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Digital phenotyping in psychological and medical sciences: a reflection about necessary prerequisites to reduce harm and increase benefits

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Digital phenotyping represents a new powerful tool to implement psychodiagnostics in many areas of psychology and medicine. The basic idea behind digital phenotyping is that digital footprints of a person left on social media, smartphones, or other sources of the Internet of Things can be used to get fine grained insights into psychological trait and state variables. Although digital phenotyping has tremendous potential to shed new light on human nature, it naturally comes with risks in the domains of privacy. Therefore, the present article reflects on necessary prerequisites on societal, scientific, and individual level to reduce harm and increase benefits of digital phenotyping.

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Background

Currently 58.7% of the world population[3] have access to the Internet and about 3.5 billion individuals[4] currently use a smartphone. The sheer number of Internet/smartphone users demonstrate that the world population could be seen as a highly digitally connected society. Without doubt the digital transformation brings advantages. Among others, the diverse digital applications and devices available enable humans to communicate in cost-effective ways via far distances and/or search for information from everywhere a signal for the smartphone/Internet is available. Against the background of Tim Berners-Lee publishing his first website only in 1991, the revolutionary development toward an *Internet of Things* (IoT), where everything from the coffee machine to the car is connected to the Internet, is unprecedented in human history and brings both chances and risks for humankind [1,2••].

In the present work we want to shed light on recent developments in the area of *digital phenotyping*, a research/business area in particular causing problems with respect to the privacy of users. Therefore, we want to a) shortly introduce the concept of *digital phenotyping*, b) give an overview on chances and risks arising from this area of research/business, and c) explain under what societal/scientific/individual perspectives *digital phenotyping* can unfold its full potential for the good of human society.

On digital phenotyping in psychology, psychiatry, and medicine

Digital phenotyping represents a new exciting area in the psychological and medical sciences [3], where digital footprints are studied to predict a myriad of psychological and medical trait and state variables. One of the first publications demonstrating feasibility to infer person characteristics from digital footprints was published by Kosinski *et al.* [4], where Facebook-Likes were analyzed to predict, for example, sociodemographic variables, personality and intelligence. In the realm of social media platforms, many other digital footprints beyond 'Likes' such as status updates, number of pictures posted and clearly also *textmining* analysis of posted comments are used to gain insights into individuals' traits/states and likely future behavior [5–7]. In this context a recent work by Eichstaedt *et al.* [8••] is of major interest. This study not only demonstrated the feasibility of predicting depression from the posted comments on Facebook, but also found support for the idea that an analysis of social media data can be used as an early detection system for the development of an affective disorder. This said, data from social media represents only *one* kind of data which can be used to predict psychological variables.

Over the past few years also many other (digital) sources have been considered promising to get insights into psychological variables of a person, perhaps the most

[3] https://internetworldstats.com/stats.htm (Accessed on 2nd March 2020).

[4] https://www.statista.com/statistics/330695/number-of-smartphone-users-worldwide/ (Accessed on 2nd March 2020).

prominent being the smartphone [9–11]. The smartphone is a highly interesting device to be studied, because on the one side, this technology is vastly distributed across the globe (currently 3.5 billion users worldwide; see above) and on the other side, many individuals carry it around 24/7 (active use about 2.5 hours a day; see Montag *et al.* [12]). Additionally, with its many in-built sensors, the smartphone provides researchers and clinicians alike with valuable insights into information relating to both the user of the smartphone and its environment including noise levels, temperature, and lux-levels (see also the 'smartphone-manifesto' [13]). From our perspective, for social scientists the study of variables of communicative behavior on the smartphone is of highest interest to get insights into social behavior and social networking processes. Closely related to this field of research, it has already been demonstrated that call-variables from the smartphone are linked to extraversion [14–16]. Moreover, longer WhatsApp use has also been linked to lower conscientiousness [12]. Aside from these studies, in the meanwhile, a large number of studies investigated links between various smartphone variables and personality underlining the feasibility to establish associations between different variables assessed via the smartphone and individual differences in psychological traits (for an overview see Sariyska and Montag [17•]). However, not only personality psychologists profit highly from the study of digital footprints [18], but also clinical psychologists, psychiatrists, and health care professionals in general: Among others, individual differences in the global positioning signal (GPS) have already been linked to depression [19,20], with higher depressed patients staying more at home than lower depressed patients.

In the near future, we will very likely be able to see certain patterns of smartphone variables being linked to psychopathological states, and this knowledge could be implemented in psychotherapeutic and psychiatric health care [21,22]. In particular, such an endeavor is attractive, because valuable longitudinal data can be produced relatively easy by tracking variables via the smartphone without further requirements on the user side. In the best case, the smartphone-tracking is running in the background without further tasks needed to be fulfilled by the patient. Such recorded smartphone data might help to provide detailed insights into psychopathological trajectories allowing for personalized mental health care with, for example, automated prompts to patients and/or mental health care professionals in case of symptom deterioration as a sign of risk for relapse (see also recent works in this area [23–25]). For example, a person recovering from a depressed episode might start to call his/her friends again, posts more smileys in SMS and shows a more active life style reflected in the GPS signal [26]. But such ideas are still speculative and structured research is much needed. This said, we also want to emphasize that the exploitation of digital footprints 'only' represents an additional data layer to be studied and used in the mental health domain: In particular, we stress that these digital traces taken alone will probably not be sufficient to completely understand or predict mental states of individuals. We believe that gathering self-report information from time to time will always be important to a) establish links between digital footprints and different psychological constructs and b) search for differences between how a person sees himself/herself and his/her actual behavior (with discrepancies perhaps pointing to clinical phenotypes). In parts, this has also been highlighted in the area of studying addictive tendencies toward Internet use, where it is hard for online users to appropriately estimate their online consumption [27–29]. Finally, we mention that both the psychodiagnostic process and the treatment of patients need to be carefully supervised by trained clinicians, something not to be overtaken but perhaps supported by an artificial intelligence-based expert system using the aforementioned *digital phenotyping* information in the near future.

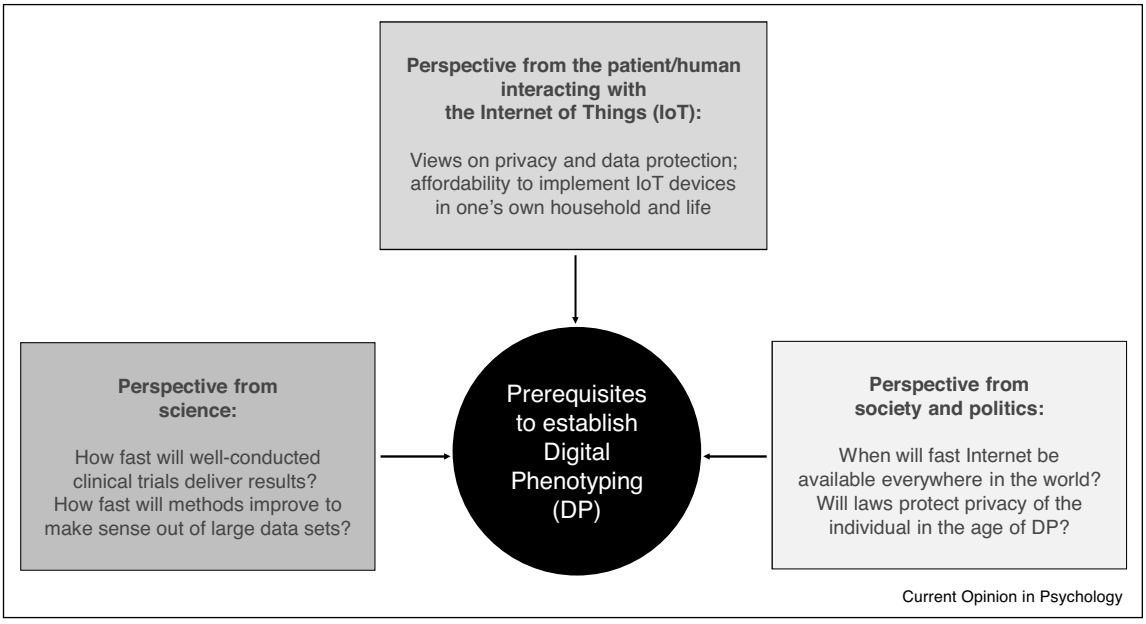
Beyond the smartphone and social media traces

So far, we only highlighted two important data sources currently studied by psychologists, namely information taken from social media or the smartphone. At the dawn of the Internet of Things digital footprints from many more sources will likely be studied in the near future [1,30], including the onboard diagnostics of the car [31] and even everyday behavior such as taking a shower [32•]. On computers also strokes on the keyboard have already been linked to different states in bipolar disorders [33]. All of this, however, without doubt comes with severe issues concerning privacy in the age of surveillance capitalism [34,35••,36], where many companies earn their money via exploitation of digital traces of a person. In particular, in areas where we deal with mental health problems ethical concerns arise, which need to be tackled [37]. Therefore, in order to ensure that *digital phenotyping* can be sustainably anchored in the psychological and medical sciences, we believe it to be of utmost importance to discuss steps, which must be taken on societal and scientific levels to ensure privacy of the individual.

Prerequisites to foster digital phenotyping producing benefits for society and reducing risks of misuse of digital footprints

In Figure 1, we depict three areas, which from our perspective need to be endowed with certain prerequisites, before *digital phenotyping* can be sustainably implemented in the psychological and medical sciences. On the individual level, a simple prerequisite will be that humans actually own a device such as a smartphone. As mentioned in the introduction, it is already apparent today that half of the world population use the Internet, but it is also true that the other half of humankind still needs to be connected to the Internet. This said, precision of *digital*

Figure 1



Prerequisites to anchor digital phenotyping successfully and sustainably in the psychological and medical sciences and beyond.

phenotyping is likely to be enhanced with more data available, hence, when we all live in environments completely connected to the Internet. This could mirror in Amazon's Alexa or Apple's Siri being asked to turn on the light or close the curtains. As the work by Cao *et al.* [32•] demonstrated, such everyday life behaviors indeed can give insights into psychological variables. For example, one can study whether a person always turns on the light in the morning at the same time, hence, probably always gets up on time. In the work by Cao *et al.* [32•], for example, individual differences in regular shower behavior and meal intake were investigated to predict academic performance. This example with its obvious 'big brother' downsides highlights the risks that need to be tackled, at least if we do not aim at societies where privacy rights of individuals are substantially restricted. Hence, in order to successfully implement *digital phenotyping* strategies, the individual need to be convinced that recorded data will not be used against the individual. Instead such data tracking should go along with advantages for the individual such as early detection of a mental health condition or tracking/feedbacking of stress/cognitive load to adjust the current work load. Probably, general attitudes toward artificial intelligence will help to understand which individuals actually embrace such a *digital phenotyping* movement and which do not. Thereby, implementing acceptance facilitating interventions (AFI) providing relevant information on benefits and risks and aiming to improve users self-efficacy might help to improve the acceptance toward *digital phenotyping* and artificial intelligence applications as it has been shown for the acceptance toward Internet-based health interventions [38,39]. But this will need to be tested in the near future: Data analysis increasingly requires artificial intelligence, and *artificial intelligence* is also built-in in many devices such as the smartphone.

As *digital phenotyping* will provide an intrusive view into the life of humans, it is of utmost importance to further consider the perspective from society and politics in need to come up with frameworks outlining in detail under which terms *digital phenotyping* is allowed and where strict regulations need to be established. The manipulation of elections by means of *digital phenotyping* represents such a problematic area, where a growing number of scientists fear that political microtargeting via studying digital footprints undermines democratic processes (but Facebook still has not abandoned the ad-business model including microtargeting (theguardian.com, 2020[5]); see also the problems with the filter bubble [40]; see recent empirical work [41]). Similarly, the potentially helpful *digital phenotyping* data on patients with depression described above could also be used to optimize the patient case mix of clinics with a diagnosis-related groups (DRG) reimbursement friendly admission system of selecting only those patients who likely can be discharged early thereby optimizing clinics profit. Trust on the individual's side is also necessary to allow *digital phenotyping* to improve health care, but with the clear

[5] https://www.theguardian.com/technology/2020/feb/01/facebook-political-ads-zuckerberg (Accessed on 2nd March 2020).

policy to not use this kind of data in the realm of insurance companies. In another context, a recent feasibility study raises the question whether *digital phenotyping* should be allowed in the context of human resources departments, even if it might help the applicants to find the perfect job [42•]. Again, such data could also be used against the applicant and this needs to be regulated. Hence, societal and political implementation of guidelines is of tremendous importance to increase trust on the individual's side and preclude misuse of this powerful new approach to exploit its potential in a societal most beneficial way. In sum, legal frameworks need to be established ensuring privacy in the age of constant surveillance. Again, such legal frameworks will heighten trust on the side of the individual to agree upon participation in projects related to *digital phenotyping*. Establishing trust is critical, because in recent unpublished work we also demonstrated that users have rather neutral views on topics related to artificial intelligence and policy making can help to turn such a neutral view into a more positive or negative attitude. A negative attitude would clearly hinder acceptance of *digital phenotyping*. Beyond the aforementioned, more powerful technical infrastructures need to be established in societies, because digital phenotyping is resource intensive from a data processing perspective.

From a practitioner's and scientist's perspective in (clinical) psychology, psychiatry and medicine, we believe the success of *digital phenotyping* to depend on structured and theory guided research. In particular, we stress the importance of theory in a research area, where data come in the form of Big data's three Vs: high velocity, high volume, and high variety. Without psychological theory being the guiding light, we fear that many spurious correlations and false positive results might appear [43,18], probably never seeing replication in other data sets. A particular interesting area for structured research relying on *digital phenotyping* might be the administration of *digital phenotyping* in the Research Domain Criteria (RDoC) framework [44]. Here, it has been put forward to study endophenotypes of mental disorders across mental health conditions instead of relying on classic diagnosis of the ICD-11 or DSM-5. As Cuthbert [45] (p. 28) puts it "RDoC provides a framework for conducting research in terms of fundamental circuit-based behavioral dimensions that cut across traditional diagnostic categories." The RDoC approach is an attempt to approve scientific research endeavors, which have been limited by problems arising from the classic manual systems such as ICD-11 (often not grasping the actual nature of a distinct mental disorder).

This said, the young research field of *digital phenotyping* still struggles with many issues: Among others, there are no standards with respect to the days needed to record human behavior on the smartphone or other digital sources to get robust insights into a psychological or mental health phenotype (but see first attempts [46]). Moreover, neither is it clear which patterns of data co-vary robustly with a certain mental disorder nor do we know for sure at what granular level variables such as the GPS signal need to be tracked to infer information on a person such as active lifestyle [47] or mental health [48]. This also touches a sensitive topic, namely only recording those variables which are actually of relevance in a respective study area. Here, researchers will also need to come up with good trade-offs between grasping data on the granularity level needed to answer a certain question, but also taking into account privacy issues.

Finally, we believe it would be an exciting area to bring the bio-sciences together with the computer sciences to ultimately get insights into our neuropsychobiology by merely studying the smartphone or other traces of the IoT. Such first works have been already put forward bringing together molecular genetic variants, MRI, and smartphone behavior [49].

Conclusions

The area of *digital phenotyping* could be seen as being part of a larger scientific movement labeled *Psychoinformatics* [26], where computer science and psychology collaborate to understand the human mind. This interdisciplinary research project is still young, but rapidly evolving. In order for the discipline to be successful, both efforts from society/politics and the sciences need to be invested in order to establish a framework ensuring privacy for the individual and at the same time improving well-being and the health care system.

Conflict of interest statement

Nothing declared.

HB has received fees for lectures/workshops and consultancy fees from chambers of psychotherapists, psychological and medical associations and training institutes for psychotherapists in the e-mental-health context. He is a principal investigator of several third party funded projects in the e-mental-health context and author of many articles and books in this field. For some of these activities he received royalties, but never from the mental health industry.

For reasons of transparency, CM mentions that he has received (to Ulm University and earlier University of Bonn) grants from agencies such as the German Research Foundation (DFG). Currently, he receives funding for a project from Mindstrong Health, Mountain View, CA, USA. CM has performed grant reviews for several agencies; has edited journal sections and articles; has given academic lectures in clinical or scientific venues or companies; and has generated books or book chapters for publishers of mental health texts. For some of these activities, he received royalties, but never from the gaming or social media industry. CM mentions that he is part of a discussion circle (Digitalität und

Verantwortung: https://about.fb.com/de/news/h/gespraechskreis-digitalitaet-und-verantwortung/) debating ethical questions linked to social media, digitalization and society/democracy at Facebook. In this context, he receives no salary for his activities. Finally, he mentions that he currently functions as independent scientist on the scientific advisory board of the Nymphenburg group. This activity is financially compensated.

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