, on music or movie platforms, and for targeted advertising, where users are in contact with algorithmic selection and filtering (Latzer et al., 2016). In order to derive a framework for algorithm literacy we first provide an overview of how and when users encounter algorithms in their Internet use and what risks, as well as benefits, are associated with algorithmic curation to outline why developing algorithm-related skills matters. Second, existing concepts in media literacy research and neighboring areas, such as digital/code literacy, new media literacy, and privacy literacy, are introduced to deduce theory-driven dimensions to address algorithm literacy among Internet users. In order to examine the current understanding and awareness of algorithms among Internet users, we further present findings from qualitative interviews to develop sub-dimensions and suggestions for an operationalization of these dimensions. Finally, we critically discuss the opportunities and limits of examining algorithm literacy based on the proposed framework.

2 Navigating algorithmic-curated environments online and why algorithm literacy matters

Algorithms largely govern the way we use the Internet. In their systematization, Latzer and colleagues (2016) outlined that algorithmic applications online encompass aggregation, filtering, recommendation, or scoring. According to this "algorithmic turn" (Napoli, 2014), algorithms have a crucial impact in terms of how we navigate the Internet: Algorithms filter the news we see, influence decisions about what we buy at what price, determine the type of music we listen to, or govern whom we interact with in social media; in particular, algorithms are implemented to calculate personalized services such as advertising, news, or product recommendations online (e.g., Bozdag, 2013; Newell & Marabellli, 2015; Soffer,

2019; Thurman et al., 2019). Because of algorithms' impact on our world perception and behaviors, they are increasingly considered as "autonomous actors with power to further political and economic interests" (Just & Latzer, 2017, p. 245) or as "emerging tools of public knowledge and discourse" (Gillespie, 2014, p. 185) with the power "to shape realities and societies" (Latzer et al., 2016, p. 402).

Arguing from a technological point of view however, algorithms can simply be defined as "encoded procedures for transforming input data into a desired output based on specified calculations" (Gillespie, 2014, p. 167) or "computational procedures" that provide some kind of output "through a software program" (Christin, 2017, p. 2). Such a purely technological understanding of algorithms however, does not allow the uncovering of the social implications and socio-technological underpinnings of algorithms, as suggested by numerous scholars (e.g., Bucher, 2017; Gillespie, 2014; Kitchin, 2017; Willson, 2017), and instead, algorithms have to be considered as embedded in a complex ecosystem with shared agency between humans and software components that permanently shape each other (Latzer & Festic, 2019).

Following this socio-technical perspective, Internet users are not mere receivers of algorithmic decisions, but they are interwoven with the process itself. Acknowledging that algorithms employed in Internet services largely rely on user-generated input (e.g., personal and behavioral data, interactions), "every click, every query, changes the tool incrementally" (Gillespie, 2014, p. 173). Considering algorithmic curation online as a socio-technological process does not imply an even power distribution between users and algorithmic systems. Instead, a growing body of research has outlined that algorithmic decision-making is associated with a wide range of potential risks – ranging from privacy infringement, forms of political and economic manipulation, censorship, and discrimination to biases in computing outputs (for an overview, see Latzer et al., 2016). Further, the algorithmic procedures of selection and filtering, as well as their underlying criteria, are invisible and largely unavailable to end users and thus remain 'black boxed' (Burrell, 2016; Pasquale, 2015). According to Burrell (2016), this opaqueness stems from different reasons, with algorithmic service providers' strategies for keeping their codes a secret as well as the complex structures of algorithmic systems coupled with lay users' lack of understanding of algorithmic operations being key aspects among them. Even for experts, it is almost impossible to understand algorithmic systems completely, particularly because algorithms are linked to the data that they process and, thus, "perform in context" (Kitchin, 2017, p. 25).

The significance of addressing Internet users' knowledge and competences in navigating algorithmic-curated online environments can be based on three key arguments: The first and most obvious reason refers to the widespread use of algorithmic systems – shaping almost all areas of Internet use – as, for instance, Latzer and Festic (2019) vividly illustrate by explaining how algorithmic applications impact users' social and political orientation online as well as their recreational, commercial, and social Internet use. As users are therefore constantly challenged to cope with algorithms impacting their decision-making, it seems obvious to systematically investigate their understanding of these systems. Second, research found that users' skills in coping with algorithms greatly differs, with the existence of some "power users" who have developed their own, specific ways of how to engage with algorithms and even manipulate them (Bishop, 2019; Cotter, 2019; Bucher, 2012). Users' (lack of) abilities to identify, understand, and potentially counter the impact of algorithmic decisions may further reinforce a digital divide that potentially leads to an increase in the benefits (and risks) that people can draw from using digital services (Gran, Booth, & Bucher, 2020). While there have been initial attempts to survey populations' algorithm-related knowledge (Fischer & Petersen, 2018; Grzymek & Puntschuh, 2019; Gran et al., 2020), a valid instrument for systematically addressing citizens' knowledge and competences is still lacking. Finally, and arguing from a policy-making perspective, providing evidence on users' algorithm literacy is critical for developing regulations, such as transparency measures, regarding the operation of algorithms and potential intervention measures (for an overview, see Potter & Thai, 2019).

In order to develop an eligible measure for studying Internet users' algorithm knowledge, skills, and competences, a conceptualization together with a critical assessment of potential challenges in terms of operationalization represents an essential basis that will be pursued in this contribution.

3 Literature review and development of dimensions of algorithm literacy

So far, attempts at developing conceptual approaches and applicable measurements of algorithm literacy remain scarce. While some conceptualizations rely on a computer scientist background (e.g., Csernoch & Biró, 2015; D'Ignazio & Bhargava, 2015; Hamilton et al., 2014; Siebert, 2018), they are of limited use in

more profoundly addressing Internet users' understanding of algorithms. In addition, some studies have inquired into specific forms of algorithm skills, such as the curation of social media feeds (e.g., Eslami et al., 2015; Rader & Gray, 2015) or news literacy, which algorithmically curated information is a part of (Vraga & Tully, 2019). Few attempts have been made with regard to developing a general understanding and measure for algorithm literacy. One notable exception is the recent study by Hargittai and colleagues (2020) in which they outline the challenges of studying algorithm literacy and give insights into a qualitative interview study design to assess adults' algorithm skills. However, a conceptualization of "algorithm literacy" or "algorithm skills" is still missing.

In order to fill this research gap, we rely on neighboring approaches developed in the broader field of digital and new media literacy to derive relevant dimensions for users' understanding and competences with regard to algorithms.

Acknowledging that media literacy has been covered using different approaches and labels (e.g., digital, information, new media literacy, for an overview, see Hobbs, 2010; Koltay, 2011), the following literature review focuses on four areas of research considered as being related to the area of algorithm literacy: (1) media literacy, which can be labeled as the umbrella term encompassing approaches to examining skills related to a wide range of different media (for an overview, see Potter, 2010); (2) digital literacy focusing on knowledge and skills necessary for using digital media applications (e.g., Eshet-Alkalai, 2004; Livingstone et al., 2005); (3) new media literacy (e.g., Jenkins et al., 2006) centering around the use of Internet and computer-based communication applications; and (4) privacy literacy (e.g., Masur, 2018; Park, 2013), which can be considered as relevant with regard to algorithms, acknowledging that algorithms rely on large amounts of (personal) data.

Starting with *media literacy*, as the umbrella concept for addressing individuals' media-related knowledge, competences, and skills, Aufderheide (1993), for instance, defined it as "the ability to analyze, augment and influence active reading (i.e., viewing) of media in order to be a more effective citizen" (p. 26). In the German-speaking discourse, Baacke's (1996) differentiation of four dimensions of *Medienkompetenz* is often cited in outlining that media literacy encompasses (1) a critical evaluation of media (content) (*Medienkritik*), (2) knowledge about the functioning of the media in general (*Medienkunde*), (3) media use skills (*Mediennutzung*), and (4) media creation skills (*Mediengestaltung*). According to these

principles, media literacy is not only about consuming media in predefined ways but also about generating content and using the media in a wide range of forms and in whatever way is effective and useful according to the user.

In addition, Livingstone (2004) proposes a broader definition of media literacy, without limiting it to a political area of informed citizenship, by stressing that „Media literacy [...] is the ability to access, analyze, evaluate and create messages in a variety of forms" (p. 5). Potter (2010) and Hobbs (2011), in contrast, introduce two different approaches for defining media literacy, namely protectionism and empowerment. The protectionism approach characterizes media literacy as the ability to protect oneself from negative effects related to media (use) and thus encompasses strategies that prevent individuals from experiencing such potential negative effects (p. 684). Pointing in the opposite direction, Hobbs (2011) refers to the opportunities connected to media (use) and defines media literacy as the ability to make your own decisions, as a consumer as well as as a creative designer.

Pfaff-Rüdiger, Riesmeyer, and Kümpel (2012) consider both perspectives – protectionism and empowerment – in their definition of media literacy. Their approach further relies on the media literacy approaches of Livingstone (2004) and the self-determination theory of La Guardia and Patrick (2008). According to self-determination theory, media literacy is connected to a conscious and well-reflected use of media, which leads to a satisfaction of personal needs. Pfaff-Rüdiger et al. (2012) divide media literacy into three dimensions, namely expertise, self-competence, and social competence. The first component, expertise, includes media knowledge and an awareness of mediality. Media knowledge encompasses "technological, legal or social discourses, [and] is a precondition for being able to benefit from the Internet while avoiding risks" (Pfaff-Rüdiger et al., 2012, p. 46). The second component, self-competence, contains evaluative, motivational, emotional, and creative skills related to media use. In particular, these dimensions refer to reflection on the benefits and risks of individuals' own media use (evaluative skills), the fulfillment of their needs (motivational skills), mood management (emotional skills), and the ability to create media, such as a homepage, themselves (creative skills). The third component, social competence, covers participatory, communicative, educational, and moral skills related to media, which subsumes not only online interactions (participatory skills) but also the processing of one's online experiences by reflecting and talking about them in real life (communicative skills). Finally, educational skills encompass the

ability to teach media knowledge and multimedia skills, whereas moral skills include the ability to relate one's actions to media-related values and norms (ibid.). Taken together, individuals are considered media literate "if they are able to fulfil their developmental tasks successfully using the media and to reflect upon the consequences and risks of their media use" (ibid., p. 54).

With the spread of digital media, a growing body of literature is investigating how users are incorporating the Internet into their daily lives and assessing how online behaviors differ between population segments (for an overview, see Hargittai, 2010, 2005; Koltay, 2011; van Laar et al., 2017). Following Gilster (1997), *digital literacy* broadly refers to how users understand and evaluate information from different digital sources. He distinguishes four main skills: (1) information search abilities in conjunction with critical thinking, (2) publication and communication competences, (3) an awareness of values and norms in the digital sector, and (4) knowledge acquisition competences. Further approaches focus on specific areas of digital skills (e.g., an evaluation of online information). Pointing in a similar direction, Livingstone and colleagues (2005) argue that abilities in terms of evaluation skills should include the ability to compare and assess online sources of information in order to identify correct information and eliminate irrelevant aspects. Hobbs (2010) specifies her approach to media literacy, stating that digital media literacy can be defined as a "constellation of life skills that are necessary for full participation in our media-saturated, information-rich society" (p. vii). According to her, these necessary skills encompass users' abilities to evaluate the quality and credibility of content and to create digital media and content for own and communal or participatory purposes using digital tools, as well as to ethically reflect on one's own communication behavior in digital media. She again stresses that literacy has both to serve practical purposes (e.g., how to find and evaluate relevant information) but also has an empowerment dimension to enable users to engage in civic activities and communities or collective problem-solving.

Coming from a more practical perspective, Eshet-Alkalai (2004) describes digital literacy as a "survival skill in the digital era" (p. 102) and divides it into five different sub-categories: photo-visual literacy, reproduction literacy, branching literacy, socio-emotional literacy, and information literacy. These dimensions cover users' ability to read and understand visual representations, the creative recycling of already existing material, the competences needed for orientation in the digital world, an awareness of danger when it comes to online

interactions, and knowledge about evaluating sources (ibid.). Focusing on ICT skills from a more general perspective (also including work-related tasks), van Laar and colleagues (2017) conducted a systematic literature review of studies focusing on the areas of digital competences, digital literacy, and digital skills, resulting in seven core digital skills, namely technical, information management, communication, collaboration, creativity, critical-thinking, and problem-solving skills. This (short) overview on scholarship addressing digital literacy already points to the diverse fields of research, which differ greatly based on the particular type of "digital media" considered in the study. We can conclude that digital literacy encompasses both concrete knowledge about digital media (and their technical underpinnings) as well as skills related to the creation, evaluation, and use of digital content and applications.

Closely related to digital literacy, some scholars have addressed competence-related demands of new media environments, such as the early Web 2.0, and the rise of social media applications under the umbrella term of *new media literacy* (e.g., Chen et al., 2011; Jenkins et al., 2006; Lin et al., 2013). Jenkins et al. (2006), for instance, reflect on the competences needed to use social web applications and consider these as a "set of cultural competencies and social skills that [...] people need in the new media landscape" (p. 4). In a follow-up paper, Jenkins (2007) proposes a concept of new media literacy comprised of twelve competences: play, performance, simulation, appropriation, multitasking, collective intelligence, judgement, transmedia navigation, networking, negotiation, distributed cognition, and visualization. According to him, this list encompasses all the necessary competences linked to new media consumption, ranging from understanding the complexity of the environment and being able to criticize the values of media content to performing social interaction and creating media content (ibid.). Chen et al. (2011) adopt a similar approach, noticing that new media introduces new genres, rules, codes, conventions, and symbol systems of communication, which justifies the need for new competences. According to them, new media literacy can be understood as "two continuums from consuming to prosuming literacy and from functional to critical literacy" (Chen et al., 2011, p. 85), while functional literacy is related to online behaviors, such as the use of media tools and content. As a result, their media literacy concept encompasses four dimensions: (1) functional consuming, (2) critical consuming, (3) functional prosuming, and (4) critical prosuming.

Based on the framework of Lin et al. (2013), as well as Chen et al. (2011), Koc and Barut (2016) developed a comprehensive scale for measuring new media literacy and presented an operationalization of its dimensions. Judging it today, however, some of the items already appear outdated, which is one of the key challenges for scale development in this area given the rapid change of new media environments.

Acknowledging that the functioning of algorithms primarily relies on exploiting (personal) user data (Tucker, 2018) and that privacy violations are considered a risk in the implementation of algorithms, conceptualizations of privacy literacy are also relevant for mapping algorithm literacy. Without stepping into the debate on privacy definitions, we refer to Burgoon's (1982) definition of privacy as the ability to "control and limit physical, interactional, psychological and informational access to the self or one's group" (p. 207). Concerning this understanding, individuals need to develop competences to uphold their control in these domains to avoid violations. Such violations may stem from both horizontal (e.g., other Internet users, such as social media contacts) as well as vertical (e.g., online service providers, governments) actors (Schwartz, 1968). Masur (2018) develops a comprehensive concept of privacy literacy, defined as the knowledge that can be acquired and the cognitive ability and skills to solve privacy-related problems on the Internet, and the willingness to implement these solutions in various communication and usage situations (p. 451). According to him, privacy literacy consists of four dimensions: (1) factual privacy knowledge, (2) the ability to reflect on privacy, (3) skills related to privacy and data protection, and (4) the ability to critically reflect on privacy (e.g., its societal relevance). Empirically however, this concept has not been operationalized yet; instead, Trepte et al. (2015) have focused on the first and, to a limited extent, the second dimension by developing an online privacy literacy scale designed to measure Internet users' privacy-related knowledge (the OPLIS scale). Park (2013) adopts a similar approach for examining digital literacy related to privacy. According to him, privacy literacy encompasses a critical understanding of data flow and its implicit rules for users to be able to act. Literacy, in this sense, should empower users to undertake informed control of their digital identities. He operationalizes privacy in three dimensions: technical familiarity, an awareness of institutional practices, and policy understanding – following a similar approach to Trepte et al.'s OPLIS scale.

3.1 Developing dimensions of algorithm literacy

Based on the literature review, four dimensions of media competence can be derived, which can be identified as being relevant across different approaches and which, at the same time, seem to be relevant for capturing algorithm literacy as well. First, two cognitive dimensions can be distinguished, namely *awareness and knowledge* and the *(critical) evaluation* of algorithms, and these are complemented by two behavior-related dimensions, addressing individuals' *coping behaviors* and abilities for *creation and design* in terms of the use of algorithms.

Cognitive Dimensions of Algorithm Literacy

- Awareness and Knowledge

Knowledge is considered a relevant (cognitive) dimension in almost all approaches to media literacy, yet it varies with regard to the sub-dimensions covered. For studying algorithms, we propose a differentiation between awareness and knowledge. While awareness captures to what extent users can tell that algorithms are implemented in a given service and how they function (e.g., sorting, ranking, filtering content), knowledge, in contrast, aims at capturing users' general understanding of the types, functions and scope of algorithms on the Internet.

- (Critical) Evaluation

The second dimension (evaluation) is also a key category in existing literacy approaches relying on the assumption that being able to evaluate and reflect on media-related techniques and content is a precondition for being capable of autonomously using (media) services and developing creative forms of use (prosuming media dimension, e.g., Chen et al., 2011; Livingstone et al., 2005; Masur, 2018; Pfaff-Rüdiger et al., 2012).

Behavior-Related Dimensions of Algorithm Literacy

In addition to the cognitive dimensions addressing algorithm literacy, two sub-dimensions are included to account for users' actual behaviors in terms of algorithmic curation, namely coping behaviors and creation and design. While some literacy concepts focus on one behavior-related dimension, we believe that developing two distinct, yet related categories is more eligible for gathering users' behavior-related skills in interacting with algorithms. While the first dimension refers to users' abilities to use existing algorithms competently, the second dimension focuses on users' skills in developing or changing algorithms themselves (e.g., based on programing competences but not limited to them) as research into users' strategies of how to cope with algorithmic curation and "play the algorithm strategies" outline (Bishop, 2019; Cotter, 2019).

- Coping Behaviors

Existing approaches consistently argue that competences regarding the use of (new) media applications as well as the ability to employ privacy protection measures are crucial components of media literacy. When adapting this dimension to the area of algorithms, two aspects need to be taken into account: First, we have to again consider that coping strategies are connected to users' knowledge and evaluation competences. Users have to be *aware* of algorithm decision-making in internet applications and are then able to, at least to a certain extent, *evaluate* the effects of such actions and, consequently, implement adequate coping behaviors. Second, and this differs in some ways from previous media literacy constructs, this dimension is not about the competence of being able to use algorithms but about the ability to use algorithms *competently*. Acknowledging that algorithms are ubiquitously employed across the Internet and that their use often happens unconsciously, literacy is not so much focused on developing skills or reflecting on how to use algorithms but instead on learning to deal with their requirements and consequences. This means that individuals are able to apply strategies that allow them to modify predefined settings in algorithmically curated environments such as in their social media newsfeeds or search engines, to change algorithms' outputs, compare the results of different algorithmic decisions and protect their privacy.

- Creation and Design

The fourth derived dimension of algorithm literacy encompasses the activities of creation and design (or functional prosuming according to Chen et al., 2011). The creation and design dimension targets user activities that go beyond the mere use of particular services and aims at capturing more elaborate forms of usage, such as users' abilities to modify existing algorithms or create algorithmic applications themselves. Even though we do not expect that the majority of today's Internet users are equipped with programming skills, this might be of growing relevance for the next generation of individuals (e.g., Klawitter & Hargittai, 2018; Popat & Starkey, 2019).

4 Development of sub-dimensions to examine Internet users' Algorithm Literacy

In order to develop sub-dimensions and to, in a follow up study, operationalize the above-described dimensions of algorithm literacy, we relied on two sources: First, we recur on existing literature, e.g., to derive areas of application of algorithms, functions as well as risks and benefits associated with these systems; second, we use data collected in a qualitative interview study among 30 German Internet users which was part of a larger project on media users' understanding and perceptions about algorithms in online contexts. The semi-structured interviews were conducted by two trained interviewers and one member of the research team. German participants were recruited following a quota on age and gender and focused on adults who were regular Internet users. Participants' mean age was around 36 years (ranging between 17 and 70 years) and the quote of gender was almost met (16 women). Interviews lasted around one hour and started with some open questions on participants' Internet use and then moved to their understanding of algorithms in general and their awareness of algorithmic operations concerning eight different domains (news selection, information searches, job searches, dating services, navigation, online shopping, music and movie selection, and advertising). The interview then moved on to a standardized task and asked users for their perceptions of risks associated with algorithms, but this will not be covered in this paper. The interviews were recorded, transcribed, and coded using the software MAXQDA.

We hereby relied on an emerging coding scheme starting with the categories of the interview guideline. This process involves repeated readings to develop and refine thematic inductive categories (Mayring, 2000).

While this study was not deliberately designed to inform an operationalization of algorithm literacy, findings of these interviews were considered as helpful insight to deduce potential items for a follow up quantitative study. We thus recur on findings of the interviews where it seems appropriate and helpful to carve out insights in how to address Internet users' algorithm literacy.

Awareness and knowledge on algorithms

Acknowledging that algorithms are considered opaque and their working often remains invisible to end-users, it makes sense to first examine users' awareness of these systems in their Internet use. A measure on algorithm literacy therefore needs to address in how far Internet users are aware of the different areas and applications where algorithms are implemented in and what functions they perform. According to Latzer et al. (2016) for instance, algorithms on the Internet serve a wide range of functions such as aggregation, filtering, recommendation, rating or even forms of content production. Among them, personalization can be considered a specific kind of information filtering which is widely employed across the web (Bozdag, 2013). While it is obvious that these areas of Internet use would be virtually unusable without the use of algorithms, lay Internet users are not necessarily aware of this kinds of algorithmic curation as research on the newsfeed (e.g., Eslami et al, 2015) or search engines such as Google (Powers, 2017) demonstrate. This was as well mirrored in the interview study. Here, we found that the awareness of algorithms differed greatly with regard to different areas of Internet use. Most of the users were aware that advertisings are personalized based on their previous surfing and shopping behaviors as one of our oldest participants explicated with regard to advertising "When I'm online [...] I come across this all the time when I am interested in something specific, for example a Spanish red wine, and then it often appears a day later [...]" (I3, male, 70). They were less familiar with the curation of their newsfeed or news in general (e.g., in news aggregators) or how algorithms were employed in services such as navigation. Items targeting users' awareness of application areas of algorithms may for instance ask users in how far they are

aware that algorithms were employed in search engines, social network sites or dating apps – or more particularly, in how far they are aware that search results as well as their newsfeed is subject to algorithmic curation.
In addition to previous concepts that address media literacy, we further suggest inquiring individuals' understanding of algorithms; i.e. how they would define algorithms in their own words. This is again a result of the user interviews. Here, we found that users differed greatly when being asked to explain algorithms in their own words. While some participants expressed at least a vague idea about the implementation of algorithms in Internet services and were likely to identify it as a 'technical' or "mathematical program that runs in the background at large companies like Google & Co" (I1, male, 37), others simply stated that they have come across the word algorithms but do not really know what it means. From a methodological standpoint, capturing users' general understanding of the term "algorithm" will be difficult to operationalize in a standardized measure but is more likely to be applicable in in-depth qualitative studies (see further Hargittai et al., 2020).

Knowledge on algorithms does not only relate to the areas of application and functions of algorithms but as well relates to the mechanisms underlying these systems. In particular, the collection and processing of personal and use related information can be cited as well as potential effects of algorithms such as filter bubbles or threats to privacy (e.g., the type of data being collected). A measure of algorithm literacy therefore needs to assess in how far users are aware of the extent and type of data algorithms recur on and understand that algorithms may carry biases and do not necessarily provide more "objective" results compared to human decisions. Further, also knowledge about potential regulatory and coping measures related to algorithm decision making in Internet applications – such as knowledge about legal regulations and user rights, e.g., regarding the automated data processing and privacy protection, need to be included into the cognitive dimension of measuring factual knowledge on algorithms. These in turn can be considered necessary requirements for users being able to apply coping behaviors. From a methodological point of view, the knowledge-dimension can primarily be assessed through factual knowledge questions, e.g., true false queries or having users select the right answer among a set of statements. One has to keep in mind that such measures of factual information are just a (poor) proxy for addressing individuals' structural knowledge which is "structured, organized, and of enduring significance" (Potter, 2019, p. 20). Following Potter, in

particular media literacy requires strong knowledge structures to competently understand and evaluate the media offer – which is primarily addressed in the second dimension of algorithm literacy.

Critical evaluation

While the awareness and knowledge dimension is targeting Internet user's factual knowledge, the second dimension is targeting users' evaluation skills, e.g., individuals' abilities to reflect on the opportunities and risks associated with algorithms and potential effects of algorithmic curation on the individual and societal level. While in academic risks associated with algorithms, e.g., potential biases in information or news presentation, discrimination, censorship, or the emergence of echo chambers and potential privacy violations received considerable attention (e.g., Flaxman et al., 2016; Latzer et al., 2016; Lepri et al., 2017; Zuiderveen Borgesius et al., 2016) it remains largely unknown how users evaluate potential implications of algorithmic curation.

In our interviews, users were most likely to associate risks related to algorithmic curation in three areas: Potential manipulation and limits to information diversity, threats to privacy and data sovereignty as well as economic interests of third parties. Many interviewees identified the area of news as critical for algorithmic systems and mentioned manipulation, censorship, filter bubble effects and more generally, limits to information freedom as potential threats of algorithms employed in the curation of news. As one participant explained: "Manipulation of users and limited diversity of opinion, and filter bubbles is actually a danger. If you look, for example, at how many people are simply radicalized somehow via Facebook, because a radical, a Nazi or a Muslim, writes something and then [the algorithm] don't show them anything else..." (I23, male, 20, similar I11, male, 19). Secondly, participants were likely to connect algorithms to privacy threats acknowledging that "[algorithms] collect data from everywhere and you don't really have any control who knows what about you and where it is stored and what happens with it (I5, female, 23).

Related to the area of targeted advertising, some participants were concerned about the manipulation of user's decision making as one of our older participants explicates "the Internet companies are not so keen on just wanting to do good to me or do good to humanity, but I assume that they all want to make

a profit. I think they push people in a particular direction to spend more. So I'm already heavily manipulated as a user which I find negative (I15, female, 54). The proposed sub-dimensions thus aim at measuring in how far users reflect on the advantages and disadvantages of algorithm-based decisions. Empirically, this dimension may recur on users' self-reports using Likert scales in how far they agree with certain statements. Such statements can either be broad in scope to assess in general 'in how far users feel capable of assessing the implications of algorithms on themselves or the society at large' as well as address concrete areas of applications of algorithms, e.g., by asking participants 'in how far they think they can well explain why users see different postings in their newsfeed' or 'in how far they have been thinking a lot about how good or bad search results in Google's hit lists really are'.

We further suggest to examine users' algorithm-evaluation competences regarding both internal reasoning (in how far they think about certain issues) as well as their abilities to articulate their ideas in social interactions which is also an indicator of users' perceived self-efficacy with regard to algorithms (Bandura, 1993; for the relationship between literacy skills and self-efficacy see Livingstone & Helsper, 2010).

Coping

While research examining users' interactions with algorithmic systems is scarce, some initial studies (even though addressing a very particular group of end users) have indicated that users have adopted different strategies to cope with algorithmic decisions, ranging from ignoring, manipulation, or criticizing these systems (e.g., Christin, 2017; Bucher, 2017). Related, Brunton and Nissenbaum (2011) indicated for data collection online that users developed ways to hide their information or engage in 'playing the system' strategies such as producing misleading, false or ambiguous data. Similarly, research on privacy has outlined that users employ a range of privacy protection measures including both technical solutions as well as information management strategies (for an overview: Masur et al., 2018; Matzner, Masur, Ochs, & von Pape, 2016). Based on our interviews, we found that users apply different coping strategies regarding the use of algorithms, e.g., by consulting different services (e.g., different search engines, shopping platforms or news media) to compare recommendations made by algorithms and to mitigate the effects of personalization. Findings also reveal that some, in particular elderly users were less competent in coping with

unwanted or inaccurate algorithmic curation e.g., in the case of targeted advertising or product recommendation resulting in a feeling of helplessness and the decision to refrain from using particular websites and services. Measuring individuals' coping strategies, thus has to take into account very different levels of expertise.

Conceptually, we may differentiate three types of coping strategies towards algorithm, namely privacy-related measures (e.g., private browsing, deleting of cookies) as highlighted by Masur (2018), result-related measures (e.g., consulting different search engines, deliberately manipulating interactions with algorithms) and third, critical communication and activism around algorithms. The latter category aims at capturing if users engage in actively questioning the application and design of algorithms on the Internet, e.g., by using online forums to discuss potential (mal)functions or changes in their design, which happen on a more or less regular basis, e.g., on social network sites such as Facebook or Twitter. In the future, we might even expand this third category to account for potential activism related behaviors, e.g., hacking, engaging in online petitions or other ways of demanding regulatory measures towards the application of algorithms.

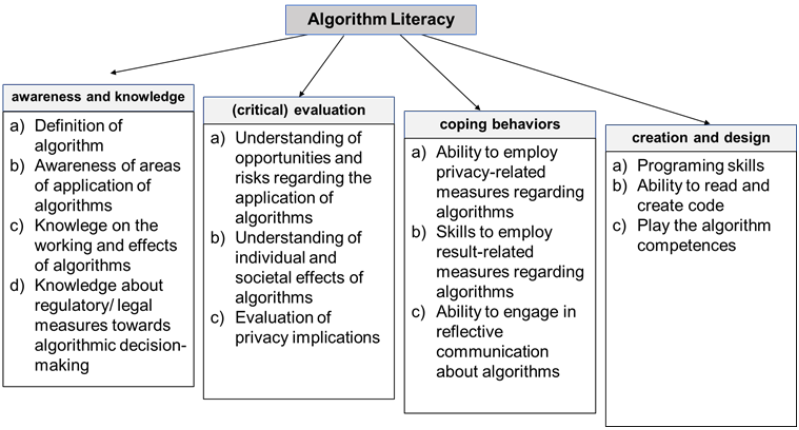
Creation design

The last dimension is the least developed area to examine users' skills regarding the use of algorithms as it is targeted towards users' abilities for modifying and creating algorithmic application (prosuming function). Acknowledging that creating algorithms requires at least some basic understanding and competences of programming we propose to capture users' programming skills and their ability to read and write code, which we see as a necessary precondition for such an endeavor. This dimension aims at capturing practices of Internet users where they transform or convert existing algorithmic applications in ways not intended by providers of designers of algorithms (as described by 'play the algorithm strategies' in the literature, c.f., Bishop, 2019). We thus suggest to further include items that comparable to the "play the algorithm" coping strategies measure if users engage in deliberately manipulating algorithms to transform their functionality.

Figure 1 summarizes the dimensions and sub-categories for algorithm literacy based on the following elaborations. While it is helpful for analytical reasons to present each of the dimensions separately, we have to bear in mind that the domains are not entirely independent from each other but are interrelated and, to

some extent, mirror a process character (indicated through the layers in Figure 1): If users lack awareness about the implementation of algorithms in a certain context and do not know anything about their operation, it is unlikely that they are able to evaluate the consequences of algorithmic decisions and even more unlikely that they are able to implement adequate coping behaviors or create and program algorithms. This mutual dependency of literacy dimensions has been outlined by previous research as well (e.g., Livingstone, 2004).

Figure 1: The dimensions and sub-categories of algorithm literacy



5 Discussion

When navigating the Internet, we are almost constantly in touch with algorithmic systems that filter, rank, or recommend the information and content that is presented to us or that decide what news or music we consume or even with whom we interact; algorithmic decisions impact most of our interactions online, and this has provoked a large number of studies inquiring into the risks, biases, and effects of algorithmic curation. At the same time, research investigating how users perceive these changes to their decision-making and how they cope with algorithms remains scarce. This article set out to propose a concept for studying Internet users' algorithm literacy. We considered literacy an appropriate framework to address relevant knowledge, competences, and skills that Internet users

may need to be able to understand, evaluate, and employ algorithms in a self-determined way. The four proposed dimensions, including different sub-categories, provide a framework for understanding algorithm literacy beyond simply measuring users' awareness of algorithmic curation (e.g., to identify supposedly ignorant users) and are based on the competences that have been outlined in previous approaches to (new) media literacy.

While the present article did not aim at developing a comprehensive scale to empirically measure algorithm literacy, we see this concept as a framework to develop such operationalization. Still, we have to bear in mind that transforming this framework into testable items is a challenge due to several reasons: The first challenge (1) concerns the *time sensitivity* of the instrument. While the first dimension, the knowledge and awareness of algorithms, can be operationalized by testing users' factual knowledge, we have to bear in mind that this knowledge, in particular in the area of algorithms, is time-sensitive – both regarding the areas of application of algorithms (e.g., what services individuals use and how algorithms are implemented into these systems) and the performance of algorithms themselves. While, for instance, today, the performance of algorithms in the area of content production is still limited (e.g., to more standardized texts), this is likely to change in the future. Addressing users' knowledge about the performance (and limits) of algorithms therefore needs to be adjusted to the actual evolvement of the capabilities of algorithms. Still, we can see some stable patterns in the ways algorithms are implemented (e.g., regarding the filtering, ranking, and sorting of information), which is unlikely to be subject to radical changes in the near future.

A second challenge (2) addresses the use *of self-reports* in measuring users' skills in terms of reflection and coping strategies (dimensions two to four). The operationalization of users' literacy through self-reports has already been critically discussed in previous research (e.g., Hargittai, 2010; Hobbs, 2017; Masur, 2018). Hargittai (2005), for instance, pointed out that measuring users' digital or computer-related abilities and skills through self-reports poses the risk of misreporting. While for the first dimension, awareness and knowledge, questions addressing users' actual knowledge are considered better predictors compared to measuring users' self-perceived abilities, examining users' coping skills would benefit from a different approach. As stressed by Masur (2018), with regard to privacy literacy, measuring users' skills would require actually observing how

users perform in terms of these behaviors in order to draw conclusions about their competencies or abilities. For practicability reasons, it thus seems reasonable to see users' actual coping strategies as a proxy for their skills.

A third challenge (3) (and at the same time a limitation of this proposed framework) is the focus on 'algorithms on the Internet'. The idea of this concept was to target algorithms that Internet users are in contact with when online, which, of course, covers a broad range of activities and situations. While this paper set out to develop a framework that can be used to assess users' algorithm literacy on a general level, this necessarily comes with limitations regarding the depth of knowledge and skills when thinking about particular services or applications (i.e., the use and evaluation of search results, online shopping, or the curation of social media environments requires specific skills and knowledge). It thus remains a challenge to create measures that are both specific enough and broad enough at the same time to measure users' actual knowledge and skills without disadvantaging users who engage with different services or applications (e.g., users who do not use social media).

Related to this aspect, the fourth challenge (4) concerns how it remains to be decided how constructs or items from existing, related literacy measures (e.g., web skills, privacy literacy, online news literacy) should be included in the measure of algorithm literacy. While these are arguably intertwined with knowledge and skills related to algorithm literacy, stretching the framework towards related constructs makes it more difficult to differentiate between both concepts and to examine their relationship.

The proposed framework thus presents a first, yet necessary, step towards deducing an empirical measure to capture Internet users' algorithm literacy. While more research is needed on operationalizing the dimensions and on the sub-categories identified, this framework provides an extension of existing (new) media literacy concepts, encompassing more recent developments in media users' media and communication environments.

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