Digital carbon footprint awareness among digital natives: an exploratory study

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Abstract. Changes in use practices due to COVID-19 have illustrated the potential of digital technology as a catalyst of more sustainable and pro-environmental behavior. At the same time, the energy consumption and environmental impact of digital applications and services has been put more firmly on the agenda. In this paper, we adopt a bottom-up approach to explore digital natives' awareness of their digital carbon footprint, i.e., related to their use of digital services and applications. We present findings from 21 semi-structured in-depth interviews that were conducted to explore (1) to which extent digital natives are aware of and reflect on their digital carbon footprint, (2) what could motivate efforts to reduce this footprint and (3) which compromises they might be willing to make in this respect. The findings point to low awareness of the carbon footprint of digital applications and services. The lack of technological understanding, public information and social awareness about the topic were identified as important factors. In terms of the motivation for adopting pro-environmental digital habits, we found that several factors indirectly contribute to this goal, including the striving for personal well-being. Finally, the results indicate some willingness to change and make compromises, albeit not an unconditional one: the alignment with other goals (e.g., personal well-being) and nature of the perceived sacrifice and its impact play a key role. With this work, we aim to strengthen ongoing efforts to increase users' awareness and to stimulate more sustainable and well-being supporting digital consumption.

Keywords: digital carbon footprint · user awareness · pro-environmental behavior · willingness to sacrifice · digital services and applications · ICT

1 Introduction

The latest Report on climate change from The Intergovernmental Panel on Climate Change (IPCC) confirms the undeniable and negative human influence on global warming and underlines the urgency in drastically reducing emissions of carbon dioxide (CO2) and other human-induced greenhouse gas (GHG) emissions in the years to come [24]. This complex global challenge is also one of the key areas in the United Nations (UN's) Sustainable Development Goals (SDGs)[33]

through SDG 13: climate action. In the scope of our work, the debate on the environmental implications of digital applications and services, as well as SDGs 3 and 12 are highly relevant. While SDG 3 targets the promotion of good health and well-being, SDG 12 aims to ensure sustainable consumption and production patterns. In this regard, these goals have implications for industries and governments, including digital industries, tech companies and regular consumers to adapt more sustainable consumption practices.

Within this broader context, digital technology and the various forms of Information and Communication Technology (ICT) seem to play an ambivalent role in promoting sustainable digital consumption practices. On one hand, it has been observed and reported that the increased use of digital technology in different contexts (e.g., work, education, leisure, ...) during the COVID-19 pandemic has had a positive impact on the environment [20,21]. On the other hand, however, Internet service usage was reported to have increased by 40-100% in comparison to pre-lockdown levels [9] and it has been shown that the overall energy demand and consumption levels have significantly increased during the pandemic [19]. Recent work on digital rebound effects consequently point to increased energy consumption and energy demands related to ICT despite increased energy efficiency [8,22], also known as the Jevons paradox [1]. Energy consumption and environmental impact of digital technology have therefore increasingly been put on the agenda (e.g., [2,27,28,32]). These concerns highlight not only production and efficiency-related aspects, but also that of demand and consumption, which also need to be taken into consideration [19,22,11].

In this respect, technological advancements and user-centered approaches tend to go hand in hand with increased expectations (e.g., higher video quality, almost zero-latency...) and may also indirectly lead to more unsustainable use and/or a higher environmental impact. For instance, in their work on how cloud service design impacts the ecological footprint of such services, Preist et al. [28] critically analyse the current design paradigm and state that *"a human-centered design process is not necessarily humanity-centered. The choices that an individual user may make can result in collective longer-term outcomes that are detrimental to the overall sustainability of the system"*. A number of recent pandemic-related examples on the other hand, illustrate that less may also be acceptable. Some video streaming services reduced the default streaming quality during the first lockdown period to avoid traffic overload, and to accommodate increased usage [14]. This has further given rise to the question of whether lower streaming quality (which may lead to a reduced footprint) is acceptable from a user's point of view, also in non-pandemic times.

Within this broader scope, the body of research focusing on topics such as adopting more sustainable lifestyles and sustainability in and through design is also steadily growing [23]. However, research on users' carbon footprint related to the use of digital applications and services, which is different from other consumer goods due to to their *invisible materiality* [3] is still rather limited [11,7]. The work presented in this paper is a part of a larger research process which aims to explore users' awareness of their digital carbon footprint, their attitudes,

perceived responsibility and agency towards current as well as future use of digital services. Such an understanding intends to provide an overview of users' state of mind regarding digital carbon footprint, while also serving as a baseline upon which future strategies can be developed to increase relevant awareness and promote more sustainable use patterns. The overall research design of our study was divided into two phases: (1) semi-structured interviews and (2) online surveys. This paper reports the findings from phase 1, an exploratory study conducted through semi-structured in-depth interview with 21 digital natives, i.e., those who have grown up in the digital era and have a strong affinity with digital technology [34]. The main motive of the current study was to explore (1) the extent to which they (digital natives) are aware of and reflect on their digital carbon footprint (2) what could motivate them to reduce this footprint and (3) which compromises they may be willing to make in this respect. The remainder of the article is structured as follows; Section 2 provides a brief overview of related work. Section 3 describes the research design. Section 4 presents the results, and this is followed by a discussion in section 5. Finally, section 6, provides a conclusion and suggests directions for future work.

2 Related work

Research focusing on the versatile role and potential of digital technology and ICT in addressing global sustainability goals (and in particular: climate action) has been steadily growing over the last 10 years (see e.g., [12,18,5]). The same applies to the stream of literature questioning the underlying techno-centric optimism, challenging dominant design paradigms and pointing to the lack of systemic analyses. Relevant work in this area has looked at the environmental impact of commonly used cloud-based services such as video streaming [6,31,32] and devices such as smartphones [30]. Several recent reports and articles [2,32,25,26] forecast an unsustainable high carbon footprint of ICT in the middle-term future, due to, among others, the increasing energy demand of data centers and the associated traffic [28]. Furthermore, there is also an increasing emphasis on the consumption and demand-side of the issue [19,22,31] which gives rise to the question, *how are digital services and applications used and what is the impact of users' behaviour?*. While it is currently not settled how one's individual digital carbon footprint can be reliably calculated, there is a growing need to involve consumers and users in the collective challenge of reducing the impact of digital applications and services on the environment [11,28].

Initial work on this topic has considered different aspects, ranging from topics that fit best under the *"sustainability through design"* umbrella such as individual consumer perspectives (e.g., [11]), everyday life practices (e.g., [29]), early strategies to inform people about their carbon footprint (see e.g., [10]), to *"sustainability in design"*-approaches. Such approaches for instance, work towards recommendations and sets of questions that can be considered during the design phase, to cover the environmental footprint of the infrastructure underlying digital services, and the devices making use of these services [28]. Aiming for more

awareness and pro-environmental behavioral changes or decision-making also requires a thorough understanding of relevant drivers and motivations. In this context, growing attention has been given to fundamental psychological needs and understanding how people try to (partly) fulfill those needs through user experiences enabled by digital technology [17]. Yet, these underlying needs and people's motivation to fulfill them may also trigger unsustainable habits or use practices (see e.g.,[15]) and as a consequence may threaten users' overall and/or digital well-being. The latter has been defined as *"a state where subjective well-being is maintained in an environment characterized by digital communication overabundance. Within a condition of digital well-being, individuals are able to channel digital media usage towards a sense of comfort, safety, satisfaction and fulfilment"* [16]. Coupling (digital) well-being-related goals with the goal of sustainable consumption seems therefore meaningful in this context.

One of the few recent studies explicitly focusing on (un)willingness to adopt online pro-environmental habits is [11]. This study, based on 17 interviews conducted in 2015 (i.e., pre-Covid-19), as well as a follow-up survey, indicated a general lack of knowledge about the ecological implications of Internet usage and uncovered competing motivations. The study also identified a sense of reluctance among the participants to change their behavior.Interestingly, many interviewees displayed cynicism and scepticism about the harmfulness of Internet usage to justify their own position [11]. [11] further found that people are more likely to take individual responsibility when being aware of the consequences of their digital behavior, thus highlighting the importance of increased awareness. The study called for follow-up research on several aspects, including the willingness to make sacrifices by adopting pro-environmental measures, and the endorsement of responsibility [11]. An example of a measure that seems acceptable for users was suggested in [31]. This comprehensive study looked into the effect of user behavior on the carbon footprint of video streaming. They found that the most relevant factors are the type of device used, the video resolution and the session duration. Based on the results, the authors suggest to reduce the default streaming resolution. Aspects from [11,31] are further considered in our study.

3   Research Design

The study reported in this paper is a part of a broader research design which is exploratory in nature. The overall research design is divided into two phases: (1) semi-structured interviews and (2) online surveys. In this paper, we report on phase 1 of the research process, i.e., the semi-structured interviews.

3.1   Semi-Structured Interviews

A total of 21 semi-structured interviews were conducted to explore (1) the extent to which today's digital natives are aware of their digital carbon footprint (2) what could motivate them to reduce this footprint and (3) the compromises they might be willing to make in reducing it.

The participants filled out a short questionnaire about their overall usage of digital services prior to the interview. All participants indicated to use both mobile phone and computer on a daily basis. Half of them reported their smart phone usage to be up to 2-3 hours each day, while the rest indicated slightly lower usage. More than half indicated more than 4 hours daily computer usage. The most used digital services reported were communication services and video- and music streaming services. The interviews were based on a detailed interview guide [13] and lasted up to one hour. The participants were first asked to introduce themselves, and to reflect on their current digital user behavior and pro-environmental habits in day-to-day life. The next part of the interview aimed to explore participants' awareness and knowledge about the carbon footprint of digital service applications in general, and of their own in particular. Examples on the carbon emissions of ICT industry were also provided to answer questions from interviewees. Finally, the last part of the interview focused on identifying their willingness to adopt more pro-environmental habits.

3.2   Sample Description

The target group for the interviews were "digital natives" (N=21), who can be characterized by their strong affinity with and use of digital services and applications [34]. Once the project was approved by the National Research Data Authority (NSD), a targeted convenience sampling approach was used to recruit students between 20 to 25 years of age. Gender balance was achieved, with eleven participants being female, and the rest (10) being male. The participants came from a range of study programs in Norway, such as chemistry, nursing, electrical engineering, cybernetics, communication technology, medicine, economics and performing arts. The youngest participant was 20 years old and the oldest was 25 years of age (Average = 22).

3.3   Data Collection and Analysis

The study took place in Norway and while nine of the interviews were conducted digitally via Zoom due to COVID-19 restrictions, 12 interviews were conducted physically. All interviews were recorded (audio and video), and conducted in the native language of the participants (Norwegian). The recorded interviews were transcribed using verbatim, and imported in NVIVO, for qualitative data analysis. The qualitative data comprised of participants' answers to the semi-structured interviews which were segmented into meaningful expressions. An open coding approach was opted, and the transcribed interviews were iteratively coded for themes.

4   Results

The interview sessions conducted with the digital natives revealed various insights regarding their digital consumption behavior. The transcribed interviews were analyzed and classified into the following four main categories: *digital*

awareness vs. digital ignorance, motivation for opting pro-environmental measures, potential pro-environmental measures and *challenges.* While the aforementioned categories primarily reflect the main objective of the study, the sub-classification of these categories further reflect the various factors influencing participants' digital consumption behavior on the basis of the three main research questions ((1) extent of participants' digital awareness (2) motivation for reducing their carbon footprint (3) and the compromises to do so).

Within this section we present the key findings corresponding to the categories that emerged from the coding process. We present selected quotes from the interviews which subsequently illustrate the categories that emerged from coding the interviews.

4.1 Digital Awareness vs. Digital Ignorance

Participants' response to reflect upon their individual digital carbon footprint seemed to vary from person to person. One respondent who showed more awareness about the environmental footprint of digital applications and services pointed to specific aspects contributing to increased energy consumption related to digital behavior, such as e-mail signatures with multimedia content. (Male, 25, Cybernetics and Robotics): *"This contributes to pretty large emissions, especially if it is only text in the mail, but a picture in addition to every mail. So I have participated in a couple of discussions where people have been aware of the issue. I have also been aware in way, I know that there are easy measures that can lead to a reduced footprint"*. Students pursuing technical studies (e.g., engineering, computer science, ...) had a better understanding of the underlying processes on the internet, due to exposure of technical literature and courses during their study. The same applies for participants with a gaming interest, where it is important to have sufficient equipment and technical understanding to manage the energy-consuming online applications.

Thus, some of the participants seemed to be aware of their digital carbon footprint (as illustrated above), while others however (15 out of 21 participants), seemed ignorant towards the subject (illustrated below). In this regard, several participants pointed to the environmental impact of big tech companies as a whole and the majority (15) of the participants did not seem to be aware of their individual digital carbon footprint. (Female, 22, Industrial Design Engineering): *"To be very honest, I did not think of this at all, and I assumed it did not matter because it does not seem like the TV or smart phone emit anything"*. Two other respondents identified data centers as the scapegoat, and pointed to the need for fundamental changes in choosing energy sources, and in the development of digital innovation. The interviews further disclosed the following factors contributing to their digital ignorance.

Lack of Technological Understanding: Participants' lack of technological understanding seemed to be an underlying factor contributing to their digital ignorance. One of the participants pointed to the *invisible materiality* of online consumption and her lack of understanding the underlying technical processes

as an explanation for her lack of awareness. (Female, 22, Social Economics): *"I think that one becomes so distanced from it, also because a lot of us don't really understand how the Internet works".* Another respondent made a comparison with purchasing by cash and credit card. (Female, 22, Medicine): *"So you need to only tap the card, and then you have paid the correct amount. With cash, you need to count pennies and notes, so that's is why maybe you are more unaware of your digital consumption [...], it's not something tangible".* Furthermore, there were misconceptions regarding third party applications and applications linked to the operating system. (Female, 24, Electronics Systems Design and Innovation): *"I do not know what the energy consumption of e.g., the calendar app is supposed to be, other than the electricity used by the phone".* As internal applications are seamlessly connected with the operating system, some participants assumed that the synchronising processes only happen within the device and thus do not generate an additional footprint beyond the energy used to charge the phone. In reality, however, many of these applications are stored and processed in data centres similar to other applications using cloud solutions.

Lack of Public Information: The limited amount of information related to the issue which is made publicly available comes forth as another contributing factor towards digital ignorance. Half of the participants wanted to have more information about the notion of digital carbon footprint and argued that this would increase their willingness to implement an eco-friendly digital behaviour. When asked about this, many indicated intentions to change. (Male, 21, Musicology): *"Yes, if I had been informed of any effective actions to reduce the carbon footprint".* Furthermore, another participant mentioned that after being aware of the environmental impact, she identifies specific habits that she can change. (Female, 20, Marketing Management): *"I actually was not aware about this environmental impact [...], now I see that there are habits I could easily change."*

Lack of Social Awareness: Furthermore, the lack of social awareness regarding digital carbon footprint comes forth as the third contributing factor towards digital ignorance. During the interviews, participants with little to no knowledge about digital carbon footprint expressed that this issue should receive more attention (e.g., in school). One participant suggested having big tech companies communicate individual energy consumption during any activity on the companies' applications to users. Another interviewee pointed to the role and responsibility of both mass media and social media. (Female, 22, Performing Arts): *"There is a huge focus in social media on how the food you are eating, fashion industry and general consumption is affecting the environment. There is a lot of focus on these subjects in the media. But no one talks about what a Google search query means."*

4.2 Motivation for Opting Pro-Environmental Measures

While a majority of the participants were not aware of the environmental impact of their digital consumption behavior and not intentionally opting pro-environmental measures, there were certain indirect factors which motivated

them in being more environmental friendly. The following sections illustrate the various factors influencing participants' motivation for opting or not opting pro-environmental measures.

Personal Well-Being vs. Environmental Well-Being: Many of the participants either directly or indirectly linked their positive consumption patterns to their personal well-being. To prevent staying longer time periods on devices, many of the participants referred to measures they use to limit their own usage, such as disabling notifications and pop-ups or only checking their social media applications certain times during the day. Over one third of the participants reported on implementing energy-saving measures on their smart devices, and also mentioned that it was purely due to a fear of not have sufficient battery when they are not at home. One respondent mentioned removing old e-mails due to storage restrictions. (Male, 24, Cybernetics and Robotics): *"I have often deleted e-mails with large attachments, because I have storage restricted to 15 GB. But I have not done it because of the environment, so I should not really praise myself for that"*.

Furthermore, a few participants reported on using apps like *Screentime* to monitor their usage, primarily with the only intention of maintaining their own well-being. (Female, 22, Medicine): *"The main reason to decrease my phone usage is for myself. I want a exciting life with the chance to develop myself. It is not due to environmental reasons that I want to restrict it."* Or as another interviewee put it, (Male, 25, Communication Technology): *"If I feel that most of the day I have mostly used the phone or the computer, so I like to put them away one hour before bedtime to read books, and it helps with relaxing."*

Utilitarian vs. Hedonic Use of Digital Technology: The purpose behind using digital technology, whether for utility (utilitarian) or entertainment (hedonic) purposes is also seen to influence participants' digital consumption behavior. (Male, 21, Cybernetics and Robotics): *"In the holiday period, I tend to use more time on social media and YouTube, but when it is school, I use the web search and watch educational videos on YouTube"*. Furthermore, the increase in the hedonic use of digital services for activities such as *binge watching* is further seen to be related to the lack of social activities as illustrated in the following section.

Engaging in Social Activities: Many of the participants mentioned how a lack of social activities compelled them to spend more time on digital services for hedonic purposes. (Male, 21, Musicology): *"When my work hours end earlier than usual or I don't schedule any social meetings in the evening, I often watch a Netflix series deep into the night"*. Further, while some acknowledge binge-watching as negative, they still find it hard to stop. (Female, 22, Industrial Design Engineering): *"Binge-watching is not good for anything, but I love watching TV-series. I can start reading books, but that is more cumbersome."* Furthermore, it was claimed that such hedonic activities such as video streaming are often combined with other activities in parallel. (Female, 22, Medicine): *"Often you become a multitasking-person as it is boring to watch Netflix, so let me play this*

game as well." Many reported on increased digital activity during the COVID-pandemic lock-down. One respondent explicitly mentioned loneliness as the main motivation for using streaming as a background noise during this period.

4.3   Potential Pro-Environmental Measures

Participants mentioned the following potential pro-environmental measures which could reduce their digital carbon footprint.

Investing in Eco-Friendly Products: Some participants indicated that they would be willing to change to a more environmental friendly streaming provider at an extra monthly cost. (Female, 22, Performing Arts): *"There would obviously be a small trade-off depending on how much more expensive it would be, but still, the environment is so important to me that I would be willing to pay more".* However, it should not go at the expense of the content offer.

Other examples included using an eco-friendly search engine such as Ecosia, where the balance between the perceived sacrifice and gain was considered more reasonable with hardly any negative impact. (Female, 22, Medicine): *"web searching is easy, and something you perform almost every day. So why not do something good out of it, such as planting trees? If it is something you do anyways without having to compromise on the user experience, then you should switch!"*

Prioritizing Content Over Quality: Close to one out of 2 interviewees performed various actions towards lower energy consumption during usage of digital applications, but the intention is usually to preserve performance, storage, battery capacity or to ensure a smooth session. (Male, 21, Biology): *"When my phone does not handle downloading data with good quality, I lower the resolution and am not bothered by the low quality".* When for example asked about the trade-off between video quality and interruption-free playback, a clear majority preferred a continuous video experience over high resolution (e.g., HD, 4K,...). This was also the case with the reduced video resolution on Netflix during the pandemic. If they would have to choose between higher video quality (but limited content offer) and a large content offer (but reduced video quality) the majority preferred the latter. (Male, 25, Electronics Systems Design and Innovation): *"The content is the most important, obviously [...] You do care about the video quality, but you use the streaming service because of the content".*

4.4   Challenges

The following challenges were identified with respect to participants reducing their digital carbon footprint.

Unwillingness To Claim Self-Responsibility: In terms of who is responsible for taking action to limit and decrease the overall environmental impact of digital services and applications, the majority of the interviewees pointed to governmental institutions and external organizations, before any individual adjustments really make sense. (Male, 24, Cybernetics and Robotics): *"I think*

it is the big companies that needs to take the main responsibility, because I do not think you can treat the public as a one herd, and place the responsibility on them". Another interviewee addressed the feeling of helplessness. (Female, 23, Norwegian Sign Language Education): *"I mostly get demotivated, because the biggest footprint is due to the huge tech corporations. This makes me feel like I can not contribute much".*

Participants considered their individual pro-environmental actions to be neither significant nor sufficient, unless larger groups of people are also willing to do the same, thereby disclaiming individual responsibility. (Female, 24, Electronics Systems Design and Innovation): *"I don't think that our independent consumption does not matter, just that it is limited how much it matters. That is why one needs to find a balance in what one is willing to do/change."* Another respondent included more reflection on the issue. (Male, 25, Communication Technology): *"This may be the huge missing motivator...Because the greater picture is bigger than one small contribution, it feels like it does not matter if you change or not. But if everyone shares this mindset, then nothing happens. So it is kind of an evil circle".* Several of the same students also honestly stated that their willingness to adapt a more eco-friendly digital behaviour is minor and their perceived responsibility is low, because there will always be other industries (e.g., the aviation industry, transport sector,...) that will require more attention in reducing the carbon footprint.

Familiarity With Current Technology: It was seen that participants' willingness to switch to a more environmental friendly application or service provider would diminish if they had used a media service for a long time and feared it would affect their experience. (Male, 21, Musicology): *"Now I feel like my Spotify has become very personalized after having it in 7-8 years. They present new music, based on my previous choices. So it would take a long time for another music provider to get to know me in the same way as Spotify".* This and other examples illustrate how network effects and lock-in mechanisms may form a barrier towards the adoption of more green behavior.

5   Discussion

The current study is positioned within the broader scope of efforts to stimulate more sustainable consumption (SDG 12), well-being (SDG 3) and climate action (SDG 13) at the micro-level, considering individual perceptions, awareness and behavior. Overall, the findings illustrate the complexity and interconnected nature of these different facets. In terms of digital awareness, the findings indicate a discrepancy between participants' awareness of how digital habits and behaviors directly or indirectly influence personal well-being on one hand, and their awareness of how such digital consumption behavior impacts the environment on the other. While a majority of the participants seemed ignorant and lacked understanding of the impact of their digital consumption (in line with [11]), several did however have a (self-)reflective and conscious attitude towards the impact of how they use digital services and applications for their own well-being.

This discrepancy seems to be mainly due to the degree to which the impact is directly or indirectly visible or perceivable. When it comes to personal well-being, the use (or restricted use) of digital services and applications is associated with the fulfillment of needs or inability to do so, thus having a noticeable influence (e.g., relaxation, companionship, productivity, stress, lack of sleep, ...). However in the context of "environmental well-being", this impact is not directly visible. It is hard to understand and difficult to link to individual choices which may in turn lead to a feeling that individual actions do not have any impact.

Generally, participants felt addressed and concerned when confronted with the topic of digital carbon footprint, argued that it should receive more attention, and identified possible arenas for increasing public awareness and public debate about it, so that more people could act upon the current issues. There were however mixed opinions about the meaningfulness and potential impact of individual measures, similar to effects reported in prior work on ethical consumption in general [4]. Consequently, the willingness to change certain habits also varied. Interestingly however, many participants who expressed low awareness of environmental impact, had already adopted specific strategies and measures to help reduce their overall digital carbon footprint, albeit not as a conscious or a primary goal.

The findings on potential compromises and sacrifices that the participants were willing to make in order to reduce their digital carbon footprint show a similar implicit pattern, as it seems to depend on how well aligned different goals are. If the compromise to make (e.g., reduced video resolution) does not interfere with the main goal (e.g., enjoy appealing video content) or does not imply a relevant loss of functionality or affordances (e.g., using Ecosia instead of Google as a search engine), the willingness to sacrifice and/or adopt a new habit seems to be larger. When the needed cost, effort or sacrifice is perceived to be high, the willingness to change seems to be much lower and in such cases, additional incentives or motivations may be needed to trigger change.

The results further reflect that the purpose behind digital consumption consequently impacts the related use patterns. For instance, as depicted in section 4, utilitarian purposes may result in specific search queries and viewing of limited informative videos, while hedonic purposes on the other hand are seen to be linked with more destructive practices such as spending time on social media and binge watching. Furthermore, the results also highlight that being involved in social activities is beneficial not only for ones' physical and psychological well-being, but also for environmental well-being, as lack of social engagement is identified to contribute towards hedonic practices such as binge watching and prolonged use of devices such as smart phones.

Finally, when it comes to the question of who bears the main responsibility to reduce the environmental impact of digital technology, the overwhelming majority of participants pointed to tech companies, governments and other organizations. However, the implicit and in some cases explicit unwillingness to claim self-responsibility is (as previously mentioned) to a large extent ascribed to the lack of mechanisms and tools to visualise environmental gains and to show

the impact of individual choices. Addressing this challenge should therefore be a key focus in future work on the topic and resonates well with what Borning et al. [3] indicate in their recent position paper on the topic: *"It's difficult to see the ecological impact of IT when its benefits are so blindingly bright"*.

Given the exploratory nature of the presented study, and its focus on digital natives by means of a convenience sampling approach, follow-up work (partly already ongoing as part of phase 2 of this research) is needed to validate the key observations on a larger scale and consider more diverse user segments. Given the potentially sensitive nature of the topic, the study may also be prone to observer-expectancy effects and social desirability bias. In addition, the current approach is heavily based on what people say and indicate that they will do. Follow-up work should extend the approach to also include methods based on what people actually do.

6   Conclusion and Future Work

In this paper, we presented results from a semi-structured interview study aiming to explore (1) to which extent digital natives are aware of the carbon footprint related to their use of digital applications and services (2) what could motivate them to adopt pro-environmental habits and measures in order to reduce this footprint and (3) which trade-offs and sacrifices they may be willing to make.

The results indicate a lack of awareness of the environmental impact of digital applications and services (both in general and linked to individual use behavior), with the majority of the digital natives who participated in the study being mostly ignorant about the topic. The lack of public information and of general, social awareness about the topic were identified as important factors contributing to this lack of awareness. Further, the lack of understanding of the underlying technological processes and infrastructure was found to play a role: as these are not "visible", their environmental impact is not either.

In terms of the motivation for adopting pro-environmental digital habits to reduce one's digital carbon footprint, the results point to several factors that indirectly contribute to this goal, including the striving for personal well-being. The motivations for using digital technology may however play a conflicting role in this respect (and may for e.g., trigger unsustainable consumption habits).

Finally, the results indicate a certain willingness to make compromises. However, this willingness is not unconditional: the alignment with other goals (e.g., personal well-being) and nature of the perceived sacrifice and effort play a key role. In addition, being able to see, visualise (e.g., a tree is planted per search) or somehow perceive the meaningfulness and impact of individual choices in this respect, seems to be of vital importance to trigger a sense of individual responsibility and agency to act.

Follow-up work is needed to validate the findings on a larger scale and work towards reliable calculation and visualisation of one's digital carbon footprint. More in-depth investigation is needed to extend the current findings and to include other other user groups and stakeholders, e.g., public sector, relevant digi-

tal companies industry. Further, more accurate methods to investigate which compromises users may be willing to make and under which circumstances should be developed. This also includes exploring what information channels young adults would prefer to get information from. Finally, at a higher level, the systematic integration of sustainability considerations in User-Centered Design processes should be further investigated and insights from established theories related to human behavior/behavioral change, persuasion and ethical consumption need to be considered and integrated in order to derive effective measures and strategies to motivate more sustainable digital consumption patterns.

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