



*Hypothesis*

# Towards Homo Digitalis: Important Research Issues for Psychology and the Neurosciences at the Dawn of the Internet of Things and the Digital Society

Christian Montag<sup>1,2,\*</sup>  and Sarah Diefenbach<sup>3</sup>

<sup>1</sup> Institute of Psychology and Education, Ulm University, 89081 Ulm, Germany

<sup>2</sup> Key Laboratory for NeuroInformation/Center for Information in Medicine, School of Life Science and Technology, University of Electronic Science and Technology of China, Chengdu 611731, China

<sup>3</sup> Department of Psychology, Ludwig-Maximilians-University of Munich, 80802 Munich, Germany; sarah.diefenbach@lmu.de

\* Correspondence: christian.montag@uni-ulm.de; Tel.: +49-731-50-26550

Received: 2 December 2017; Accepted: 30 January 2018; Published: 6 February 2018

**Abstract:** The present article gives an overview on central challenges humans face at the dawn of complex digital societies and the Internet of Things (IoT), i.e., a world completely connected to the Internet. Among the many challenges to be handled in digital societies is a growing fragmented life style leading to loss of productivity as well as moments for self-reflection. In all this, it is of tremendous importance to understand the impact of digital worlds on our brains and psyches and to reveal possible unintended side-effects of technology use. Does human nature change due to constant interactions with virtual realities? In this context, we also face the challenge to design digital worlds according to our mammalian-emotional heritage deeply anchored in subcortical areas of the human brain. Here, we refer to emotional needs as carved out by Panksepp's Affective Neuroscience Theory and how they can or cannot be fulfilled in digital worlds. Aside from a review of several key studies dealing with the raised challenges, some first solutions to successfully meet the mentioned problems are provided to achieve sustainable and healthy digital worlds, with whom humans can interact carefree on a daily basis.

**Keywords:** fragmentation of everyday life; Internet and smartphone addiction; primary emotional systems; neuroplasticity; human-computer-interaction; productivity; future work places; digital depression; digital etiquette; homo digitalis

## 1. Background

Mankind is on the verge for a big leap forward towards new kinds of societal living forms. In June 2017, about 50% of the current world population had access to the Internet [1]. Considering that it is only a bit more than 25 years since the programming of the first website by Tim Bernes-Lee, it is of unprecedented event how digital worlds have shaped our societies. From nearly everywhere, we can access online worlds via small technological devices such as the smartphone—made popular in 2007 by Apple's Steve Jobs.

The breathtaking transformation of human societies can be illustrated by ubiquitous access to digital worlds and the opportunity to communicate in easy ways long distance at nearly no cost. Moreover, humans are able to search their ways in unknown territory and distribute knowledge beyond all borders. Right now, our society develops rapidly towards a totally Internet-connected world, where everything from a classic household device such as the vacuum cleaner to the desktop computer is part of the Internet of Things (IoT). Aside from this, digital transformations also impact on diverse areas of (tele-)medicine. Among others, a recent study demonstrated that both tracking-technologies in the realm of physical

activity enhance recovery of patients suffering from cardiovascular disease [2]. Another interesting work pointed out the feasibility to use avatars for communication in medical settings [3].

Although most of the mentioned possibilities due to technological advances are clearly positive, a growing number of researchers point at negative consequences due to constant interactions with online worlds. Therefore, we discuss in the present work several challenges hindering a sustainable development towards a healthier (in particular, less-stressful and happier) society traversed by abundant digital streams. The described challenges start from fundamental shifts in self-reflection/-presentation, the fragmentation of everyday life, the impact of digital worlds on the human brain and emotional needs, to impacts on well-being, happiness, and social interaction and the need for a digital etiquette. These topics are also entwined and their presentation order follows the shortly explained logic in the next paragraph.

Section 2 starts with an important psychological topic from everyday life in digital societies—namely, how the interaction with digital technologies impact on how we reflect on and present ourselves. This is enriched by a related topic presented in Section 3, namely how everyday life is fragmented, among others due to constant interruptions in times of abundant incoming messages via social messenger channels such as Instagram, Facebook, WhatsApp and WeChat. These digital platforms are often accessed via applications on smartphones. Note, that these channels are often used for self-presentation issues and for many online-users mirror to some extent who we are in terms of immediate social feedback in the form of Likes, etc. Sections 4 and 5 shed some light on the neuroscientific basis of social media/Internet use and these topics have been already discussed from a psychological perspective in Sections 2 and 3. In detail, Section 4 aims to characterize social media/Internet usage on a structural/functional brain imaging level, whereas Section 5 (a) gives an outline on potential molecular underpinnings of social media/Internet usage; and (b) aims to make an argument for designing sustainable digital environments according to our evolutionary emotional heritage. The present work on *Homo Digitalis* closes with a plea for a digital etiquette, a pleading resulting from the arguments put forward in Sections 2–5. This work closes with a summary including the key points of the present paper.

Some of our thoughts in the following article have in parts been covered in earlier own works and are brought together for this article (e.g., [4–12]). This is also necessary, because some of these works have only been published in German language. We are aware of the fact that other researchers would emphasize different topics of relevance in the study of *Homo Digitalis*. Therefore, it is not the aim of the present review to give an exhaustive overview on every possible topic in this area. This would also not be possible in a paper as the present one given the myriad of possible areas of relevant research in digital societies. Therefore, the chosen topics of this paper reflect to a great extent the research interests of the authors in the last years.

## 2. New Forms of Self-Perception, -Reflection, and -Presentation

Given the omnipresence of the smartphone and digital media in our lives, a basic psychological question is to what extent technology-initiated routines shape self-perception, self-reflection, self-presentation and the impression one makes on others. In the following, we first discuss the general theoretical concepts of the “self” related to such questions, and then the particular example of self-presentation in the context of social media and related psychological phenomena.

The issue of self-perception in digital environments concerns the human self in the narrowest sense, i.e., the immediate pre-reflective in first-person experience (in philosophical conceptions of the “self” often called the “minimal self” [13]) but also the “narrative self”, referring to one’s personal identity and continuity across time, building “a more or less coherent self (or self-image) that is constituted with a past and a future in the various stories that we and others tell about ourselves” [13] (p. 15). In contrast to the narrative self, the minimal self does not involve a perceptual or reflective act of consciousness but is immediate and non-observational [13] (p. 15).

Obviously, the opportunities for experiencing both types of self are also increasingly shaped by digital environments. While the relevance for the narrative self is relatively evident (e.g., representations of biographical data through postings in social media), and research demonstrated how people actively use such opportunities to construct their identity, telling stories about oneself and portraying a desired image to others (e.g., [14–16]), relations of digital technology to the “minimal self” and the direct bodily experience are relatively underexplored.

First insights might be drawn from research on “self-perceptions beyond the body”. In a recent study, Liepelt, Dolk and Hommel explored to what extent technical devices, that now mediate what previously has been achieved by social face to face interaction (e.g., a computer mouse and a smartphone), become incorporated into representations of the body [17]. Based on variations of the prominent “rubber-hand illusion” (RHI) paradigm, their findings suggested that the perceived bodily self is rather flexible. The rubber-hand illusion describes the fact that, when people are facing a fake hand that is stroked synchronously with their own occluded hand (i.e., if there is a match of tactile and visual information), they experience the illusion that the fake hand becomes a part of their own body [18]. In the study by Liepelt et al., it has been shown that there were equally pronounced effects for the rubber hand and a computer mouse lying on the table concluding that the ownership perception may extend to non-corporeal objects [17].

A question at hand is, whether this can also be extended to non-tangible, virtual objects as representations of the self (e.g., social media profile pictures), and to what degree the perception of manipulations of these representations affect momentary bodily sensations.

While previous research in the domain of human-computer interaction so far considered mainly effects for the “narrative self” and reflective judgments (e.g., effects of editing social media profiles for self-esteem, selfies introducing a new form of self-reflection), it also requires an advanced understanding and explicit contrast to the “minimal self” and the aspects one experiences in the present situation. This will allow for a more proper understanding of one’s holistic experience of the self, mediated through experiences with real as well as digital objects. If, for example, hurts (e.g., negative comments) to selfies in social media are perceived as immediate bodily pain, this provides a more profound understanding of the meaning of digital self-representations for peoples’ well-being and motivations. This line of reasoning can also be related to the traditional notion of the extended self in consumer psychology, stating that “knowingly or unknowingly, intentionally or unintentionally, we regard our possessions as parts of ourselves” [19] (p. 139), and which has been recently extended to the notion of the “Extended Self in a Digital World”, especially considering self-extensions and self-presentations through dematerialized objects, digital possessions, and digital relationships [20]. On a broader level, this poses the question whether in peoples’ view on themselves and their environment, the digital world is represented as a parallel entity, or as an integrated part of the “real” world on equal footing.

### 2.1. Self-Presentation in Social Media

A particularly rich source to study the relevance and mechanisms of digital self-presentation are social media. For many, social media have become an important source of self-esteem (e.g., [21,22]). Given this, posting one’s life can turn into a social competition. Of course, the competition gets stronger with the amount of (Facebook) friends: The more social media connections, the more people to compare and compete with. In the end, the story of one’s own self told to others may gain more importance than the moment itself, and the more extraordinary, the better. This attitude reflects what Keinan and Kivetz denote as “experiential CV”, i.e., an experiential checklist [23] (p. 935). More specifically, they argue that “choices of collectable or memorable (unusual, aversive, extreme) experiences lead consumers to feel productive even when they are engaging in leisure activities, as they ‘check off’ items on an ‘experiential check list’ and build their ‘experiential CV’”. Indeed, their study shows that, given a choice between a pleasurable and a memorable (tellable and presentable) experience, people tend to choose the latter.

This effect is of course well supported through social media and their in-built incentive mechanisms such as hunting for “Likes”—the digital reward for anything—which eventually makes the online spent time all meaningful. What basically started out as a nice (but from social media platform designer also well calculated) idea, i.e., an opportunity for appreciation, soon can become the ultimate source of happiness for many. This, for example, becomes clear when looking at the various strategies that people developed to get more “Likes”. For example, a quick Google search provides you with “best tags” and “best categories” to get more “Likes” for Instagram pictures. A very effective tag is “like4like”, i.e., a deal saying that “if you like my picture I’ll like yours”. This of course, makes the original picture or experience totally irrelevant. Given that many people devote much of their lifetime to achieve a perfect presentation of their narrative selves to receive the most number of “Likes” on social media platforms, an important challenge is to create social media platforms in a way that they really encourage sociality and connectedness, without losing the original meaningfulness of the moments that people share.

## 2.2. Psychological Mechanisms: The Example of the Selfie-Paradox

Another important endeavor is to gain a deeper understanding of the psychological functions and mechanisms behind self-presentation in the digital world. Already a single phenomenon such as the “selfie” reveals rich insights into the complex functions of social media as a means of self-presentation and the formation of identity, and also the diverging views on one’s own self-presentation and the perception by others. A selfie is a self-portrait photograph of oneself (or of oneself and other people), taken with a (phone) camera held at arm’s length or pointed at a mirror that is usually shared through social media [24]. Taking, posting, and viewing selfies has become a daily habit for many, especially in the younger generation. According to a poll with 3000 people, among those aged 18–24, every third picture taken is a selfie [25]. An obvious question is how such an intensive concern with portraying oneself affects values in our society, or may be associated with personality traits such as narcissism (e.g., [24,26,27]). In fact, the current discussion in and outside academia about the value and consequences of selfies is quite diverse. While some highlight the value of selfies as a new material for creative work and the enhanced possibilities to convey emotions (e.g., [28]), or as a trigger for self-study and self-observation [29], others are primarily concerned about negative consequences related to the excessive self-presentation and people’s obsession for taking the perfect selfie—such as decreased mindfulness, focusing on photographing oneself rather than what is happening around us and the needs of others [30], causing conflict in relationships [31], fostering body dissatisfaction [32], narcissistic behavior [24,26,27], or in general a superficial world, with the selfie as “a prototype of expressive inauthenticity” [33] (p. 1853). In this world of permanent documentation and digital self-presentation, already young children seem to have forgotten (or they never learnt) to retain natural behavior. As soon as a camera is present, they immediately take an (unnatural) photo smile, so that candid photographs of childhood become rarities [30].

While the academic discussion already pointed out the complex positive and negative effects potentially related to selfies and other forms of digital self-presentations, studies on the “selfie-paradox” [34] provided a first systematic exploration of how selfie-takers themselves reflect on the image and perceived consequences of selfies, relations to personal and societal values, and to what extent there are differences between self- versus other judgments on own selfies.

In summary, the findings by Diefenbach and Christoforakos outline selfies as a complex and somewhat ambiguous practice [34]: In their survey on the perceived consequences of selfies, a considerable ratio of participants agreed to potential negative consequences of selfies, such as selfies creating an illusionary world (67%) and threats to self-esteem (62%), whereas only small parts of the sample acknowledged positive aspects such as independence (14%), meaning (14%), or relatedness created through selfies (8%). Moreover, the vast majority of participants (82%) declared they would prefer seeing more usual pictures instead of selfies in social media. Interestingly, the critical attitude towards selfies was more strongly reflected in evaluations of others’ selfies than evaluations of one’s

own selfie pictures: while own selfies were judged as more authentic and self-ironic, others' selfies were judged as more self-presentational. This systematic discrepancy may be part of the explanation for the "selfie-paradox", where millions of online users are regularly contributing more and more selfies to social media, despite their critical view towards selfies in general. Although being annoyed by the narcissistic appearance of others' selfie pictures, the single individual obviously interprets own selfie behavior in a more generous way, and assigns attributions (authentic and self-ironic) that make own selfies appear as more justified than those of others. In sum, this pattern seems indicative of a classical self-serving bias, i.e., "an ego-biased attribution", where "we try to explain our behavior in terms that flatter us and put us in a good light" [35] (p. 213). In addition, judgments on own versus others' selfies may also be affected by the fundamental attribution error, i.e., a focus on internal characteristics (character or intention) in explaining another person's behavior in contrast to a focus on situational factors when interpreting one's own behavior [36]. Interestingly, it has been shown that the typical attributional differences between actors and observers can be reversed by literally changing one's view, namely, when seeing one's own behavior from another person's perspective based on videotapes [37]. Likewise, an interesting question for future research in the context of selfies could be whether different framings of own selfies (e.g., judging a taken selfie in one's picture collection on one's own smartphone versus judging a taken selfie as it appears in a communication partner's messenger window) may affect selfie attributions in a similar direction.

The example of the selfie-paradox may be seen as prototypical for many critically discussed effects in social media (and also outside the digital world). On the one hand, humans generally might see a (digital) development in critical ways, on the other hand, they also might neglect to see how every individual, in particular one's own person, contributes to such a development. Humans interpret own behavior in a self-serving manner and disregard bidirectional influences. In the "selfie-case", Diefenbach and Christoforakos reported that the typical showy and narcissistic poses may just have become an established and accepted way of how to present oneself in a selfie [34]. Meanwhile, such a selfie might even meet our expectations of what a typical selfie looks like. In so far, a new social norm could have been established.

From the individual's point of view, one may actually pick the showy pose just "for fun" without further serious intent and a touch of self-irony. However, each showy selfie pose may also serve as an invitation for others to imitate that pose (and possibly justifying it with the same idea of self-irony). This might result in an escalating process shaping the aforementioned social norms. From a psychological perspective, the opportunity for self-presentation without an obvious revelation of self-presentational needs, may be part of the secret of their success. As Diefenbach and Christoforakos conclude: what is "here called the selfie paradox and selfie bias could also be a key factor for their popularity" [34]: On the one hand, selfies provide a lightweight possibility for self-presentation, where people can strategically adjust and experiment with their digital self-presentation and the impression they make on others. On the other hand, selfies provide a somewhat ambiguous form of self-presentation that can be still considered as playful and does not urge the selfie-taker to feel narcissistic. On the contrary, showy selfie poses may even be interpreted as self-irony, at least by the selfie-takers themselves.

### *2.3. Escalating Processes in Digital Self-Presentations*

One can of course question whether selfies or an increasingly self-presentational world are a serious problem worth to be discussed here. However, independent of single phenomenon such as a selfie, the example reveals several challenges related to the increasing role of digital environments as a starting point for self-perception, reflection and presentation and mutual reactions to such presentations.

In a more general manner, findings such as from the reviewed selfie-research hint at the challenge that despite many persons see negative repercussions as a consequence of a certain behavior, people often may promote (knowing or unknowingly) to the dissemination of such behavior themselves

because of their biased interpretation of their own behavior. While this is not an exclusive problem of the digital world, digital environments make it even more relevant. Being connected with “the whole world”, a single individual’s behavior gets exponential effects and can quickly result in escalating processes on large-scale level. Another reason for conflicts and misunderstandings within statements and self-presentations in digital worlds is that, for many contexts, there are no established rules yet. While the general freedom for self-expression can be seen as a positive achievement of the Internet era, we more and more become aware that the Internet and social media also provide an environment for the latent development of non-desired consequences. Taken together, one of the challenges lies in an acknowledgment/understanding of the fundamental role of digital worlds in everyday interactions. Although at first glance a simple selfie behavior seems to be rather harmless, such behavior represents part of a fundamental shift towards a complex digital society dramatically influencing how humans interact on a daily basis.

### 3. Fragmentation of Everyday Life

According to statista.com [38], currently more than two billion humans use a smartphone. Although this powerful computer device without doubt facilitated many activities of everyday life, our private and work lives have become more and more fragmented not only due to a constant influx of messages via social media channels such as WhatsApp or WeChat, but also due to an enormous amount of e-mails absorbing our attention. It has been put forward earlier that we forget to live the moment because of the constant distraction by manifold digital devices [12]. Although smart usage of smartphones and related devices such as tablets can enhance productivity, we believe that the “true” association between smartphone usage and productivity resembles an inverted U-function. If used smart and in the right amount smartphone usage can enhance productivity, but crossing a still to be defined threshold smartphone usage decreases productivity (see also [39]). A high load of incoming messages fragmenting the work process might illustrate such an approximate threshold.

Duke and Montag provided first empirical evidence for the idea that smartphone addiction (hence excessive use of the smartphone) is inversely linked to self-reported productivity [7]. They also put forward that this effect might be in parts explained by the factor high number of daily interruptions (in this work, perhaps not optimally defined by the loss of hours on the smartphone every day; note that estimating the exact number of daily interruptions on smartphones via self-report is a task nearly impossible to be achieved. Future studies need to directly track this on the smartphones (see new developments in the field of Psychoinformatics [40])). Why should daily interruptions play an important role to understand loss of productivity?

#### 3.1. A Short Introduction to the Flow Concept

A prominent psychological framework to understand this idea is called the flow-concept. The flow-concept originally has been introduced by Csikszentmihályi and describes a psychological state of high productivity and positive affect, but also time distortions, to name a few characteristics [41]. While experiencing a state of flow, humans are totally absorbed into the task at hand, while forgetting about time and space around them. An important prerequisite to experience flow is the match between the ability of a person and the difficulty of a given task. Imagine: If you have to follow a task at work, where your own skills do not match the difficulty of the task at hand, this can either lead to boredom (the task is too simple for you) or to anxiety (when the task is too complicated). Both mismatches will hinder a person to enter the flow channel (see Figure 1).

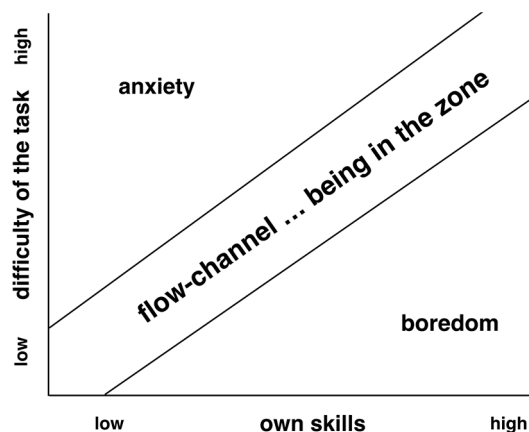


Figure 1. The Flow Model adapted from Csikszentmihályi [41] (p. 74).

Further constituents to achieve a state of flow represent a clear structure/goal of the task at hand (including an immediate feedback; see [42]). Of relevance, another prerequisite to enter the flow channel and “to get into the zone” is a high focus on the task at hand, hence a concentrated mind. In this context, it has been shown that even short disruptions such as 2.8 s can derail the train of thought as presented in Altmann et al. [43]. Therefore, constant incoming messages via diverse technological devices might hinder entering the flow-zone. To outline this a bit further: Although smartphone usage easily can absorb a person’s attention and result in a state of flow, this often might be counter-productive, in particular when more important jobs have to be accomplished. Please see also works by Lin et al. demonstrating the possibility of experiencing time distortions on smartphones [44]. Ironically, the success of Facebook can also be linked to flow experiences while browsing Facebook profiles [45]. Insofar, the flow experience at work might be hindered by experiencing flow and losing time on Facebook. In sum, future research endeavors need to come up with solutions to better provide humans with productive work environments fostering states of flow at work.

### 3.2. Counteracting Fragmentation in Work Settings

Several ideas have been already put forward to reduce fragmentation of everyday life and to better cope with a growing number of digital messages coming in via many channels. Among others Kushlev and Dunn provided first evidence that answering e-mails at defined time points (and not everywhere and always) reduces stress and heightens well-being [46]. In line with this, quitting Facebook use for just one week also elevated life satisfaction and emotional well-being [47]. Moreover, Montag et al. provided data which underline the importance to use classic zeitgebers such as a real alarm clock in the bedroom or a classic wristwatch (no digital iWatch or similar product) in order to not turn to the smartphone for checking the time [48]. It has been reported by many persons that instead of checking the time on the smartphone, they end up doing a different task on their phones. In a way, our attention is often getting hijacked by the smartphone. Even better, after such a phone session to check the time, we often still do not know the current time, because we forgot to check it. Finally, new work by Ward et al. suggests that just a smartphone lying on the desk reduces the available cognitive resources and distracts us from the work task at hand [49]. In short, structuring daily life in times of information overload is more important than ever.

As about 36–40% of the investigated smartphone users also reported using the smartphone in the last five minutes before going to bed and in the first five minutes after getting up [48], it becomes obvious that humans are in need for “digital free-zones” in order to get enough sleep and start the new day fresh at the work place. Not surprisingly, both Internet addiction and its sibling smartphone addiction (see [8] for an explanation on the overlap of the terms) has been associated with poorer sleep quality/duration (e.g., [50,51]). Note that a study by Lanaj et al. showed that the here described effects

are bit more complex though [52]. Checking e-mails in the evening led only to a loss of productivity the next morning when participants of this study reported low control over their jobs.

To end this section: Smartphones represent a powerful technology changing our societies at rapid pace. With the fast distribution of the IoT, new solutions need to be established to provide workspaces, where we still can concentrate and be creative. Sometimes to become creative might also mean to be idle. Research on mind-wandering demonstrated that this kind of mental activity can enhance creative thought [53]. Therefore, too much usage of technological devices, in particular as a mean to distract oneself in situations such as waiting for the bus or on a commute, might undermine creative thinking. As mentioned in the beginning, IoT describes a world completely connected to the Internet. Here, things starting from the fridge in the kitchen to the toothbrush in the bathroom all will be connected to Internet. Insofar, we live more in more in digital worlds, not only when interacting with a classic computer or the smartphone as outlined earlier as a prime example of current human-computer-interaction (HCI) interaction.

#### 4. The Impact of Digital Worlds on the Human Brain

One very timely research endeavor deals with the investigation of the impact of digital worlds on our brains. Do digital worlds even have the potential to change our brain structure and brain functionality (hence also our psyches)? Will the current ongoing technological/digital revolutions have a lasting imprint on our mammalian—human nature? The answer to this question is very likely a “Yes”. However, given the lack of studies in the field dealing with this exact question, the nature of observable changes will be a matter for strong debate for decades to come. The following section summarizes some initial arguments, which, in our opinion, make it likely that such brain changes occur.

##### 4.1. Neuroplasticity of the Human Brain

First, abundant evidence from the neurosciences demonstrated over many years that our brains are not as hard-wired as thought for a long time. Our brain is characterized by being neuroplastic (e.g., [54]). This means that our daily experiences and our manifold interactions with diverse environments have a lasting impact on human’s most precious organ. Among others, this has been demonstrated convincingly by studies using structural magnetic resonance imaging. Here, researchers both investigate individual differences in (gray matter) brain volumes [55] and white matter architecture [56]. Such investigations are conducted on whole brain level, but more often also on smaller brain areas such as amygdala or hippocampus to better understand which brain areas exactly are shaped by a certain environmental influence.

Arguably, one of the most prominent studies in structural brain imaging (seen from a historical point of view) has been conducted by Maguire et al. [57]. This group of researchers demonstrated in their work that taxi drivers passing the straining orientation test called “The Knowledge” in London were associated with higher gray matter volumes of the posterior hippocampus compared to control persons. The (posterior) hippocampus is also known as navigational system of our brain (see also an earlier work by Maguire et al. [58]). Meanwhile, a follow-up study also brought the evidence that growth of this brain area can be causally linked to successful learning of London’s street map [59]. Abundant other examples exist demonstrating principles of neuroplasticity. Among these are the investigation of learning to juggle [60], learning for the medical exam [61], learning a foreign language [62], learning an instrument [63,64] and using mindfulness techniques [65]. Notably, changes due to different environmental exposures have also been shown on a functional brain level (e.g., see studies on psychotherapy/mindfulness [66–68] or functional brain changes due to blindness [69]). Deriving from such studies, one could sum up our brain’s rewiring processes by the (oversimplifying) slogan “Use it or lose it”. This means that when we learn something, the relevant brain regions for the practiced activity is trained like a muscle. Hence, a neuroplastic brain represents in many ways a normal and healthy state, something also made clear by nobel-prize carrier Eric Kandel, famous for his works on long term potentiation in the aplysia (e.g., [70]). In an interview he mentioned:



“My colleagues and I have found out that when an animal learns something, there is an alteration in the communication between nerve cells and, thus, the brain changes .... So you have an anatomically different brain after you have learned something than the brain you had before” [71]. Learning is re-wiring your brain. This means that your brain will have also slightly have changed after reading this article. Admittedly, currently, we largely lack the methods to demonstrate this on a molecular level in the living human brain. Aside from the positive training effects, detrimental effects on brain volume and also functions need to be mentioned. Such have been observed in many psychopathological states including reductions of hippocampal regions in depressed patients [72] and brain volume reductions in dementias such as Alzheimer’s disease (e.g., [73,74]). Let us switch to our initial question: Will interactions with digital worlds shape our brains?

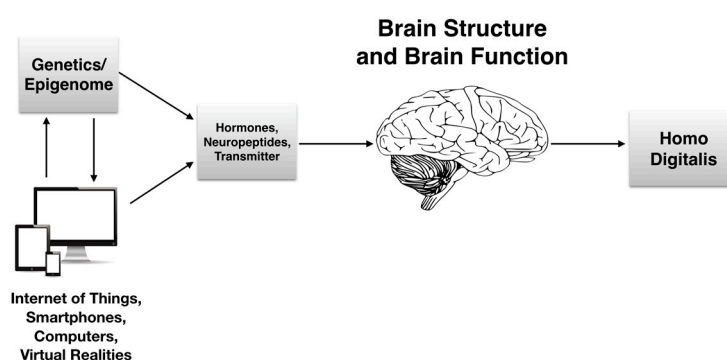
#### *4.2. Interaction with Digital Worlds and Brain Changes*

To answer this question, a large body of studies is noteworthy investigating associations between individual differences in tendencies towards Internet addiction and brain structure/function (for an overview see [75] or the compendium by Montag and Reuter [76]). Unfortunately, only few studies investigated if some of these Internet addiction-brain correlates are causally linked to Internet (over-)use. This would support our notion that digital worlds or better the interaction with digital worlds shape our brains and minds. A new study by Zhou, Montag et al. indeed provides support for the idea that digital worlds shape our brain [77]. In this study, it could be demonstrated that one hour of gaming of a well-known massive multi-player online role play game (MMORPG) over the time course of six weeks led to reduction of gray matter volume in the left orbitofrontal cortex, a brain region known to play a role in motivational and emotion regulation processes (e.g., [78,79]). At the beginning of the study, gaming experts (compared with gaming novices) were already associated with lower gray matter volume of the right OFC. Intriguingly, lower volumes of the right OFC were also associated with more addictive tendencies towards playing this game.

In other realms, and aside from Internet Gaming Disorder (see also the inclusion of the term as an emerging disorder in section III of DSM-5 [80]), also growing efforts can be seen to map brain correlates of digital world usage. Given that about two billion persons use Facebook [81] and about 800 million humans use Instagram [82], the investigation of these platforms’ effects on our brains without doubt represents an important and timely research endeavor. While many researchers deal with the question of whether Facebook usage even leads to depressive symptoms (see next section), first studies elucidated the mechanisms why so many humans spend much of their precious spare-time on these social online platforms. Aside from a review by Ryan et al. presenting different motives for Facebook usage (“relationship maintenance, passing time, entertainment, and companionship”, [83] p. 133), the neurosciences provided evidence that striatal activations including the nucleus accumbens represent a very prominent region of the brain to understand its response in the anticipation of reward in form of “Likes”. New studies by Sherman et al. underline the importance of striatal activity when participants of their studies were presented with own posted pictures from the Instagram platform receiving either many or only a few “Likes” [84,85]. Support for the role of the nucleus accumbens in Facebook usage comes from a recent brain structure study linking lower volumes of the nucleus accumbens to higher frequency and longer staying on the Facebook application as directly tracked on smartphones [86]. Days ago, a study has been accepted [87] demonstrating that the brain’s subgenual anterior cingulate cortex (ACC) gray matter volume is inversely linked to WeChat addiction, maybe the most important messenger app in Asia (about one billion users). The ACC plays a pivotal role in addiction research and lower ACC volumes have also been observed in substance dependent addiction (e.g., [88]). All presented brain imaging studies on social media usage did not reveal insights about potential causal changes due to spending (too) much time on platforms such as Facebook. For example, one question urgently to be answered is as follows: Do lower volumes of the ventral striatum’s nucleus accumbens represent a vulnerability factor for spending too much time on Facebook or does this already resemble a consequence of overboarding usage? Filling the void in a slightly

different framework, Gindrat et al. provided compelling evidence that daily smartphone usage indeed shapes the human brain [89]. The authors came in their EEG study to the conclusion that “Our results suggest that repetitive movements on the smooth touchscreen reshaped sensory processing from the hand and that the thumb representation was updated daily depending on its use. We propose that cortical sensory processing in the contemporary brain is continuously shaped by the use of personal digital technology” [89] (p. 109).

Comparable to the mentioned studies in the field of neuroplasticity, it seems that the daily interaction with digital worlds shape our brains, but we have to take into account the many different forms of possible online interactions to understand the to be expected complex ways on how our brains are changed (see also the complexity of grasping the different forms of online addictive tendencies; see [90–92]). Psychology and the neurosciences possess a great array of technologies to investigate the impact of digital worlds on our brains and psyches. The future hopefully will see more and more works asking how digital worlds change who we are both on structural and functional brain levels, as outlined in this section, but also on molecular and molar levels by considering (epi)genetic mechanisms. It is well known that much of our genetic information is densely packed in cell kernels and not available at all times. A myriad of environmental factors such as diet behavior, doing sports, undergoing psychotherapy, stressful life events, etc. modulate gene activity via methylation processes and histone modification (see [10,93]). What are the exact effects of digital worlds on the epigenome? Will they be observed in vast areas of the epigenome or be rather sporadic and likely depend on the specific kinds of interaction with digital worlds? For example, a digital stressor might impact on the epigenome of the glucocorticoid receptor gene [94,95] as glucocorticoids are of high relevance for the stress axis in the human body. If digital worlds impact on human interrelations, the epigenome of the oxytocin (receptor) gene might be altered (e.g., [96,97]), because oxytocin has been demonstrated to be of high relevance for social cognition [98]. Only by investigating the effects of digital worlds on the different levels of our brains will perhaps lead to an answer to the question if we are moving on towards Homo Digitalis (see also Figure 2). One of the reviewers noted that this figure and several topics discussed in the present work also fit very well with the research field of Neuro-Information-Systems (shortly called NeuroIS). Therefore, we point also to this important research area [99]. The overlap with the present work becomes clear, when considering the definition that NeuroIS “makes use of neuroscience and neurophysiological tools and knowledge to better understand the development, use, and impact of information and communication technologies” (taken from the summary of the cited NeuroIS book [99]).



**Figure 2.** Will interactions with the Internet of Things (IoT) shape the human brain towards Homo Digitalis? This can be investigated in the future on molecular genetic, epigenetic, endocrinological and neural levels (the picture of the brain and the technology devices have been taken from pixabay.com). The arrows demonstrate the direction of effects (please note that further arrows are imaginable, but are not presented here to keep the Figure simple).

## 5. What Are Our Emotional Needs in a Digital Society?

Aside from the question how digital environments shape our brains, an important research question deals with the question how we should design and create digital environments under consideration of our evolutionary emotional heritage.

### 5.1. A Short Introduction to Panksepp's Affective Neuroscience Theory

According to the prominent Affective Neuroscience Theory (ANT) of Jaak Panksepp, across the mammalian brain seven primary emotional systems have been homologously conserved [100]. These primal emotions represent tools for survival and dysbalances in neural circuitries underlying these basic emotions have been considered as sources of psychiatric disorders such as depression (see [101–103]). Jaak Panksepp dedicated his life career to the mapping of neuroanatomies underlying primal emotions by means of electrical stimulation of the brain and psychopharmacological challenges [104].

The seven primary emotions are called SEEKING, LUST, CARE and PLAY (positive emotions) and FEAR, SADNESS, and ANGER (negative emotions) (these are written in capital letters to not confound them with same sounding terms in the literature) [105]. The underlying neuroanatomies and molecules can be found in Montag and Panksepp [106]. Each primal emotion serves an important function with SEEKING being the neural circuit linked to exploration behavior mirroring our “Go Get It-System” (getting resources), LUST being of relevance for reproduction of our species, CARE as the emotional neural circuitry of relevance for nurturing one's own offspring so that they eventually also can have families when having grown up and finally the PLAY system of high relevance for learning social competencies in childhood and motoric skills. On the negative emotional side an in-built FEAR system signals our organisms a dangerous situation and fuels us with energy to get out of the danger zone. A SADNESS circuit is deeply anchored in all mammals, because we have the need for companionship (sapiens is stronger in groups) and in particular rely on strong social support in childhood (human children cannot survive without support of their caregivers). The SADNESS circuit is also called “Separation Distress” circuit as its activity is triggered by losing a loved one, being alone or as a child when the caregiver is out of sight. This results in a SADNESS (PANIC) reaction (crying) signaling to our closest kin our need for help. Finally, an ANGER/RAGE circuit, deeply rooted in our ancient mammalian brain, is (sometimes easily) triggered by situations of (strong) frustrations or in the animal world in situation of territorial conflict (see for an overview [101]; see also links between high ANGER and vengefulness [107]).

### 5.2. Interaction of Primary Emotional Systems with Digital Worlds

All these systems can interact with digital worlds and we will give some examples for such interactions in this section. First, diverse content exists on the world wide web to fulfill our digital needs, at least at first sight. Humans can act out their PLAYful tendencies by playing Internet games, they can choose to follow sexual desires by the consumption of online pornography or searching for a real mate via digital platforms such as Tinder or similar dating channels (LUST). The need for being CAREd for might be provided by self-help groups dealing with countless topics speaking to nearly everyone in need. Clearly, all this is accompanied by SEEKING activity, providing energy to follow these activities (it is the “Go Get It” system energizing us). On the other side, negative effects can also be stimulated by interactions with online worlds. A FEAR response might be elicited by both viewing gruesome content on video channel platforms, but also in a total different area of digital developments, outlined as follows: For many, the technological progress happens at a too quick pace and humans FEAR to not be able to hold up with these developments. With the rapid development of artificial intelligence, tremendous efforts will be in need to be invested to hold a tight grip on FEAR responses towards a faster and faster developing society. The emotion of SADNESS also has been shown to play an important role in the interaction of digital worlds. Abundant evidence demonstrates that

overusage of digital channels is strongly linked to depression (see next sentence), whereas SADNESS is well-known to be the primary emotion most closely linked to depression [103]. Both Internet and smartphone addiction have been shown to be tightly linked with ADHD/depression [50,108,109] and lower life satisfaction [110–112], although it is still unclear if depression is a causal factor for overusing digital worlds or a consequence of being online. In the opinion of the authors ultimately both causal chains are imaginable and likely to be true. For sad and lonely persons usage of social messenger platforms such as Facebook might provide companionship, but on the other hand also elicit envy. Social comparison might then backfire and also lead to stronger depression tendencies. See also the earlier part of our article, where we highlighted tendencies of humans to present the “best” parts of their lives online and thereby only presenting an artificial or only very small part of their identity. Finally, the ANGER response is also common when interacting with online digital worlds. In this context, the concept of Technostress needs to be considered [113,114]. Imagine yourself working on a document and having not saved your work for hours. Then, a computer breakdown happens. Alternatively, imagine that your operating system is working super-slow, while you are in a hurry. All this all too commonly results in an ANGER response. In this context, we also refer to new ideas on how to handle technostress using a stress-sensitive adaptive enterprise system [115].

Before coming to the next paragraph, dealing with the design of work places, etc. according to our emotional needs, we point to a limitation of the present section as we only deal with Panksepp’s AN theory, which arguably presents a rather narrow scope in the realm of emotion theories. Clearly other important emotion theories exist, which could be applied to human-computer-interaction (e.g., affect control theory [116]). Nevertheless, we demonstrated in a recent article why an AN framework is in particular useful for a neuroscientific study of technology use: In Table 12 of the work by Montag et al., a detailed roadmap is provided helping to provide researchers with abundant transmitter/neuropeptide candidates to be tested underlying emotional aspects of human-computer interaction [117]. To our knowledge such a roadmap has not been provided by other emotion theories. In so far the present Section 5 can be easily also brought together with Section 4 of the present work, where the impact of digital worlds on the human brain has been discussed on a structural/functional brain level. ANT will in particular be able to guide the molecular study of human-machine-interaction. To illustrate this with an example: it is well known that the neuropeptide oxytocin plays an important role for the primary emotions of SADNESS and CARE. If a study demonstrates that SADNESS/CARE might elicit certain usage patterns in the online world (or be a result of such an interaction), the study of oxytocin might illuminate mechanisms underlying this kind of HCI on molecular level.

### *5.3. Designing Virtual/Digital Worlds According to Our Emotional Needs*

If we take a step back now, we believe that it is time and of utmost importance to design digital worlds according to our emotional needs. On the one hand, it needs to be made sure that digital work spaces, online platforms and future developments in AI are designed in a way to not activate negative primary emotions deeply anchored in the ancestral parts of our brains. Activation of our ancient negative primary emotional systems results in negative affect and therefore counteracts our well-being. Progress towards a healthy and less stressful digital society can only be successful, when humans will get the impression that such a progress in digital areas is made transparent (think also about data privacy issues) and society at least aims to respect and include all citizens in this design process without leaving someone behind. In this context, see also a new work by Sindermann et al. (not published yet) assessing the attitude towards artificial intelligence in Germany, UK and China demonstrating that most of the study’s participants are somewhat indecisive in their attitude against AI [please contact author C.M. for more information]. Digital worlds have to be designed in ways that they bear few frustration potential and take into account the fact that we are all social beings. Many will state that some aims have been achieved already, because platforms such as Facebook, WhatsApp and WeChat are unbelievable successful (and these are “social” platforms). It should be reminded though that these platforms only do their job in parts well. Otherwise, usage of Facebook & Co. (Menlo Park, CA, USA)

would not result or go along with negative affect for many users. In particular, posts eliciting envious emotions in the perceiving person (perhaps via social comparison) might be linked to depressive symptoms. Hunting for Likes has been described as another problem in an earlier section of the present work. Moreover, our needs will always be to some extent lived out in an analogous way. If you imagine that something really bad happened in your life, would you prefer a supporting smiley via a digital message or a real hug? The neurosciences demonstrated the powerful impact of real interactions and human touch on our brain chemistries including the bonding hormone oxytocin [118,119].

## 6. “Digital Depression” and “Digital Etiquette”

Technology pervades all aspects of our lives, and exerts continuous impact on thinking, feeling and social interaction. In contrast to impairments of cognitive abilities (“Digital Dementia”) or physiological side-effects of technology use (e.g., effects of the typical smartphone body posture such as neckpain, backache, shallow breathing), the term “Digital Depression” [4] underlines threats to subjective well-being and happiness. In addition to “depression” in a pathological sense, as discussed in the last section, the term as used by Diefenbach and Ullrich is rather meant in a metaphorical sense, relating to the question of whether social media, fitness trackers, and continuous smartphone use are actually in line with one’s emotional and psychological needs, and in which cases the gradual development of routines around technology use may have led to effects that, if closely considered, nobody ever wanted [4].

### 6.1. Technology-Mediated Behavior in Conflict with Social Norms

In fact, smartphone mediated behavior often breaks up established social norms, for example the commitment to fixed appointments versus the nowadays convenient last minute cancelling/delay of a date via WhatsApp. If I know I can tell my date I will be late, I will pay a little less effort to make it in time. Likewise, it is just one click to send a message into a group chat (“sorry friends—I won’t make it tonight”), which is obviously a lower barrier than calling all those friends, explaining why one has to cancel the appointment and being confronted with their disappointment on the phone.

Another example is the more and more rare time of full attention for the conversation partner, often undermined by parallel smartphone use. In a recent survey on smartphone usage routines (in parallel to a study by the Pew research center from 2014), 97% reported daily usage for surfing the web, and 87% reported smartphone usage as their most recent social activity (e.g., meetings with friends) [6]. Interestingly, only 11% see their own smartphone usage in social settings as critical, seeing that phone use takes a lot of their attention. In contrast, the smartphone use by others is seen as more critical, 87% say that the phone use of others hurts the conversation or atmosphere “sometimes” to “frequently”. What seems easily manageable and no problem for one’s own person (i.e., paying attention to the direct conversation partner(s) and the phone in parallel), is perceived as annoying and a sign of disrespect if others show the same behavior. Please see the parallels with these biased views of one’s own behavior as discussed earlier with posting selfies.

To experience the omnipresent and often destructive influence of smartphones on conversational atmosphere, one often just needs to look around in a café or other places where people usually meet for social interaction. “Digital communication comes first” seems to have become an accepted habit, especially among younger users. Any impulse from the digital world—a phone call, a smartphone push notification, a text message—evokes instant reaction. You read the message, and probably even answer it immediately. This happens independent of the actual importance of the received message, the situation you are in, and independent of what your direct conversation partner may feel like if your attention repeatedly shifts away from an emotional meaningful moment to this smart piece of technology. Thus, it is no wonder that studies already demonstrated that a silent phone lying on the table has negative impacts on the conversation atmosphere [120]. The threat is always present—the conversation could be interrupted any time. Relating to such patterns of conflicts between social norms

and technology-mediated behavioral routines, Diefenbach et al. coined the term of “disrespectful technologies” [5].

### 6.2. Finding Healthy Routines of Technology Use: The Example of WhatsApp Usage

Indeed, finding healthy routines of technology use actually poses a challenge to people. For example, a recent study on the instant messaging service WhatsApp [121] revealed that the extent of the perceived communication quality/well-being depends on the individual usage routines and settings, such as single chats (consisting of only two communication partners) versus group chats with more than two people, or the usage of features such as “Last Seen” and “Read Receipts”. The “Last Seen” feature indicates the last time a communication partner opened WhatsApp. It thus allows the user to monitor others’ communication behavior and provides the ground for implicit cues and interpretations (e.g., although the communication partner was online and could have seen my message, he or she has not answered my message yet). The “Read Receipts” feature provides even more definite information about the communication partner’s WhatsApp behavior: two blue tick marks indicate that the communication partner has received and read the message. Given that such features are activated, it further plays a role whether users actively use these features, or whether they have turned it on but are not looking when someone was last online or if someone had already read their message (passive usage). One result of the study by Blabst and Diefenbach was that perceived stress of participants with active usage was significantly higher than perceived stress of participants with passive usage of “Read Receipts” [121]. Those findings are in line with previous studies [122,123], reporting that actively looking if a sent message has already been read, can create an atmosphere of stress. Another interesting finding was that especially participants who reported to feel stressed through WhatsApp features such as “Last Seen” and “Read Receipts”, provided more negative evaluations of WhatsApp usage. More specifically, those who tended to feel stressed through WhatsApp features also tended to perceive WhatsApp usage as not having done anything meaningful and a waste of time [121]. It is thus not the technology per se but rather the individual usage which can cause symptoms of “Digital Depression”.

### 6.3. Physiological and Psychological Symptoms of “Digital Depression”

Finally, technology-usage related phenomena on a physiological level may often be considered in relation to psychological aspects as a symptom of “Digital Depression”. For example, in a study by Drouin et al., 89% of the surveyed participants report the experience of the “phantom vibration syndrome”, i.e., feeling your phone is ringing or vibrating even though it is not [124]. On a psychological level, phantom vibrations may result from the fear to miss something important or even feel cut-off from the world, if not being in constant digital contact. Of note, this concept has been coined as *Fear of Missing Out* (abbreviation: Fomo; [125]). As Drouin et al. discuss, phantom vibrations may just be seen as a “contemporary versions of social sensitivity or social anxiety” and also related to personality traits [124] (p. 1496). In their study, participants higher in conscientiousness reported fewer vibrations and the strength of emotions associated with text messages was a positive predictor of experienced bothersomeness of phantom vibrations. This is also in line with other research demonstrating that low conscientiousness is associated with longer WhatsApp usage [92] and higher Internet/smartphone addiction [126]. Participants who have stronger emotional reactions to text messages (e.g., feeling disappointed when messages are not received) are more bothered by phantom vibrations, just as they are more likely to have negative psychological consequences of text message dependency (e.g., thinking life is empty without text messages), it is argued by the authors. Consequently, the authors conclude that this kind of emotional reactivity could also be related to “other types perceptual “hallucinations”, such as thinking that someone is calling out your name or, among those with anxiety sensitivity, perceiving innocuous sensory stimuli as potentially threatening” [124] (p. 1496). The vast majority of participants (91%) in the study by Drouin and colleagues, however, considered phantom vibrations to be “only a little” or “not at all” bothersome,

pointing at the question whether the physiological phenomenon per se must actually be considered as pathological [124].

#### 6.4. A Call for a Digital Etiquette

Altogether, the most relevant point seems how the constant smartphone usage affects our everyday life well-being and fosters or undermines opportunities for self-reflection and positive development. As outlined above, the fragmentation of everyday life poses a challenge to productivity and creative thinking. This not only pertains task fulfillment and work-related productivity but also personal development. In a world where unfilled time slots have totally vanished, there is less boredom and therefore less and less chance for self-reflection: in a moment where meaningful or uncomfortable questions could pop up, one has possibly already entered WhatsApp or YouTube (see also [127]).

Thus, while we cannot (and possibly should not) totally escape from technology, an important challenge is to reflect on one's personal way of use and deliberate limitations, thereby taking responsibility for one's own and others' wellbeing. Regarding the social dimension, it also needs a conscious reflection on a digital etiquette, i.e., the integration of technology in established culture, the adequate use of technology in social settings or intentionally technology-free areas. This aspect not only refers to peoples' private lives and well-being, but is also highly relevant for the working domain, where digital etiquette becomes part of the business culture design (see also [6]).

### 7. Conclusions and Limitations

Creating sustainable work places and zones to relax and fulfill our emotional urges in complex digital societies will present a major challenge for researchers across the globe. Naturally, we only could concentrate on a few challenges of digital societies and the IoT in this work. Another not further discussed challenge concerns data protection issues, because, with the ubiquitous IoT, everything we do will leave a trace. The emerging discipline of Psychoinformatics demonstrated already in first studies what insights can be derived from digital traces of the IoT with respect to psychodiagnostics on individual level (see for a review [40,128,129]; see also a recent interesting work on the potential of psychological targeting [130] perhaps in parts also endangering democratic processes [131]). To present the reader with a short summary of the most important research avenues to be tackled in the near future, according to this review/hypothesis paper, we add the following short bullet points:

- Understand how new forms of self-perception, -reflection, and -presentation affect social communication
- Find strategies to foster flow experiences in times of a fragmented life style
- Investigate how the interaction with digital worlds shape human brains and how we can hinder detrimental effects on the human brain
- Design digital worlds according to our emotional evolutionary heritage to foster well-being in digital societies
- Find meaningful rules for social communication in times of abundant available access to digital distractors

**Acknowledgments:** The position of C.M. is funded by a Heisenberg grant awarded to him by the German Research Foundation (DFG, MO2363/3-2).

**Author Contributions:** C.M. and S.D. conceived the structure of the present review; C.M. wrote Sections 1 and 3–5, whereas S.D. wrote Sections 2 and 6. Both C.M. and S.D. critically revised the complete manuscript.

**Conflicts of Interest:** The authors declare no conflict of interest.

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