

# Going digital: how technology use may influence human brains and behavior

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The digital revolution has changed, and continues to change, our world and our lives. Currently, major aspects of our lives have moved online due to the coronavirus pandemic, and social distancing has necessitated virtual togetherness. In a synopsis of 10 articles we present ample evidence that the use of digital technology may influence human brains and behavior in both negative and positive ways. For instance, brain imaging techniques show concrete morphological alterations in early childhood and during adolescence that are associated with intensive digital media use. Technology use apparently affects brain functions, for example visual perception, language, and cognition. Extensive studies could not confirm common concerns that excessive screen time is linked to mental health problems, or the deterioration of well-being. Nevertheless, it is important to use digital technology consciously, creatively, and sensibly to improve personal and professional relationships. Digital technology has great potential for mental health assessment and treatment, and the improvement of personal mental performance.

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## The “Digital Revolution”: remaking the world

Within a few decades, digital technology has transformed our lives. At any time, we can access almost unlimited amounts of information just as we can produce, process, and store colossal amounts of data. We can constantly interact, and connect, with each other by use of digital devices and social media. Coping with the daily demands of life as well as pursuing pleasure in recreational activities appears inconceivable without the use of smartphones, tablets, computers, and access to Internet platforms. Presently, over 4.57 billion people, 59% of the world population, use the Internet according to recent estimates (December 31<sup>st</sup>, 2019), ranging between 39% (Africa) and 95% (North America).<sup>1</sup>

People are spending an enormous, “insane” amount of time online, according to the latest Digital 2019 report compiled by Ofcom<sup>2</sup>: on average 6 hours and 42 minutes (06:42) each day (between 03:45 in Japan and 10:02 in the Philippines), half of that on mobile devices, on average equating to more than 100 days per year for every Internet user. According to a landmark report on the impact of the “decade of the smartphone,”<sup>3</sup> the average person in the UK spends 24 hours a week online, with 20% of all adults spending as much as 40 hours, and those aged 16 to 24 on average 34.3 hours a week. Britons are checking their smartphones on average every 12 minutes. In the US, teen screen time averages over 7 hours a day, excluding time for homework. Digital technology has become ubiquitous and entwined with our

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modern lives. As Richard Hodson in the *Nature Outlook* on “Digital Revolution,” 2018, concluded, “an explosion in information technology is remaking the world, leaving few aspects of society untouched. In the space of 50 years, the digital world has grown to become crucial to the functioning of society.”<sup>4</sup> This period of societal transformation has been considered “the most recent long wave of humanity’s socio-economic evolution”. As a “meta-paradigm of societal modernization based on technological change” induced by the transformation of information, it supersedes earlier periods of technological revolution based on the transformation of material and energy, respectively, spanning over 2 million years altogether (Hilbert, p 189 in this issue).

In particular, the excessive use of digital technology during adolescence has given rise to grave concerns that this technology is harmful and damages the (developing) brain or may even cause mental health problems. Public concern culminated in Jean Twenge’s 2017 article “Have Phones Destroyed a Generation?,”<sup>5</sup> which linked the rise in suicide, depression, and anxiety among teens after 2012 to the appearance of smartphones. All-too-familiar pictures: parents and children, or couples, or friends, at the table, staring at their phones, texting; colleagues staring at screens, busy with emails; individuals, heads down, hooked on their phones, blind to their surroundings, wherever they are. Individuals interacting with their devices, not with each other. “The flight from conversation,” which may erode (close) human relationships and with them the capacity for empathy, introspection, creativity, and productivity - ultimately, the social fabric of our communities. Sherry Turkle, who has studied the relationship of humans with technology for decades, has articulated these concerns in *Alone Together* and *Reclaiming Conversation*.<sup>6,7</sup> Thus, “life offline” has become a consideration and advice to limit screen time and practice digital minimalism has become popular.<sup>8</sup> The concerns about screen time and efforts to keep us from staring at our devices and detox our digital lives came to a sudden end with the COVID-19 coronavirus pandemic.<sup>9</sup> Almost overnight, nearly our entire personal, professional, educational, cultural, and political activities were moved online. The dictum of social distancing necessitated virtual togetherness.

### Changing human brains and behavior?

The use of digital technology has changed, and continues to change, our lives. How could this affect human brains

and behavior, in both negative and positive ways? Apparently, the ability of the human brain to adapt to any changes plays a key role in generating structural and/or functional changes induced by the usage of digital devices. The most direct evidence for an effect of frequent smart phone use on the brain is provided by the demonstration of changes in cortical activity (Korte, p 101 in this issue). Touching the screen repetitively – the average American user touches it 2176 times a day<sup>10</sup> – induces an increase of the cortical potentials allotted to the tactile receptors on the fingertips, leading to an enlargement, ie, reorganization of the motor and sensory cortex. It remains to be determined whether this reshaping of cortical sensory representation occurs at the expense of other motor coordination skills. Processes of neuroplasticity are particularly active in the developing brain, especially during stages of dynamic brain growth in early childhood. For instance, as demonstrated by functional magnetic resonance imaging (fMRI), extensive childhood experience with the game “Pokémon” influences the organization of the visual cortex, with distinct effects on the perception of visual objects even decades later. Furthermore, as shown by diffusion tensor MRI, early extensive screen-based media use is significantly associated with lower microstructural integrity of brain white matter tracts supporting language and literacy skills in preschoolers.<sup>11</sup> Also, adolescence is a time of significant development, with the brain areas involved in emotional and social behavior undergoing marked changes. Social media use can have a profound effect; eg, the size of an adolescent’s online social network was closely linked to brain anatomy alterations as demonstrated by structural MRI. The impact of digital technology use, both negative and positive, on these and many more brain-related phenomena has been elaborated in the review by Korte, who provides a comprehensive overview of the field.

The most direct approach to assess the effect of excessive digital media use on (adolescent) brains presently appears to be the analysis of the neurobiological mechanisms underlying Internet and Gaming Disorder (IGD) (Weinstein and Lejoyeux, p 113 in this issue). The authors thoroughly survey existing brain imaging studies, summarizing the effects of IGD on the resting state, the brain’s gray matter volume and white matter density, cortical thickness, functional connectivity, and brain activations, especially in regions related to reward and decision making, and neurotransmitter systems. Taken together, individuals

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with IGD share many typical neurobiological alterations with other forms of addiction, but also show unique patterns of activation specifically in brain regions which are associated with cognitive, motor, and sensory function. The effects of the Internet on cognition have been comprehensively elaborated by Firth et al.<sup>12</sup> Examining psychological, psychiatric, and neuroimaging data, they provide evidence for both acute and sustained alterations in specific areas of cognition, which may reflect structural and functional changes in the brain. These affect: (i) attentional capacities, which are divided between multiple online sources at the loss of sustained concentration on a single task; (ii) memory processes - permanently accessible online information can change the ways in which we retrieve, store, recall and even value knowledge; and (iii) social cognition; the prospects for social interactions and the contexts within which social relationships can happen have dramatically changed. A complementary contribution rounding up these reviews is provided by Small et al (p 179 in this issue). Among the possible harmful “brain health consequences,” these investigators emphasize attention problems and their potential link to symptoms of attention deficit-hyperactivity disorder (ADHD); furthermore the (paradoxical) association of excessive social media use with the perception of social isolation, observable at any age; the impaired emotional and social intelligence, poorer cognitive/language and brain development, and disrupted sleep. A substantial part of this review is devoted to the positive effects benefiting brain health in adults and the elderly, which are referred to below. Independent of ongoing research on the negative and positive implications of digital technology use, there remains a common feeling that there is something about the whole phenomenon that is just not “natural.” “We did not evolve to be staring at a screen for most of our waking hours. We evolved to be interacting with each other face-to-face, using our senses of smell and touch and taste – not just sight and sound... it cannot be healthy to stray so far from the activities for which nature has shaped our brains and our bodies.” Giedd (p 127 in this issue) challenges this notion in his fascinating review on “The *natural* allure of digital media,” putting the intensive digital media use during adolescence into a grand evolutionary perspective. He argues that the “desire for digital media is in fact exquisitely aligned with the biology of the teen brain and our evolutionary heritage,” with three features of adolescence being particularly relevant to this issue: (i) hunger for human connectedness; (ii) appetite for adventure; and (iii) desire for information.

### Screen time: boon or bane?

As with any major innovation that has a profound impact on our lives, finding useful information and orientation means discerning scientific evidence from media narratives. Thus, synthesizing data from recent narrative reviews and meta-analyses including more than 50 studies, Odgers and Jensen (p 143 in this issue) could not confirm a strong linkage between the quantity of adolescents’ digital technology engagement and mental health problems. “There doesn’t seem to be an evidence base that would explain the level of panic and consternation around these issues” said Odgers, in the *New York Times*.<sup>13</sup> The authors point to significant limitations and foundational flaws in the existing knowledge base related to this topic; for instance, the nearly sole reliance on screen time metrics; the disregard of individual differences; the circumstance that almost none of the study designs allowed causal inference. On the other hand, a highly robust finding across multiple studies was that offline vulnerabilities (such as risks present in low-income families, communities, etc) tend to mirror and shape online risks. The observed social and digital divides are presently being magnified through the coronavirus crisis and most likely to increase in the future, further amplifying the existing inequalities in education, mental health, and prospects for youth. The authors strongly advocate the need and opportunities to leverage digital technology to support youth in an increasingly digital, unequal society in an uncertain age; see their suggestions for parents, clinicians, educators, designers and adolescents in *Box 1*. Similarly, performing an in depth overview of the existing literature, Dienlin and Johannes (p 135 in this issue) could not substantiate the common concerns that digital technology use has a negative impact on young (and adult) peoples’ mental well-being. Their findings imply that the general effects are in the negative spectrum but very small – potentially too small to matter. Importantly, different types of use have different effects: thus, procrastination and passive use were related to more negative effects, and social and active use to more positive effects. Thus, “screen time” has different effects for different people. Digital technology use tends to exert short-term effects on well-being rather than long-lasting effects on life satisfaction. “The dose makes the poison”: both low and excessive use are related to decreased well-being, while moderate use increases well-being. With a strong sense for clear explanation, the authors introduce the concepts, terms, and definitions underlying this complex field, a most

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valuable primer to educate the interested reader, while also addressing the methodological shortcomings that contribute to the overall controversial experimental evidence.

Thus, against common concerns, digital technology as such does not affect mental health or deteriorate well-being. Its use can have both negative and positive consequences. Technology simply does not “happen” to people. Individuals can shape the experiences they have with technologies and the results of those experiences. Thus, it is important to shift the focus towards an active, conscious use of this technology, with the intention to improve our lives and meaningfully connect with each other. This has become, more than ever, important now: “There is increased urgency, due to coronavirus, to use technology in ways that strengthen our relationships. Much of the world has been working, educating, and socializing online for months, and many important activities will remain virtual for the foreseeable future. This period of physical distancing has shed light on what we need from technology and each other... “ Morris (p 151 in this issue) introduces her article addressing the enhancement of relationships through technology in the most timely manner with a preface on “Connecting during COVID-19 and Beyond.” In this synopsis, she sums up five directions to “build on as we connect during and after the pandemic.” Furthermore, in her review, she examines how technology can be shaped in positive ways by parents, caregivers, romantic partners, and clinicians and illustrates with real life examples creative and sensible ways to adapt technology to personal and relational goals (see also ref 14). Highlighting the importance of context, motivation, and the nuances of use, this review encourages people to understand how technologies can be optimally used to improve personal and clinical relationships.

### Digital tools in diagnosis and therapy

The use of digital tools for practical clinical applications and improvement of mental health conditions is gaining increasing acceptance, especially due to smartphone accessibility. This could fill at least in part the treatment gap and lack of access to specialized (psychotherapeutic) care, particularly in developing countries. Even in countries with well-developed health care systems, only a minority of patients receives treatment in line with the recommendations provided by evidence-based treatment guidelines. Thus, as elaborated in a thorough, comprehensive review

by Hegerl and Oehler (p 161 in this issue), web-based interventions, especially in the case of Major Depression (MD), a highly prevalent and severe disorder, promise to be a method that provides resource-efficient and widespread access to psychotherapeutic support. The authors provide detailed information on available tools for digital intervention and their core principles; these are mostly based on principles of cognitive behavioral therapy, but also include elements of other psychotherapeutic approaches. As evident from meta-analyses summarizing studies that use face-to-face psychotherapy as a comparator, digital interventions can have equivalent antidepressant efficacy. Importantly, web-based interventions are most efficient when accompanied by adequate professional guidance and, if well designed, can be successfully integrated into routine care. The authors also address carefully the risks and limitations as well as unwanted effects of available digital interventions. Another powerful digital technology is gaining importance as a clinical tool in mental health research and practice, virtual reality (VR). According to Valmaggia and collaborators (p 169 in this issue), “At any time or place, individuals can be transported into immersive and interactive virtual worlds that are in full control of the researcher or clinician. This capability is central to recent interest in how VR might be harnessed in both treatment and assessment of mental health conditions.” To date, VR exposure treatments have proven effective across a range of disorders including schizophrenia, anxiety, and panic disorders. In their review, the authors summarize comprehensively the advantages of using VR as a clinical assessment tool, which could “radically transform the landscape of assessment in mental health.” Thus, VR may overcome many of the limitations concerning the diagnosis of psychological phenomena through its ability to generate highly controlled environments, that is, real-world experiences. In addition to increasing ecological validity, VR enhances personalization, that is, VR experiences can be tailored to match individual needs, abilities, or preferences. Furthermore, VR enhances an individual’s engagement with the test or assessment. Additional advantages include the capture of real-time, automated data in real-world contexts. In sum, the authors have thoroughly addressed the opportunities and challenges of VR in any relevant aspect. Finally, to complement the applications of digital technology to improve mental health, Small et al (p 179 in this issue) provide, in the second part of their review, rich information about specific programs, videogames, and other online tools, particularly for the

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aging brain. These may provide mental exercises that activate neural circuitry, improve cognitive functioning, reduce anxiety, increase restful sleep, and offer many other brain health benefits.

## Emerging key messages

Several key messages emerge from these reviews, which cover a substantial amount of studies: first of all, scientific evidence does not support the common concerns that excessive use of digital technology causes mental health problems and a deterioration of well-being. There is increasing consensus that the methodological foundation is weak in many studies, in part explaining the controversial results and small effect sizes obtained to date. Above all, it appears absurd to collapse, as was common practice, the highly complex interaction between “machine and man” into a uniform quantitative screen time measure. Research,

public policies, and interventions need to focus on the *user*, and not the *extent of usage* of technology. *Who* spends time and in *what form* with the digital devices is what is important. This leads us to what should be the main subject of interest, but has mostly — conceptually and factually — been disregarded: the human “individual” with its motivation, intentions, goals, needs, predispositions, familial, educational and social background, and support systems, or lack thereof. Needless to say, this calls for the consideration of individual differences in all aspects of research and application. Thus, digital technology is not intrinsically good or bad: it depends on the uses it is being put to by the user, and it can be utilized by individuals in both negative and positive ways. Now, more than ever, during and post coronavirus times, it is important that technology is taken advantage of to improve communication and enhance personal, professional, and societal relationships, guaranteeing equal opportunities for access and development for all. ■

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