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**From "online brains" to "online lives": understanding the individualized impacts of Internet use across psychological, cognitive and social dimensions**

Joseph Firth[1,2], John Torous[3], José Francisco López-Gil[4,5], Jake Linardon[6], Alyssa Milton[7,8], Jeffrey Lambert[9], Lee Smith[10], Ivan Jarić[11,12], Hannah Fabian[1], Davy Vancampfort[13,14], Henry Onyeaka[15], Felipe B. Schuch[16,17,18], Josh A. Firth[19,20]

[1]Division of Psychology and Mental Health, University of Manchester, Manchester Academic Health Science Centre, Manchester, UK; [2]Greater Manchester Mental Health NHS Foundation Trust, Manchester Academic Health Science Centre, Manchester, UK; [3]Division of Digital Psychiatry, Department of Psychiatry, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA, USA; [4]Health and Social Research Center, Universidad de Castilla-La Mancha, Cuenca, Spain; [5]Department of Environmental Health, T.H. Chan School of Public Health, Harvard University, Boston, MA, USA; [6]School of Psychology, Deakin University, Geelong, VIC, Australia; [7]Central Clinical School, Faculty of Medicine and Health, University of Sydney, Sydney, NSW, Australia; [8]Australian Research Council, Centre of Excellence for Children and Families over the Life Course, Sydney, NSW, Australia; [9]Department for Health, University of Bath, Bath, UK; [10]Centre for Health Performance and Wellbeing, Anglia Ruskin University, Cambridge, UK; [11]Laboratoire Ecologie, Systématique et Evolution, Université Paris-Saclay, Gif-sur-Yvette, France; [12]Biology Centre, Czech Academy of Sciences, Institute of Hydrobiology, České Budějovice, Czech Republic; [13]Department of Rehabilitation Sciences, KU Leuven, Leuven, Belgium; [14]University Psychiatric Center, KU Leuven, Leuven, Belgium; [15]Department of Psychiatry, Massachusetts General Hospital, Boston, MA, USA; [16]Department of Sports Methods and Techniques, Federal University of Santa Maria, Santa Maria, Brazil; [17]Institute of Psychiatry, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil; [18]Institute of Health Sciences, Universidad Autônoma de Chile, Providência, Chile; [19]Department of Biology, University of Oxford, Oxford, UK; [20]School of Biology, University of Leeds, Leeds, UK

In response to the mass adoption and extensive usage of Internet-enabled devices across the world, a major review published in this journal in 2019 examined the impact of Internet on human cognition, discussing the concepts and ideas behind the "online brain". Since then, the online world has become further entwined with the fabric of society, and the extent to which we use such technologies has continued to grow. Furthermore, the research evidence on the ways in which Internet usage affects the human mind has advanced considerably. In this paper, we sought to draw upon the latest data from large-scale epidemiological studies and systematic reviews, along with randomized controlled trials and qualitative research recently emerging on this topic, in order to now provide a multi-dimensional overview of the impacts of Internet usage across psychological, cognitive and societal outcomes. Within this, we detail the empirical evidence on how effects differ according to various factors such as age, gender, and usage types. We also draw from new research examining more experiential aspects of individuals' online lives, to understand how the specifics of their interactions with the Internet, and the impact on their lifestyle, determine the benefits or drawbacks of online time. Additionally, we explore how the nascent but intriguing areas of culturomics, artificial intelligence, virtual reality, and augmented reality are changing our understanding of how the Internet can interact with brain and behavior. Overall, the importance of taking an individualized and multi-dimensional approach to how the Internet affects mental health, cognition and social functioning is clear. Furthermore, we emphasize the need for guidelines, policies and initiatives around Internet usage to make full use of the evidence available from neuroscientific, behavioral and societal levels of research presented herein.

**Key words**: Internet, social media, cognition, mental well-being, attention, memory, social functioning, addiction, artificial intelligence, culturomics

The digital revolution has transformed almost every aspect of our daily lives. From our leisure activities, to professional endeavors, to social interactions, the Internet has embedded itself deep in the core of contemporary lifestyles worldwide. What is less apparent, however, is the potential impact of this pervasive technological adoption on the human mind itself. In 2019, this topic drew the attention of a paper in this journal[1], which reviewed the literature around how the Internet may be influencing our attentional capacities, memory processes and social cognition.

Since the publication of those initial findings, the integration of the Internet into societal fabric has continued to expand. As reflected by a Pew Research Center's analysis[2], there has been a consistent growth in smartphone ownership and an ongoing upward trajectory in global Internet utilization, with nearly 50% of youth describing themselves as "always online" in 2023. Recent studies have also shown how these trends have accelerated in the context of the COVID-19 pandemic[3], which produced a marked shift in the population's reliance on digital technologies for work and social communication, further entrenching digital technology into daily routines.

Along with observing even further adoption, we are also learning more about *how* people are spending their time online, which is ever-changing. For instance, there is an ongoing shift towards online media (primarily music and video), away from traditional media broadcasting. Radio networks lose ground to online music streaming and podcasts, with the average user spending around 100 min each day listening to music via apps, and a further hour listening to podcasts[4]. Online video platforms have grown considerably in recent years, now rivalling traditional television in terms of total viewing time among users[5], and YouTube has become the most popular social media website[2].

Within this, the nature of online videos has shifted, due to innovations in the delivery of short-form video content following the meteoric rise of TikTok, which gained global fame after amassing over a billion downloads in 2019[6]. In turn, Instagram, Facebook and YouTube have introduced similar short-form video features, such as "reels" and "shorts". Collectively, this shift has profoundly influenced the way in which online videos are produced and consumed worldwide.

There is also a concomitant change in the perceived societal value attached to online entertainment. For instance, a university in Ireland offers now a four-year bachelor's degree course in content creation and "influencing"[7].

However, the latest global data from 2023[4,5] show that social media continue to represent the largest portion of Internet usage in the modern digital landscape, with working-age users spending over 2.5 hours daily on various platforms, accounting for 38% of their total time. While 24% of teens reported being online constantly in 2015, that number rose and remained at 46% in both 2022 and 2023[2]. Accordingly, much of the evolving scientific and public debate

around the psychological and societal impacts of the Internet has focused on this facet of the online world, with numerous recently emerging national health policy documents and clinical guidelines[8,9], along with a mass of new academic literature across all aspects of how the Internet may influence mental health, cognition and sociality.

In response to recent changes in our perceptions and understanding around Internet usage, this paper updates the 2019 review[1], expanding upon the leading hypotheses around how the Internet can impact upon mental, cognitive and social health. We take into account the latest data from both quantitative and qualitative research, to shed new light on the experiential aspects of how Internet usage can affect individuals' mental states, and elucidate the putative sociodemographic, psychological and behavioral factors that may mediate this.

## PSYCHOLOGICAL IMPACTS OF INTERNET USE: A PERSONALIZED PERSPECTIVE

The potential impact of Internet use on mental health continues to permeate mainstream media and public consciousness, particularly with regards to social media and youth. For instance, the US Surgeon General's 2021 statement on adolescent mental health[9] drew considerable attention towards this, focusing mostly on the negative impacts of social media on mental health, and even pointing towards this as a suspected driving factor of the dramatic increase in suicide rates and self-harm seen among US young people in recent years. Additionally, an ongoing lawsuit brought by several US states against Meta, the company which owns Facebook, alleges that the company knowingly harmed the physical and mental health of young users by utilizing psychologically manipulative features on its platforms[10].

On the other hand, major mental health advocacy groups, such as the US National Alliance on Mental Illness (NAMI), while recognizing the potential psychological risks of social media, also highlighted some real-world benefits observed in certain contexts. In particular, the in-depth discussions about mental health which can unfold on these platforms are thought to be reducing stigma, improving understanding, and providing a valuable source of peer support for some people[11]. As the public debate on this issue inevitably continues, it is necessary to re-evaluate the empirical evidence regularly, in order to inform our understanding and public health advice/initiatives.

Overall, recent studies have indicated that the potential negative impacts from Internet use (and particularly social media) are not heavily linked to the amount of time spent online. For instance, a large-scale epidemiological research[12] synthesized data from reviews, meta-analyses and cohort studies to assess digital technology's correlation with depression and anxiety, and a robust analysis of these relationships in adolescents was conducted across multiple national datasets[13]. Both studies found only minimal evidence to suggest a causal or

direct relationship between the amount of time that people spend online and mental health outcomes.

Such null findings on linear associations may partly be due to a U-shaped curve existing between Internet use and well-being. In fact, a further study within the US National Survey of Children's Health[14] found that moderate levels of digital screen time (1 to 2 hours per day) were associated with better psychosocial functioning among children than low (i.e., <1 hour) or high (~5 hours) levels.

While these large-scale studies are informative on a macro level, our ability to determine the nature of underpinning relations between Internet use and mental health from such research alone is limited. The last five years have seen an increase in studies attempting to provide causal evidence by assessing the effects of social media withdrawal on mental health. These studies hypothesized that, if such technologies are driving adverse psychological states from daily engagement, withdrawing oneself partially or entirely should produce notable changes in well-being.

Bringing together the latest evidence on this, a 2023 systematic review of 23 randomized controlled trials (RCTs)[15] indicated that partially or completely abstaining from social media use does appear to produce significant improvements across a range of mental health domains. Depression was the most frequently assessed outcome, with 7 out of 10 RCTs finding medium-to-large effects in favor of the social media withdrawal intervention. Three out of six RCTs assessing anxiety reported notable positive effects from withdrawal, while three out of eight RCTs assessing general well-being found only small indication of benefit. Some of the RCTs observed simultaneous benefits occurring across multiple domains, with an RCT of 111 adults reporting medium-to-large effects on depression, anxiety and well-being among those randomized to a week-long social media break, compared with controls[16].

On the other hand, a robust study of three preregistered field experiments (N=600) found that abstinence days from social media yielded no differences in well-being compared to using social media normally[17]. Furthermore, some studies have observed negative psychological effects from cutting down on social media. For example, one RCT of 78 students from the United Arab Emirates observed decreased life satisfaction and increased loneliness after a seven-day abstinence from social media compared with a control group[18], whilst another crossover trial in the UK found that daily withdrawal from social media decreased social connection, thus reducing well-being[19].

Overall, there has been a slew of null or contradictory findings emerging from both large-scale observational research[12-14] and RCTs[16-19] examining the "absolute" effects of social media engagement/withdrawal on mental health. Therefore, future research must move towards a more nuanced approach examining the factors and context which determine the psychological outcomes of social media engagement.

Our previous review[1] concluded by highlighting the need for further research to establish how individual characteristics, such as age, may influence the effects of Internet usage on mental health. Since then, the nuances of how age may affect the psychological impacts of Internet use have been deeply explored in a study[20] which analyzed the interaction between social media use, life satisfaction, and developmental stages in a large UK cohort including 84,011 individuals aged 10 to 80 years.

The findings revealed "windows of sensitivity" to the adverse psychological impacts of social media through the life course, with discernible differences between males and females in the developmental risks. Specifically, negative impacts from overuse of social media were first seen among females in the earliest stages of adolescence, between the ages of 11 and 13 years. In males, adverse relations between social media and life satisfaction appeared between 14 and 15 years of age, with both groups showing a further developmental sensitivity towards the end of adolescence (19 years)[20].

Along with age and gender, other studies have begun to observe that individual characteristics and situational factors can affect vulnerability to adverse outcomes of Internet use, typically finding that the same risk factors which increase marginalization and disadvantage "offline" (such as family dysfunction, mental health problems, disability, subjective feelings of loneliness and social isolation) also increase the vulnerability to online harms in young people[21-24].

From an academic perspective, these valuable findings serve to demonstrate that considering putative vulnerability factors within population-scale analyses can increase our understanding of how Internet usage impacts mental health. From a practical perspective, the windows of sensitivity and the key risk factors identified are immediately useful, in order to start exploring strategies to ameliorate adverse consequences of online time in those most at risk.

While recognizing the utility of such progress, the field can now move beyond it, by searching for the inter- and intra-individual factors underpinning people's "online lives", and how they determine the psychological, cognitive and social outcomes of Internet usage.

**ENDLESS ENGAGEMENT IN THE ONLINE WORLD**

The association between digital technology use and mental health is complex. On the one hand, it appears that some public concerns over general technology use and adverse outcomes in young people may be overblown, given the lack of robust evidence for overall effects[25]. That said, the Internet does inarguably provide a platform for young people to become exposed to "online harms", with many valid concerns expressed over obvious threats

such as cyberbullying, exposure to pornographic material, and gambling[26-29]. Moreover, the gravity of the issue of exposure to suicide-related content has been highlighted by a study[30] reporting that almost a quarter of young people who died by suicide in a UK sample had suicide-related Internet experiences (e.g., searching for methods of suicide). Since these discrete threats from online world have been comprehensively examined elsewhere[22,31,32], we instead seek here to elucidate how the nuances of general Internet usage, apart from these high-risk activities, may affect cognitive and psychological outcomes.

The most problematic Internet usage is referred to as "Internet addiction". Instead of defining it by a quantifiable amount of time spent online, an addiction to the Internet is better conceptualized as a compulsive need to engage with specific online platforms (e.g., social media or gaming) at the expense or neglect of other personal, social and occupational responsibilities[33]. Key indicators of addiction include prominent shifts in mood when away from the Internet for even a relatively short while (withdrawal symptoms), an increasing amount of time spent on these platforms to achieve satisfaction (tolerance), and conflict with other activities and/or real world social relationships[33].

Despite the term "addiction" describing a relatively extreme usage that affects real-world social functioning, a recent meta-analysis across 32 countries involving 63 independent samples with >34,000 individuals[34] revealed that, even under the strictest classifications of addiction to social media, the general prevalence is estimated to be around 5%.

While many "normal" behaviors not involving the Internet have the potential to become addictive, an emerging body of qualitative research has begun to shed light on how the online world specifically seems to exert a strong compulsion towards constant usage in some young people[26,27,29,35-41]. Adolescents express concerns about a "*constant stream of entertainment*"[41], affecting critical activities such as homework and sleep[38,41]. Some young people connect their digital behaviors to addiction-like cravings. For instance, in a mixed methods study conducted in the US, focusing on university students' social media use, a participant elaborated: "*I created an unhealthy habit for myself that is like playing a slot machine. It leads to me craving to check social media more for the gratification*".

Some parents also directly witness the addictive potential and resultant distraction and unresponsiveness of their children[27,35]. For example, in an Australian qualitative study[27], parents reported that certain online games are so addictive for children that they can impact self-regulation and standard self-care behaviors to a dramatic extent, in even the youngest of digital media users: "*We had to ban Roblox for ages because he wouldn't go to the toilet. He would wet himself playing games because he didn't want to die in the game*".

The difficulty of self-regulation when engaging with social media is also depicted by the novel qualitative literature capturing the experiential aspects of this topic, with participants describing in detail the challenges towards cutting down their time on such platforms[42]. Several

users describe how social media algorithms are designed to encourage prolonged, high-frequency usage[41]. Platforms such as Instagram may promote or exacerbate compulsive use through push notifications, algorithm-generated content recommendations, and continuous binge-watching functionalities such as auto scrolling[29,40]. Notifications, especially from social media and online messaging, are viewed as rewarding yet highly addictive, contributing to extended screen time from the perspectives of young people, parents and health professionals[36,40,43]. Despite attempts to turn off notifications[41], young adults describe feeling compelled to check them, and the act of checking becomes a habitual process[29], contributing to extended screen time[36].

Several of these engagement facilitators feature prominently in the aforementioned lawsuit from US states against Meta (Facebook), which suggests that the company used: a) dopamine-manipulating recommendation algorithms; b) social comparison features; c) audiovisual and haptic alerts that cause users to turn their attention away while at school and sleeping; d) visual filters that can promote body dysmorphia, in order to gain and sustain young people's engagement[10].

The psychological mechanisms behind this compulsion to check, and the difficulty to disconnect, are described as challenges to attention, self-control, and time management. For instance, the ability to successfully self-regulate engagement can be challenging when users are in a "*trance*" or "*mindlessly scrolling*"[42]. In an Australian qualitative study with university students, a young person reported: "*I need someone else to kind of tell me, to just catch me out on that, because once I'm on there and I'm scrolling, … I'm stuck*"[42].

In recognition of this, various self-regulation strategies have been reported by participants in qualitative studies, such as reducing accessibility by moving phones out of reach or hiding them, muting phones, disabling notifications, setting alarms, planning out the day, and keeping busy[41,42,44]. In some studies with adults, participants expressed a strong motivation to uphold digital discipline, but acknowledged the need for more severe restrictions, such as uninstalling apps, to achieve self-determined disconnection, especially during periods of emotional vulnerability[44].

## FROM NURTURING CONNECTIONS TO "FEAR OF MISSING OUT"

As the science in this field is progressing, it is becoming clear that the Internet-brain relations are not only dependent on quantity of usage, or even individual characteristics such as age, gender or other factors which may affect vulnerability. A more fine-grain understanding of the impact of Internet usage on mental health can be gleaned by moving away from looking at outcomes on a linear spectrum of "good" to "bad". It should be acknowledged that users

can be experiencing both positive and negative psychological effects of Internet usage simultaneously, through the multitude of ways by which their lives are entwined with the online world[45].

Studies have been using objective metrics to differentiate between types of social media activity, such as primary posting one's own content vs. commenting on or "liking" other people's posts, or "active use" (e.g., targeted one-on-one exchanges such as sending private messages or posting status updates) vs. "passive use" (e.g., monitoring the online life of other users' profiles) [46,47]. However, such research has so far failed to produce consistent evidence for a specific style of Internet engagement driving positive or negative mental health outcomes[46,47]. Instead, most of the evidence on how specific uses of the Internet can differentially affect mental health is found in research focusing on the experiential aspects of young people's engagement with digital devices. For instance, large scale surveys have found that, while over 90% of adolescents identify at least one way in which technology is negatively affecting their everyday lives[48], the majority also report that being online has positive effects on their work, education and social relationships[49].

Social media platforms provide opportunities for users to maintain and strengthen social connections, which can be especially beneficial in circumstances where physical interactions are limited, such as remote working, or for individuals with mobility issues[50]. In particular, there is research evidence that social media use contributes to the overall ability of older adults to engage more fully and effectively in social contexts, thereby enriching their social well-being and interactions[50]. Moreover, during the COVID-19 pandemic, several studies observed that social media usage ameliorated some of the social isolation produced by lockdowns in youth[51], while adolescents who did not have access to a computer experienced substantially worsened mental health outcomes over that period[52].

Using the Internet to stay connected to friends is a prime example of a behavior that can bring psychological benefits. However, the social aspects of the online world can also result in a "fear of missing out", a phenomenon referred to as "FOMO". FOMO is people's apprehension that they are missing rewarding experiences which others are having, resultantly creating a strong desire to stay continually connected, which has been linked with both increased social media use and poorer mental health outcomes[53].

A few RCTs have explored this experimentally. One trial of 61 adults observed lower rates of FOMO after a 7-day social media break compared to a control group[54], while another trial of 143 students found no differences in FOMO after participants were asked to limit their social media use to 10 min per day for 3 weeks compared to using social media as usual[55]. Indeed, it is even conceivable that withdrawing from social media could increase adverse emotions tied to FOMO in long-term users whose social lives are deeply connected with online happenings.

Again, the nuances of this phenomenon are best captured in qualitative research, which shows that motivation to engage and spend more time on social media is compounded through social and recognition needs, exacerbated by comments and "likes", which foster habitual and compulsive usage[39,41]. These themes are covered in a single quote of a female teenager reporting that: "*It's just so addictive. When you hear a notification it's really hard not to look at it, especially when it's a fun group chat with your friends and you don't want to miss out*"[36].

Herein lays the dual nature of Internet engagement. It serves as a beneficial tool for maintaining social relationships, but simultaneously fosters a sense of missing out when one is disconnected. This highlights the need for understanding and educating individuals on fostering a balanced sense of connection in the online world.

## SOCIAL COMPARISONS AND SELF PERCEPTIONS IN THE ONLINE WORLD

The usage of Internet also leads to social comparisons, which is another key mechanism through which online lives can exert positive or negative effects on psychological well-being. For instance, a study of 150 students in Pakistan[56] presented compelling evidence that daily usage of Facebook decreases self-esteem, due to the high amount of young people (88%) engaging in social comparisons when using that platform. These results have been supported by a study in Germany, which administered self-report questionnaires every day for 2 weeks, finding that daily social media use resulted in lower self-worth, which was mediated by upward social comparisons[57].

On the other hand, two crossover trials measuring multiple facets of well-being, respectively in 600 and 236 participants[17,19], found no evidence to suggest improved self-esteem after social media abstinence compared to normal usage. Similarly, a larger, longer-term (3 weeks) experience sampling study from the Netherlands observed that the effects of social media on self-esteem varied substantially among individuals, with some of them even reporting positive effects[58], again speaking to the idea that the outcomes may be more linked to the specifics of *how* an individual uses and responds to these platforms.

Within the debate around the psychological effects of social comparisons in the online world, one aspect gaining considerable attention is the impact on body image, and the potential for unrealistic social comparisons in this domain to result in or perpetuate eating and weight disorders.

There are numerous features of Internet and social media that are thought to contribute to the onset and maintenance of eating, body image and weight disturbances. Users are often exposed to an abundance of content that depicts unrealistic body shapes and idealized eating and exercise plans[59]. Furthermore, social media platforms and photography apps also feature

image editing tools, which results in proliferation of enhanced, edited or manipulated photographs of unattainable body types in the online world. This, alongside the use of physique-enhancing drugs by influencers while presenting themselves as "natural"[60], leads to a hyper-focus on physical appearance in the online world which is thought to increase preoccupations with eating, shape and weight[61]. Furthermore, there has been a proliferation of online groups promoting dangerous weight control behaviors, such as pro-eating disorder websites and forums, which can also adversely influence the eating and exercise patterns of vulnerable individuals, particularly young women[62].

A substantial amount of work has investigated the relationships of social media usage with eating, body image and weight disturbances, and meta-analytic research has provided evidence of cross-sectional, longitudinal and causal associations[63,64]. Nascent research is further investigating the psychological pathways by which social media usage confers risk to these issues. The available evidence suggests that "online social comparisons" may result in internalization of appearance ideals, and this, along with the perceived pressure to conform, is the mediating mechanism for Internet-induced issues with body image and eating[65,66].

Qualitative research also shows how such social comparisons can affect even those individuals who are aware of misleading presentations in the online world, influencing their body image and broader perceptions of their selves and lives. One user explained that "*a person has a feeling that they have a boring life or that everyone is beautiful and amazing because they see many profiles where the most beautiful things are presented, an abstract image of a person… So I think that influenced me even when I realized it… even when it was not a real image of life*"[67].

Much less has been done to understand whether the above risk relationship is also underpinned by an impairment of neurocognitive functions. Deficits in inhibitory control could be one explanatory mechanism linking social media use with eating, body image and weight disturbances[68-70]. In fact, neurocognitive research indicates that the activity of brain regions involved in this cognitive process (e.g., the mid-cingulate cortex) may be impaired in individuals who use social media excessively[71], similar to what has been reported in those displaying symptoms of food addiction and binge eating[68,72].

Attentional bias is another cognitive process that may be involved. Research using eye tracking technology and information processing tasks (e.g., dot-probe, Stroop task)[73,74] indicates that people with underweight eating disorders show selective attention to appearance promoting or threatening stimuli (e.g., attractive vs. unattractive photographs, images or words), which may be mediated by an overactivation of the amygdala and the ventromedial prefrontal cortex[75]. In contrast, people with obesity or binge-eating disorder display attentional biases towards food cues (i.e., words or images of hyper-palatable foods) using these same paradigms, which appear to activate the neural circuity implicated in reward

seeking, in turn inducing food craving and susceptibility to overeating[76]. Extrapolating these findings to the digital environment, it is plausible that, in some individuals, exposure to the ubiquitous online content geared towards appearance (e.g., selfies, muscular and slender physiques), exercise (e.g., motivational quotes) or food (e.g., fast food advertisements) contributes to the onset or persistence of certain eating, body image and weight disturbances via these attentional biases.

While this presents a clear risk for users who are engaging with social media in ways that accommodate their biases in a detrimental manner, it also provides an opportunity for addressing misperceptions around ideal and attainable body shapes in a positive manner. An example is given by an experiment[77] in which undergraduate females were exposed to a series of TikTok videos either promoting body neutrality or fitting with usual narratives around idealized physiques. Post-exposure assessments indicated that the neutrality group experienced heightened body satisfaction and improved mood, in contrast to peers who viewed typical videos.

These findings highlight that, if used correctly, social media may have a potential for improving body image perceptions in young people. More insights in this regard could be gained from further investigation into the cognitive mechanisms underlying social comparisons in the online world. This is particularly true with respect to attentional biases, as certain types of technology usage have been thought to alter attentional processes themselves, as discussed in the next section.


**POINTLESS DISTRACTION VS. POSITIVE STIMULATION**

In our previous review[1], we discussed the nascent evidence around the ways in which Internet use may affect our cognitive abilities across the life course, particularly with regard to the two areas of neurocognition which had received the most research interest at that time. First, how attentional capacities may be influenced by the continuous influx of digital content and notifications. Second, the leading hypotheses and evidence around how ubiquitous access to unlimited factual information online may affect our capabilities for storing and retrieving information ourselves. Since the time of that review, a wide body of literature has emerged in this area, offering further insights into the impact of online activities on attention, memory and other aspects of human cognition.

Recent large-scale observational studies indicate that extensive device use in children may indeed negatively impact their concentration. For instance, the relationship between screen time and attention based on parent-reported data was examined in over 2,300 preschool-aged children[78]. Results showed that children with more than two hours per day of

screen time (13.7%) were almost six times more likely to present clinically significant inattention problems compared to children watching less than 30 min per day, along with showing increased incidence of clinically significant attention-deficit/hyperactivity symptoms.

Despite these strong associations, it remains difficult to directly attribute attentional difficulties in young people to Internet usage, given the lack of causal evidence for improving attention through withdrawal. For instance, an RCT of 76 students found that one week of being instructed to reduce social media by 50% led to no differences in behavioral or self-reported measures of sustained attention when compared to reducing social media by 10%. However, the mean reduction in social media use in the control arm was actually 38%, which may have explained the null findings[79].

Results from the latest neuroimaging research have provided a more comprehensive view of the interaction between digital device use and brain functioning. For example, the Adolescent Brain Cognitive Development (ABCD) study had gathered data from a total of 11,878 participants aged 9 to 10 years by the time of the latest analyses, performed in 2023[80]. The evaluation of changes in brain network dynamics over a two-year period found no consistent evidence for causal relations between digital screen media usage and functional connectivity in children.

Further insights on this are provided by another investigation[81], which delved into the specifics of how various types of screen media activities were related to brain structure and cognition among 4,277 children from the same ABCD study. Some screen media activities were found to be linked to poorer cognitive outcomes, while others were associated with better performance. For example, activities such as video watching and gaming appeared to hold links with structural patterns indicative of greater maturation in the visual system. Furthermore, gaming activities correlated with increased orbitofrontal volume, holding a positive relationship with fluid intelligence. On the other hand, results indicated a negative relationship between social media use and crystallized intelligence. Along with revealing the complexity of the relations between screen media activities and cognitive performance, these findings provide further evidence for the principle of moving beyond examinations of overall screen time metrics, to instead focus on delineating how the nature of people's interactions with the online world may determine cognitive as well as psychological impacts of digital device usage.

Beyond population-scale neuroscience research, several smaller-scale behavioral studies have provided a more fine-grain understanding of how digital devices affect attentional capabilities in the actual moment of usage. A momentary assessment protocol[82] was used to assess how university students' tendency to become distracted from important tasks (measured via self-reported procrastination) was related to their mobile smartphone use in real-time (captured by passive data collection). While only weak associations were found when looking for overall trends across the entire sample, the results presented compelling

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evidence for individual variability in the type of smartphone uses which encourage procrastination. Some users were more readily distracted by video streaming (e.g., YouTube), others more so by browsing the Internet, and others turned attention to online games when procrastinating[82]. Using a similar methodology, another study[83] also found no overall associations between how often adolescents check their phone and procrastination. Instead, the degree of task delay across individuals was related to how "automatically" (i.e., habitually) the participants used social media, rather than the frequency.

These behavioral observations are aligned with the recent qualitative literature, which shows how the habitual nature of social media engagement presents threats to attention. For example, in an Australian qualitative study, a student reported that "*[checking social media is] 100% an automatic thing. I would just like go to bed, lay down and just immediately go on my phone and start scrolling, and before I realise it, like four hours later, then I become conscious*"[42]. This captures the broader experiences of young people, who often voice concerns about the impact of smartphones on attention span and concentration, leading to struggles with distraction during unstructured time[39,43]. Within this, the phenomenon of getting lost in social media is often highlighted, with participants entering a "*trance*" or "*mindlessly scrolling*"[42], leading to a loss of track of time[39,42,84].

On the other hand, an emergent qualitative literature has highlighted that the cognitive outcomes of Internet usage depend on both the specific context and the individual. A central consideration is that digital devices provide children with endless opportunities for education[26,38]. For example, in a Canadian study exploring parents' perceptions of screen time in children, one participant commented: "*Not to say that iPads are really great, but my daughter does learn things from the iPad… she does puzzles, and has the memory game on there*"[26].

Alongside this, whereas media multitasking has traditionally been presented as an adverse behavior for cognition in children and adults[85], qualitative studies have revealed that Internet-enabled multitasking, such as listening to podcasts while commuting or completing chores, can also have positive effects[44,84], making individuals feel "*productive*", expanding their world while physically engaged in other tasks[84]. Interestingly, the tension between emotional gratifications of multitasking and its potential hindrance to deeper cognitive processing is also experienced by technology users. For instance, in a Norwegian study[44], the contextual aspects of how digital reading (and/or audiobooks) affects the processing of textual content were captured, with several participants indicating a preference for lighter texts when using digital screens, compared to preference for paper-based alternatives when reading deeper works, as "*serious reading needs paper*"[44].

Gaming is another area of screen time with mixed perceptions among parents and young people. While the heaviest gamers do experience more communication and academic

problems at school[86], both parents and young people report benefits from moderate levels, such as developing visuospatial skills and improving cognitive functioning[87].

Collectively, these findings from neuroscience, behavioral and qualitative research suggest that a possible method for attenuating the detrimental cognitive effects of digital device use could be through providing individuals with new means for consciously identifying which aspects of their own online time are most likely to interfere with their tasks and goals. This could allow providing a more personalized intervention to deliberately address one's own habits than the general withdrawal protocols that fail to produce significant improvements in cognition[79].

## THE OFFLINE EFFECTS OF AN ONLINE WORLD: IMPLICATIONS FOR BODY AND BRAIN

Another putative factor determining the cognitive outcomes of digital engagement is how time spent online may be impacting other "pro-cognitive" behaviors, such as physical activity and sleep. Despite the numerous advantages that the Internet offers, it has contributed to a notable rise in sedentary behavior across the population[88], which in turn could impact attention, memory and other cognitive aspects[89]. The strongest empirical evidence supporting this possibility, sometimes referred to as the "displacement hypothesis", is provided by various meta-analyses and reviews that have either specifically investigated the association between sedentary behavior and cognition[90-93], or examined the relationships between multiple lifestyle factors (including sedentary behavior) and cognitive outcomes[94,95]. The findings consistently indicate that higher levels of sedentary behavior are linked to reduced cognitive function and heightened risk of cognitive dysfunction across the lifespan[96].

Cognitive decline has been reported to be half as prevalent among adults who engage in sufficient physical activity, compared to their less active counterparts[97]. Engaging in physical activity at any point in adulthood, and to any extent, has been found to be associated with a higher cognitive state in later life[98]. This idea is substantiated by moderate-to-strong evidence indicating that physical activity has positive effects on cognitive functioning both in early and late stages of life and in specific populations characterized by cognitive deficits[99].

Engaging in excessive Internet use through becoming engrossed in sedentary activities such as online browsing, social media engagement and gaming, in ways which could displace physical activity time, may represent a pathway towards cognitive detriments of digital device usage[100]. Within this, it is important to consider that different types of sedentary behavior may differentially affect cognition. Specifically, recent studies have indicated that "mentally active" sedentary time (such as reading a book or even playing video games) may be preferential to

"mentally passive" sedentary behavior (such as watching TV or online videos), with the former being provisionally associated with better cognitive outcomes and lower incident dementia risk[96].

Supporting this, a recent UK Biobank study – including more than 1,000 patients with bipolar disorder and almost 60,000 psychiatrically healthy controls – demonstrated that, in both groups, a global cognitive score was inversely associated with mentally passive sedentary behavior (TV watching) and positively associated with mentally active sedentary behavior (computer use). Age-related decrements in cognition were more evident in those who engaged in less mentally active sedentary behavior[101].

Another pathway through which online time may affect cognition is through the potential impact on sleep[102]. The growing trend of people, especially youth, to spend more time engaging in online activities on a daily basis can result in substantial consequences for their sleep habits, including reduced sleep duration, erratic sleep routines, and impaired sleep initiation and cessation times[103-106]. This can have a direct impact on cognitive functioning, as a lack of sleep can affect attention, memory and executive functions[107]. Moreover, disruptions in sleep caused by excessive online activities can lead to difficulties in concentrating, learning, and remembering information[108]. Supporting this, a recent study has shown that the usage of digital devices before bedtime in adolescents is associated with slower reaction time and reduced attention span on continuous performance tasks, particularly in morning hours[109].

Another issue of concern has been the "blue light", which is the portion of the visible light spectrum emitted by digital screens that has a particularly high energy level compared to other colors[110,111]. Exposure to this light, especially before bedtime, can interfere with the production of melatonin[112], disrupting the sleep-wake cycle and leading to fragmented and less restful sleep[110], which in turn may have a negative effect on cognitive functioning[113]. In this context, exposure to digital screens during leisure time has been related to lower sleep quality in adolescents[114]. Addressing this through "blue blocking", which can be achieved via physical (i.e., screen filters or glasses) or technological (apps for reducing blue light emission) means, may represent a possible route for attenuating screen-induced deficits in sleep[115].

Overall, mounting evidence suggests an inter-connectedness of sleep, sedentary behaviors (including Internet usage) and physical activity, which is inseparable from their relationship to cognitive health across the lifespan. This is reflected in recent initiatives to develop "24-hr movement guidelines" which include physical activity, screen time, and sleep duration across the entire day. Adhering to recommended levels of 24-hr movement, screen time and sleep has been linked with higher global cognition[116] and total cortical and subcortical grey matter volumes in children[117], along with reduced incidence of cognitive difficulties in adolescents[118]. Furthermore, in pre-schoolers, the reallocation from sedentary behavior and sleep to moderate-to-vigorous physical activity was positively associated with inhibitory

control[119]. Despite the potential benefits, adherence to the physical activity, sedentary behavior and sleep guidelines is worryingly low worldwide, especially among children and adolescents[120].

From a time-use epidemiology and 24-hour continuum perspective, increased Internet time, as a sedentary behavior, can displace time available for other healthy behaviors (physical activity or sleep)[121]. Thus, adverse cognitive consequences of Internet usage could be partly attributable to a cascade of cognitive consequences from these physical effects. If this is true, then addressing health behaviors in Internet users could represent a feasible and effective method for improving cognition, especially in healthy older adults[122]. Indeed, a meta-analysis found evidence that web-based lifestyle programs can positively influence brain health outcomes, and potentially offer a protective effect from aging-related cognitive decline[123].

While we may have a friend in the enemy for improving cognition throughout Internet usage (especially for certain populations such as older adults)[10], it does seem reasonable, from a public health perspective, to recommend that Internet use should not significantly contribute to increased sedentary time and should not displace physical activity time or sleep duration. Additionally, further research should be conducted to inform policy recommendations around displacing mentally passive with more mentally active Internet usage, in order to potentially attenuate the cognitive downsides of the increased sedentary time incurred while engaging with the online world.


**REVISITING SOCIAL OUTCOMES OF "ONLINE LIVES"**

While a primary concern around online activity is that it may detract from real-world social activities[124] and potentially lead to social isolation[125,126], it is also the case that many of the most used and time-consuming online activities are in themselves "social", albeit in an online context[34,127].

Blurring of boundaries between social media and real-life experiences is now viewed as an integral part of many, particularly young people's, lives. In the qualitative literature, the social nature of multi-screening is emphasized, with individuals reporting watching alongside people connected digitally[28,36,43]. Live gaming and personal livestream shows were also seen in qualitative reports as particularly "social", since they allow to interact with others digitally through memes and chat[29]. Qualitative findings further highlight changing communication patterns and a shift in norms to multi-communicating, with individuals frequently resorting to messaging on smartphones even during face-to-face interactions with each other[28].

Recent studies have demonstrated that social media and online games are more than time-consuming entertainment, and serve a purpose beyond just staying in touch with friends in the absence of real-world contact. Rather, research increasingly demonstrates that these activities actively shape social cognitive processes themselves[128,129]. One example of this is how engagement in social media platforms requires interpreting and responding to a broad range of emotional cues and perspectives, which potentially may hone face-to-face empathy skills[130]. A longitudinal survey of Dutch adolescents showed that social media use held a relationship to improved cognitive and affective empathy[131]. However, negative behavioral aspects of social media have also been noted, with research participants reporting that people behave differently on these media, often resorting to using their phone as a protective sanctuary in challenging face-to-face social situations[41].

The psychological implications of social media feedback are also increasingly explored. Internet users seem to recognize the challenge of resisting the pressure to "care too much" about social media validation, underscoring the psychological impact of the pursuit of likes and comments on platforms such as Instagram and Facebook[36,41]. Additionally, recent findings indicate that health professionals also identify the "likes" feature on platforms such as Instagram as a significant motivator for compulsive use[40], as these simple indicators of endorsement can fulfill users' social and recognition needs, acting as a form of positive reinforcement.

The social aspects of Internet use are further emphasized in qualitative research as driving digital behavior, particularly with regards to the role of online actions or even inactions as important social signals[36,41]. Participants describe how failure to engage with friends' social media posts through likes and comments could be misinterpreted, leading to concerns about unintentionally hurting someone. One young person in a Norwegian focus group explained: "*Yes, the pictures were nice, but you don't always have to comment on every single one. But still, you feel like you need to, because… otherwise it may be like: "Oh, she didn't comment on my picture!" It may be interpreted negatively*"[41]. Affirmations on social media are viewed as potentially detrimental to emotional health by young people, in that, if participants receive limited affirmation from peers, it could lead to negative emotions[36]. However, the nature of these social media interactions, often devoid of non-verbal cues, can also lead to misunderstandings or a superficial understanding of complex emotional states[132]. As such, further research on disentangling these relationships between social media activity and social cognition are now needed.

As individuals move more and more towards receiving information (such as global and local news, political opinions and sociological insights) from online outlets[133-135], it is also notable that the social connections held by people on social media are likely to shape the information to which they are exposed[134,136]. This can lead to social echo chambers and result

in online social movements that transcend into the real world[137,138]. The Internet does provide an arena for diverse viewpoints, which can enhance decision-making skills. Yet, caution needs to be given to how the echo chambers and filter bubbles prevalent in online spaces can also potentially lead to polarized thinking and impaired social judgment[136,137,139].

Anyway, the extent to which information from online sources actually shapes individuals' judgment remains debated, due to the complexity of how behaviors actually spread in online social networks[140], and the ability for related emotions to also spread across social media[141-143]. More research exploring the fundamentals of how complex behaviors transmit between individuals in real-world networks would now be useful[144,145]. This is specifically of interest in terms of social decision-making.

Online multiplayer games appear to offer a different dynamic to social media activity in relation to social cognition[146]. Online gaming often involves collaborative problem-solving and strategy development[147], which has been suggested to potentially allow enhancing of user perspective-taking and collective decision-making skills[146]. However, these environments can also foster competitive and, at times, aggressive behaviors[148], and some recent research suggests that this may negatively impact empathy and prosocial behavior[149,150]. While this research area is currently of much importance[147], a recent systematic review found a very limited number of studies which suitably investigated social cognition (as assessed by neuropsychological tasks) in relation to gaming[146]. Further empirical research on this topic is certainly needed.

The relationship between online social activities and cognitive processes is currently the focus of various lines of research, yet it is important to recognize that real-world activity can significantly shape online social functioning and abilities as well[141,145,151-153]. This interaction creates a multi-dimensional "feedback loop" between offline activities and online social contexts. For instance, individuals with extensive experience in sports or outdoor activities often demonstrate superior spatial awareness and strategy planning in online gaming environments, translating their real-world skills into the virtual world. Alongside this, recent research within neuroscience has revealed that individuals who were raised in areas that were complex to navigate spatially were also better at navigating virtual worlds[154].

This interplay can be intentionally harnessed. For example, some professional e-sports players report using physical and mental training regimens, akin to traditional athletes, to improve their reaction time, endurance, and overall gaming prowess[153,155].

Overall, these examples clearly illustrate the ongoing feedbacks between the online and offline worlds. Future research delving into the extent of these interactions across various domains will be crucial, especially as our online lives continue to intertwine with and impact our offline realities. This exploration will be pivotal in understanding the full spectrum of how digital and physical experiences shape human behavior and cognition.

**THE ADVENT OF "CULTUROMICS"**

The ongoing digital revolution, with increased societal switching to Internet use, is offering new opportunities to study population level shifts in interests, opinions and behaviors manifesting in the online world. The vast, readily available and rapidly growing body of online digital data contains valuable information on human behavior, daily rhythms, attention, interests, attitudes, norms and values, with a high spatial and temporal resolution. These represent key research topics of the emerging field of "culturomics", which is focused on the study of human culture through the quantitative analysis of large bodies of digital data[156,157]. Culturomics is increasingly used in a wide range of scientific disciplines, especially within social sciences and humanities[158].

Some of the commonly studied digital materials include social media, search volumes from web search engines such as Google, pageviews from online encyclopaedias such as Wikipedia, image and video sharing platforms such as Instagram and YouTube, and online news platforms, with analytical methods ranging from natural language processing to machine learning[157]. These approaches have been used to provide insights into various issues relevant to mental health.

For example, the diurnal variation of depression-related health information seeking on the Internet has been analyzed in Finland[159]. The study showed that the interest in depression-related terms and help seeking had clear diurnal patterns, consistently peaking during the night-time, between 11 pm and 4 am. In a similar vein, a text analysis of millions of Twitter posts was used to assess diurnal and seasonal mood rhythms, and their differences among individuals (i.e., chronotypes), cultures, and across the globe[160]. It was found that positive affects (such as enthusiasm, delight and alertness) and negative affects (such as distress, fear and anger) tend to vary independently. The former peak in the morning, likely due to positive effects of sleep, as well as near midnight, while the latter peak during night-time. It was also observed that seasonal peaks in depression and anxiety in the Northern latitudes are mainly driven by diminished positive affects, triggered by the reduced day length.

It is important to note that the use of online digital data in research faces certain caveats and challenges, such as uneven global Internet coverage and access, language barriers and cultural differences, data sharing restrictions, temporal data availability and decay, property issues, and personal data protection[161]. Nonetheless, if properly used, these approaches promise to become major tools in the field of social sciences, psychology and psychiatry.

Culturomics is also beginning to provide new insights into how the Internet is affecting our attention at a societal level, beyond the individual cognitive effects. Online social interactions and consumption of information are both characterized by attention transience, a pattern of diminishing public attention towards particular issues and cultural products[162,163]. Attention

decay represents a natural process driven by various psychological and cognitive factors such as limited attention span, selective attention, and attention saturation and fatigue[162-164]. It generates periodical issue-attention cycles, which represent an intrinsic and predictable process by which the public gains and loses interest in a particular issue over time[163,165].

The process of attention decay has been intensifying with the hyperproduction, dissemination and consumption of online information and content, which increasingly compete, saturate, overload and exhaust cognitively limited attention spans. For example, by modelling data from various online platforms such as digitized books and magazines (Google Books), movie ticket sales (Box Office Mojo), Internet search volumes (Google Trends), social media (Twitter), forums (Reddit) and encyclopaedias (Wikipedia), spanning periods from six to 100 years, an increasingly steeper rise and fall of public attention related to a particular issue over time was observed[162], with increasing frequency of attention shifts between issues. A similar study on public attention towards different environmental issues based on Internet search volumes indicated narrowing windows of public attention, with attention half-life being limited to few days or weeks[163]. This research area may be relevant to the mental health field, particularly as dissemination of information on mental health issues and anti-stigma campaigns are concerned.


## THE FUTURE OF MENTAL HEALTH IN THE METAVERSE


As technological progress continues to penetrate our daily tasks and social lives, the integration of virtual reality (i.e., replacing a real-life environment with a simulated one), augmented reality (i.e., adding digital elements to a real-life environment), and artificial intelligence technologies in online platforms is poised to revolutionize our understanding and practice of social interaction[166-168].

Virtual and augmented reality technologies promise a new frontier in how we interact and engage with each other, by offering immersive experiences that more closely simulate real-world interaction[166,167,169,170]. Indeed, recent studies are demonstrating that these technologies have the potential to significantly enhance social understanding and empathy, as they can create environments where individuals can experience and navigate complex social scenarios in a controlled, yet realistic manner[166,169,170].

This immersive approach offers a unique platform for training and enhancing social skills, allowing individuals to practice and develop empathy and social understanding in diverse settings. Nevertheless, it also has the potential to distract users from real-world social interactions and the benefits that they can bring, determining an even greater influence of the online world on individuals' social relationships and processes in concerning contexts

(particularly through potential addiction to these technologies, which currently remains untested)[170-172].

The idea of further immersing our social interactions and daily lives into the online world through virtual reality has received considerable interest and investment, through the concept of "the metaverse". The metaverse can be described as an expansive virtual space, generated and accessed through a combination of virtual and augmented reality technologies, existing continuously on the Internet, and persisting regardless of user engagement[172,173]. The metaverse also offers a high degree of interactivity, in terms of both user-environment interactions and user-to-user connections.

Notable features of the metaverse include a fully functional digital economy, enabling the creation, purchase and sale of virtual goods (including those for use by individuals' virtual selves, or "avatars"), and significant user-generated content, with users having the capability to both create and modify elements of the metaverse space itself. For all of this, interoperability is a key goal, such that the metaverse could eventually support the exchange of assets, data and avatars across various platforms and providers.

As of now, the fully functional and integrated metaverse remains an aspirational concept – with current manifestations primarily accessible through individual virtual and augmented reality platforms. While persistent virtual worlds exhibiting certain characteristics of the metaverse already exist on these platforms, they are not yet interconnected and all-encompassing.

The implications of the metaverse extend beyond entertainment and gaming, being relevant to a variety of fields, such as finance, education, professional development, and social networking. For the field of psychiatry, the metaverse offers innovative avenues for patient interaction, data collection, and the simulation of complex social settings, thus opening new frontiers for research, clinical and even community interventions[172,173]. However, the mental health impact of the metaverse is unclear at the moment, and indeed its future is currently in flux.

Despite the ambitious efforts towards metaverse adoption demonstrated through the Facebook's rebranding to Meta, the move of its social networking platform towards an immersive virtual world has yet to be embraced by users. Similarly, the adoption of Decentraland – one of the most well-funded metaverse products, with a valuation over 1 billion US dollars – remains remarkably low. Preliminary investigations report that it has only 38 daily users[174] and that only 9% of user-created worlds in the metaverse are ever visited by more than 50 unique people[175]. Nonetheless, these are only single, early examples of such offerings, and these virtual spaces are likely to expand, improve and interconnect after initial growing pains.

There is an expanding literature on the potential of the metaverse in the field of medicine, including psychiatry. The speculation and hope are well embodied in the term "MEDverse", conceptualized as the entry of the metaverse into a medical context[173], or the MeTAI, a metaverse of medical technology and artificial intelligence[176]. It has been argued that the metaverse, and related virtual reality platforms, may offer customized exposure to specific situations (social or environmental) that can be used to deliver the next generation of exposure therapies. Such therapies have been proposed for mood disorders, anxiety/phobias, attention-deficit/hyperactivity disorder, eating disorders, post-traumatic stress disorder (PTSD), and schizophrenia[172,173,176,177].

This approach can take the form of "avatar therapy", which involves immersive virtual reality where patients can interact with digital avatars representing various aspects of their own personality, and/or other entities. For instance, in the treatment of anxiety disorders or PTSD, patients can practice interacting with avatars in controlled social situations, or gradually exposing their own avatars to fear-inducing scenarios in a safe, virtual environment[170,172,177]. Avatar therapy can also be used for fostering self-compassion, through patients interacting with avatars of themselves in various states, helping to develop a kinder self-perspective, as demonstrated in a recent pilot study in which 15 patients practiced delivering and receiving compassion from themselves in a virtual body[178]. A major benefit to such interventions is the controlled nature of the virtual interactions and environments, which provides a uniquely customizable therapeutic tool that can be adjusted to the specific needs, personality and progress of the patient[172].

Complexities of avatar therapy include the currently poorly understood "Proteus effect", whereby individuals' behaviors and attitudes seem to conform to their avatar's characteristics[179,180]. Meta-analyses have consistently demonstrated a small-to-medium effect on behaviors and attitudes as a result of this phenomenon[179]. While this can be intentionally harnessed to facilitate positive outcomes (i.e., through building avatars with characteristics that align with therapeutic goals), there remains a risk for the Proteus effect to inadvertently drive adverse outcomes in unexpected ways. For example, an avatar therapy for social anxiety could begin with immersing patients into a busy social environment, but without any direct or challenging social interactions with other avatars in the space. While this may serve as exposure therapy for the social anxiety, the lack of meaningful interactions with other characters could lead to the patient feeling ignored or overlooked, reinforcing feelings of insignificance or inadequacy in ways which translate to other social situations.

More recent research has demonstrated that the Proteus effect also appears to translate across different digital contexts, with a cross-sectional study of 345 e-sport athletes revealing that their digital personality in the e-sport world influenced the nature of their interactions with a digital health care system[180]. Further research is required to establish how attitudes and

behaviors within virtual worlds spill over to real life settings, and a thorough understanding of human interactions with avatars' characteristics would be crucial in mental health care intervention design, to ensure that the Proteus effect supports rather than hinders therapeutic objectives.

Like other emerging technologies, the clinical potential of the metaverse will be impacted by its approach to user privacy, active moderation (safety), and transparency[177]. These concerns have already limited the mental health potential of social media, even when efforts and intentions were well intended, such as towards suicide prevention[181]. Also, as with other digital platforms, the concern that time spent on the metaverse could have a negative impact on mental health has been raised[182]. In a qualitative study from the UK[87], for example, parents held concerns about their children using virtual reality that included contact with strangers or violence, or that may be socially isolating. Parents reflected that they would continue to prefer real-world engagement and exercise. As one parent put it: "*I would see it [virtual reality] as inferior to physical activity in the real world*".

The role of artificial intelligence in shaping social cognition can be equally transformative[183]. Its ability to analyze vast amounts of data can provide deep insights into human behavior and social interactions and lead to more personalized and effective online social experiences, increasing the influence on social cognitive skills[183,184]. Recent advancements, particularly with the development of sophisticated large language models, have significantly expanded the scope and capabilities of relational agents (i.e., computational artifacts designed to build and maintain social-emotional relationships with their users).

Although the potential for relational agents to shape human social activity has long been acknowledged[185], the extent to which modern artificial intelligence systems can offer more nuanced and adaptive human-computer interactions, transforming the way in which we engage with and comprehend social dynamics[183], has been only recently realized. These advanced relational agents can now understand and respond to a wide range of human emotions and contexts, providing interactions that are more personalized, empathetic, and contextually relevant[183,186].

The sophistication of these models lies in their ability to analyze and process vast amounts of linguistic data, allowing them to mimic human conversation with remarkable accuracy[187]. This enables a deeper level of engagement and a more meaningful understanding of social cues and norms. Whether by offering support in mental health applications, or assisting in learning and development, or simply providing companionship, these relational agents are becoming increasingly able to address diverse individual needs and preferences[188-190].

In essence, the evolution of artificial intelligence has not only made these human-computer interactions more engaging and realistic, but has also paved the way for a future in

which technology can seamlessly integrate into the social fabric, enhancing our ability to connect and understand each other in a digitally connected world. Still, issues of bias in these models and concern for stigma remain. A proactive approach to creating large language models and artificial intelligence programs that promote ideals of care versus promulgating today's biases is critical, especially as the current generation of programs have been trained by reading the Internet and social media websites. It is saddening, but not surprising, that stigma around schizophrenia already appears in images of this condition generated by artificial intelligence[191].

Emerging qualitative research with both patients and physicians emphasize that there is no current consensus in people's views of artificial intelligence, with perceptions ranging from highly positive to entirely negative[192]. For example, physicians have reflected on the potential of artificial intelligence for reducing their workload and the overall burden on the health care system (*"But it will dramatically ease our workload, won't it? Considering that there is currently a shortage of personnel and increased workload, it would be a very good solution"*), whilst patients emphasize that humans remain critical for the relational aspects of care interactions (*"I think that humans can express emotions, empathy, help, and give hope for a better tomorrow better than any machine"*)[192].

The combination of virtual/augmented reality with artificial intelligence opens further avenues for social training and therapy[166-170,189]. For instance, in therapeutic settings, virtual reality can create safe and controlled social situations[190,193,194], where artificial intelligence-driven analytics can offer real-time feedback and personalization, enhancing the effectiveness of interventions aimed at improving social skills in individuals with social cognitive deficits[194,195].

This intersection of technology and social cognition could not only enrich our online interactions, but also provide valuable tools for addressing and improving social functioning in individuals with various needs. As we continue to integrate these technologies into our lives, their potential to enhance our social understanding and interactions can grow exponentially, making them essential tools for both personal development and clinical practice. The future of social cognition, in this regard, seems not only technologically advanced but also more empathetic and inclusive. Yet, the current concerns surrounding online social activity are also magnified to the same extent as the benefits[171,181,186,192].

**CONCLUSIONS**

The evidence and insights gained from this review can considerably advance our understanding of the Internet's impact on our mental health, cognition and sociality, moving

beyond general trends and dichotomous foci of the "online brain" to further investigate how the specificities of individuals' "online lives" determine the outcomes of Internet-brain interactions. Through synthesizing the ground-breaking quantitative and qualitative research from neuroscientific, behavioral and sociological research on this topic, we offer a refreshed perspective on how digital interaction influences mental states, both on a daily or momentary basis, and over the life course. Overall, the latest findings underscore the complexity of brain-Internet interactions, and how outcomes are dependent upon a multitude of sociodemographic, psychological and behavioral factors, crucially documenting that Internet usage is not a singular experience, but rather varies based on individual characteristics and contexts.

Within this, a shift emerges from the traditional research questions or interventions which approach the Internet (and its various uses) as either "good" or "bad", to instead detail the potential for simultaneous positive and negative psychological and cognitive impacts from most online activities. Accordingly, future research is encouraged to adopt a fine-grained approach towards examining how the specifics of individuals' online lives influence their mental health, self-perceptions, cognition, lifestyle and sociality, considering the myriad ways in which Internet use is woven into the fabric of daily life.

Alongside this, the emerging field of culturomics provides the means for using the Internet (and the associated data) to gain a more dynamic understanding of societal changes in habits, attitudes, abilities and even interactions with the offline world. Furthermore, the potential of technologies such as virtual reality, augmented reality, and artificial intelligence to further transform the ways in which we interact (online and offline) is clearly emerging, while the need for a continuing rigorous evaluation of the possible neuropsychosocial impacts of the new technologies has to be constantly taken into account, in order to inform the next era of digital engagement.

Overall, the findings of this review move us towards gaining a nuanced, individualized understanding of the Internet's influence on psychological, cognitive and social functioning. On the basis of this, we advocate for future research, guidelines and initiatives to consider cross-disciplinary findings from neuroscientific, behavioral and societal levels of research, in order to adopt an evidence-driven and multidimensional approach towards addressing the benefits and drawbacks of our interactions with the online world.

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