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How does the time children spend using digital technology impact their mental well-being, social relationships and physical activity?

An evidence-focused literature review

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HOW DOES THE TIME CHILDREN SPEND USING DIGITAL TECHNOLOGY IMPACT THEIR MENTAL WELL-BEING, SOCIAL RELATIONSHIPS AND PHYSICAL ACTIVITY? AN EVIDENCE-FOCUSED LITERATURE REVIEW.¹

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ABSTRACT

Based on an evidence-focused literature review, the first part of this paper examines existing knowledge on how the time children spend using digital technology impacts their well-being across three dimensions; mental/psychological, social and physical. The evidence reviewed here is largely inconclusive with respect to impact on children's physical activity, but indicates that digital technology seems to be beneficial for children's social relationships. In terms of impact on children's mental well-being, the most robust studies suggest that the relationship is U-shaped, where no use and excessive use can have a small negative impact on mental well-being, while moderate use can have a small positive impact. In the second part of the paper, the hypothetical idea of addiction to technology is introduced and scrutinized. This is followed by an overview of the hypothetical idea that digital technology might re-wire or hijack children's brains; an assumption that is challenged by recent neuroscience evidence. In conclusion, considerable methodological limitations exist across the spectrum of research on the impact of digital technology on child well-being, including the majority of the studies on time use reviewed here, and those studies concerned with clinical or brain impacts. This prompts reconsideration of how research in this area is conducted. Finally, recommendations for strengthening research practices are offered.

KEYWORDS: digital technology, time use, excessive use, well-being, mental health, physical activity, social relationships, addiction.

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EXECUTIVE SUMMARY

The first part of this paper reviews existing knowledge on how the time children spend using digital technology impacts their well-being, in order to understand when and why digital technology has a positive or negative influence on children. This is relevant as children's engagement with digital technology is increasing in all parts of the world, together with concerns about whether this is healthy or harmful. The methodology used is an evidence-focused literature review which includes studies of children aged 0-18. In addition to summarizing existing evidence, the paper emphasizes the methodological limitations that exist in this area of research. The literature is reviewed in light of these limitations to determine how much it can truly tell us about the impacts on child well-being. The paper highlights that methodological limitations need to be more carefully considered in research, attributing the general lack of conclusive evidence to such limitations. The paper offers concrete recommendations on how research in this area might be improved.

The second part of the paper engages with the hypothetical idea of addiction to technology, in light of increasing concerns that some children's excessive engagement with digital technology may be a mental disorder that could cause significant long-term harm. The theoretical assumptions underpinning this body of research are reviewed together with existing knowledge around risk-factors. Methodological limitations, which are particularly severe in this area, are also given due consideration. The popular-science notion that digital technology may re-wire or hijack children's brains is also scrutinized, drawing on recent neuroscience evidence.

A broad definition of digital technology is used in this paper. It includes digital devices such as computers, tablets and mobile phones, as well as the many digitally mediated activities that children today engage in via these devices, such as using the internet, going on social networking sites, chatting online or playing video games. Television is considered separately. Child well-being is considered a multi-dimensional concept, which in this paper covers mental/psychological, social and physical dimensions. The paper does not consider in depth the impact that specific content or online experiences may have on children. While recognizing that these are important factors in determining the outcomes of children's online engagement, this paper focuses specifically on the impact of time use.

1.1 How does the time children spend using digital technology impact their mental well-being?

In summary, the evidence reviewed suggests that moderate use of digital technology tends to be beneficial for children's mental well-being, while no use or too much use can have a small negative impact. In the arguably most robust inquiry to date, it was found that these positive and negative impacts were very small and not as relevant as other factors known to be of importance to children's mental well-being. This is in line with findings from a meta-analysis of 40 studies of both adults and children, where a negligible negative effect of internet use on well-being was reported. In this context, several authors suggest that to improve children's mental well-being, it is more important to focus on other factors such as family functioning, social dynamics at school and socio-economic conditions, while also ensuring that children use digital technology in moderate amounts. Instead of focusing only on the impacts of time spent on digital technology, researchers should pay more attention to the influences of the content children encounter and the activities they participate in online, in addition to their social and family environments.

1.2 How does the time children spend using digital technology impact their social relationships?

The evidence reviewed here suggests mostly positive outcomes from using digital technology in terms of children's social relationships - to an extent that consensus may be said to exist. It is generally found that children's social relationships are stimulated by digital technology; they use it to enhance their existing relationships and stay in touch with friends, while those who have less social capital at the outset may use it to compensate for this and build positive relationships. While early research found indications of some negative impacts, these seem to have largely been attenuated, since the majority of a child's social circle is now online. However, research in this area sometimes struggles to measure children's time use appropriately, since it is difficult to determine when someone is socializing online and for how long, given that many children have near constant access. More research is needed on the potential negative effects of passively browsing social networking sites, as this might make children envious of other people's carefully crafted online personas, potentially leading to feelings of inadequacy.

1.3 How does the time children spend using digital technology impact their physical activity?

The evidence reviewed here is mixed as regards the impact on children's physical activity and does not provide much clarity. While some studies found that screen time was associated with a reduction in physical activity, other studies suggested that this relationship is not direct, and that reducing screen time will not necessarily motivate children to spend more time on physical activity. It has been suggested that already inactive children may spend more time using digital technology, which would explain why some studies have found a negative association between screen time and physical activity. While better measures of screen time and time use in general are needed to improve research in this area, it might be helpful in the future to focus on whether reductions in screen time lead to increases in physical activity. If this is not the case, as some research suggests, it might be worthwhile asking how we can motivate children to spend more time on physical activity, irrespective of the time they spend on digital technology.

1.4 Conclusions and recommendations for future research

This paper has reviewed evidence of the impact of time spent using digital technology on children's well-being across three dimensions: mental/psychological, social and physical. The literature review found little support for the displacement hypothesis, which posits that the harm posed by technology is proportional to exposure. While time spent on digital technology does, to some extent, take time away from other activities, which in some situations (such as periods of high volume of school work) can be problematic, current evidence does not suggest this will have any major or long-lasting impact on children in the well-being dimensions reviewed here. Although many studies have been conducted, most suffer from theoretical, conceptual or methodological limitations, which make the results unreliable in terms of providing solid evidence of impact. The evidence base is inconclusive and - at this point - unsuitable for underpinning policy or interventions. Recommendations are made to improve quality and reliability of research and debate in this area:

- **We need to fine-tune our measurement of children's digital engagement.** Aggregate measures of 'screen time' are conceptually problematic, as the different devices children use and the content of children's digital engagement are ignored.

- **More longitudinal studies are needed for hypothesis-testing confirmatory research.** Most research up to now draws on cross-sectional data which is helpful for hypothesis generation, but unsuitable for hypothesis testing and for capturing the long-term outcomes that interest us. The cumulative effects of spending a lot of time using digital technology from a young age are particularly important to study in future research.
- **Researchers need to consider children's life contexts and socio-demographics to the greatest extent possible.** More control variables need to be included in quantitative studies to ensure that variables that have known effects on child well-being outcomes are not excluded. Children's online experiences cannot be studied in isolation from their lives in general.
- **Reproducibility of research and the reliability of findings needs strengthening.** There could be much to gain by encouraging researchers to register their hypotheses before collecting data and sharing the pre-registration protocol, data and analysis code with each publication, following an 'Open Science' approach. Such an approach ensures that every policy-relevant research finding is produced in a transparent way, is computationally reproducible and that all materials are freely accessible online, where they can be vetted by colleagues.
- **Given the conflicting evidence-base, media reporting needs to become considerably more nuanced.** All too often news articles share evidence from single studies, or studies that are methodologically weak or that exaggerate or misrepresent the results. This can lead to a situation where the debate is based only on a snapshot of existing evidence, with little consideration of its relative strengths and weaknesses. This is not only the responsibility of journalists - science communication by researchers and universities needs to be improved to reflect accurately research findings, their generalizability and limitations.

2. INTRODUCTION

Children's use of digital technology has increased rapidly over the past decade, raising important questions around how time spent on digitally-mediated activities may affect children in positive or negative ways (Putnam, 2000; Turkle, 2011; Bell, Bishop and Przybylski, 2015; George and Odgers, 2015). As George and Odgers state, the question is no longer *if* children are using digital technology, but *how, why, and with what effects* (2015). Clearly, digital technology offers many potential benefits to children, allowing them to connect with peers or access educational resources or entertainment (Livingstone and Bober, 2006; Valkenburg and Peter, 2009; boyd, 2014). At the same time, there are legitimate concerns around who children interact with online (Pew Research Center, 2012), if they experience cyber-bullying or access age-appropriate content (boyd and Hargittai, 2013), or whether screen-based communication may jeopardize their social development or well-being (George and Odgers, 2015).

Even though adults also use digital technology to a great extent, concerns tend to centre on children's use because of the many social, biological, cognitive, and psychological changes that characterize this life period. Children go through critical developmental stages, such as identity formation and building positive friendships while immersed in the digital age (George and Odgers, 2015). Turkle (2011) has argued that children today are interacting more with their phone than with each other, which may cause them to miss out on important social experiences. Others say that children still interact with one another as much as before and that the interactions are of similar quality; it is the venues for social interaction that have changed, becoming digital (e.g. boyd, 2014). Because friendships and communication with peers are important for the development of life-long social skills, there are concerns that children's social skills might somehow be altered or negatively affected when digitally mediated (George and Odgers, 2015). This extends to a broader societal concern that children may lose out in important areas of life because they spend so much of their time in front of screens. In this respect, the digital age has introduced new challenges for parents who face the difficult task of striking a balance between allowing independent exploration, and providing appropriate limitations and oversight (Pew Research Center, 2016).

Responding to some of these concerns, researchers have explored how the time children spend using digital technology impacts their lives across various domains. Over the course of the past two decades, individual research studies have indicated that increased use of digital technology might have some negative impacts on children's well-being, ranging from mental health issues such as depression (Kim et al., 2010) or addiction (Young, 1996), to public health issues like obesity (Sisson et al., 2010). At the same time, most of these claims have been disputed by other scholars and many studies show how digital technology brings great benefits to children (e.g. Livingstone et al., 2011; Byrne et al., 2016; Baranowski et al., 2008; Granic, Lobel and Engels, 2014), highlighting its social and interactive features (e.g. boyd, 2014; Cole and Griffiths, 2007; Hussain and Griffiths, 2009; Valkenburg and Peter, 2007), how it opens up new opportunities for performance, creativity and expression (Lowood, 2007) and features as an everyday practice in the home for purposes of social interaction and relaxation with the family (Enevold, 2012). Recent research suggests that video gaming positively influences cognitive, motivational, emotional and social development (Granic et al., 2014), while other research suggests that video gaming might disrupt children's sleep patterns (Dworak et al., 2007). So what can we make of such a seemingly contradictory body of evidence?

As Chas Critcher wrote (in Drotner and Livingstone, 2008), concerns that new technologies, activities or content may impact children negatively are not a recent phenomenon in Western public discourse, but go as far back as the early 1900s. At that time, there were concerns about how access to public cinema would affect children, followed by worries around the negative impact of comic books, targeted from the late 1940s by bans in parts of the United States because they supposedly made young people criminal and promiscuous. Concerns escalated with the introduction of the television in 1950, which was blamed for being addictive and isolating. In the 1970s, computer games were accused of making people both addicted and aggressive. It is not surprising to see the same pattern repeated today with digital technology, but it is important to critically appraise the legitimacy of these concerns.

Understandably, parents, teachers and others who have an interest in children's health and well-being become increasingly concerned as children spend more time using digital technology, but are also confused by the lack of consensus on whether this is good or bad for children. This confusion is apparent not only among parents in the developed world, but also in developing countries where children are increasingly gaining access to digital technology. For example, survey data from the Swedish Media Council (Statens Medieråd, 2013) show how parents in a developed country with near-ubiquitous access to digital technology consider online gaming a great asset in their children's lives, providing them with many opportunities to benefit, while at the same time they rate online gaming as one of their greatest sources of worry, fearing that children might spend too much time playing. A similar narrative emerged from focus groups with parents of child internet users conducted in South Africa (Burton, Leoschut and Phyfer, 2016), where parents acknowledged the many benefits that the internet could offer to their children while simultaneously expressing concern over the time their children spent online and the many risks they may encounter in the process. Clearly parents face a difficult task in mediating their children's use of digital technology, but nevertheless an important one due to the central roles that both parents and digital technologies play in a child's life. In the interest of making this task easier, this paper presents the results of an evidence-focused literature review of how time spent on digital technology impacts on children's lives, focusing on impacts in three domains: mental well-being, social relationships and physical activity. The paper examines the gaps in evidence and suggests new directions for future research and improvements to research methodology.

The main research question posed in this paper is:

How does the time children spend using digital technology impact on their well-being?

Because children's well-being is a complex concept with no universally accepted measurement, one common approach to conceptualizing child well-being is to consider it as a multi-dimensional concept, covering mental/psychological, social and physical dimensions (Chapple and Richardson, 2009).

The research question was broken down into dimensions, as follows:

- I. How does digital technology impact children's mental well-being?
- II. How does digital technology impact children's social relationships?
- III. How does digital technology impact children's participation in physical activities?

While child well-being in relation to digital technology has been explored using a variety of subjective and objective measures, any references to child well-being in this paper refer to self-reported, subjective well-being - unless stated otherwise.

2.1 Terminology and theoretical assumptions

In the interest of clarity, the term *digital technology* will be used as a catch-all term that includes digital devices, such as computers, tablets and mobile phones, as well as the many digitally mediated activities that children today engage in via these devices, such as using the internet, going on social networking sites, chatting or playing video games. Television is not encompassed by this term and will be mentioned separately, when relevant.

The term *excessive use* will be used to denote that a significant amount of time is spent using digital technology, but without quantifying how much time this implies in practice. This approach is taken because there is no official threshold for when the time spent using digital technology is determined to be excessive, as this is highly individual; some people are able to spend a great deal of time on digital technology without experiencing any adverse outcomes. In this respect, I will adopt Larkin and Griffiths' (1998) perspective that for some individuals in some contexts, it makes sense to use digital technology 'excessively' because the positives outweigh the negatives. Where studies have provided specific time-thresholds for excessive use, this will be highlighted.

For scholars studying time use and digital technology, the main purpose is typically to investigate how time spent on digital technology impacts an individual in various domains. For example, studies may look at specific outcomes such as how time spent on digital technology impacts self-reported well-being over time, or if perceived quality of friendships is increased or reduced. When applied to children, studies of time use typically aim to uncover the eventual risks of overusing digital technology and investigate how to ensure an optimal developmental trajectory, avoid life interference, and mitigate potential negative health outcomes.

A common assumption in this area of research is that time is a zero-sum commodity and therefore time spent on digital technology will inevitably detract from other activities that are thought to be more valuable, such as socializing face-to-face, reading books, or exercising; this is sometimes referred to as the *displacement hypothesis*, which posits that harm caused by technology are linearly proportional to exposure (Neuman, 1988). This hypothesis initially received some support and its assumptions served to inform early policy statements and guidelines that proposed restrictions to children's engagement with digital technology, such as the former guidelines by the American Academy of Pediatrics (AAP, 1999). However, more recent evidence suggests that today, the displacement hypothesis may be simplistic or even inaccurate, because recent technological developments offer many opportunities for children to pursue developmentally valuable challenges and activities (Przybylski and Weinstein, 2017). These developments are reflected in AAP's updated policy statement, which contains a less restrictive set of guidelines, recognizing the value of digital technology for the younger age groups too (AAP, 2016).

In light of these developments, some researchers have argued that the impact of digital technology on children might not necessarily be linear, in so far as more use does not always lead to worse outcomes. Przybylski and Weinstein (2017) suggest that the impact of the time spent on digital technology on children may, instead, be explained by a curvilinear relationship (Przybylski and Weinstein, 2017), which challenges the displacement hypothesis. In other words,

not using digital technology at all might be expected to have a negative impact on children, while moderate levels of use could have a positive impact, and excessive use might have a negative impact. Problematically, there is no clear agreement on when the time spent on digital technology shifts from being moderate to excessive, as this is likely to be highly individual. In this respect, excessive use is a value-laden term and determining 'How much is too much?' inevitably depends on the age of the child, her/his individual characteristics, the culture that she or he lives in and her/his broader life context. For digital technology especially, opinions on how much is too much also vary over time and across generations. This makes the question in relation to digital technology particularly complex, as we may expect adults and children to have different opinions on the matter, with neither group necessarily being more right than the other. This has made it difficult for researchers to design appropriate studies on time use that allow us to make recommendations grounded in children's lived experiences, because adult perceptions on how much is too much tend to drive the inquiry. Since we cannot yet objectively determine how much is too much for a given individual, drawing the line between an engaging digital hobby and excessive use is difficult – many people have hobbies which they sometimes spend a bit too much time on to the detriment of other activities, but this is not always a problem for them, as much as it might be a problem for the people around them (Cover, 2006; Charlton and Danforth, 2007; Kardefelt-Winther, 2014; Kardefelt-Winther et al., 2017).

Some scholars who study time use and digital technology have taken an exclusively clinical approach to the subject, arguing that people use digital technology excessively because they are addicted to it, or addicted to specific activities mediated by digital technology. The harm that is assumed to result is seen to be similar to the harm resulting from substance addiction. The assumptions that underlie this perspective is that behaviours and activities can be addictive in much the same way as substances (Marks, 1990; Marlatt et al., 1988) and that digital technologies, due to their many rewarding features, may be particularly addictive. Addiction to digital technology is typically measured by asking questions based on substance addiction assessment instruments (Petry et al., 2015). The key aim for studies appropriating an addiction perspective has been to show that digital technology can be truly addictive, consequently advocating the need for professional treatment of those who are affected. The proposal that digital technology can be addictive has been challenged by many researchers over the years and there is no consensus yet on whether such a perspective on excessive use of digital technology is accurate or useful (Griffiths, 2000; Cover, 2006; Kardefelt-Winther, 2014; van Rooij and Prause, 2014; Griffiths et al., 2016; Aarseth et al., 2016).

Research on time use and addiction deal with distinctly different questions, but researchers often conflate them. While both areas focus to some extent on the link between time use and negative outcomes for the individual, the addiction perspective is driven by the underlying assumption that excessive use of digital technology may be caused by an addictive disorder, rather than driven by fascination or engagement. The addiction perspective also takes a binary approach where an individual either has an addictive disorder or not, and where the presence of disorder always leads to negative outcomes. In comparison, the study of time use views the time children spend on digital technology on a continuum where some negative outcomes can co-exist with benefits. That researchers conflate these perspectives has led to conceptual struggles in this area of research and in the public discourse, which has been recognized and discussed by several groups of researchers in recent years (Griffiths et al., 2016; Aarseth et al., 2016; Kardefelt-Winther et al., 2017). One unfortunate consequence of this confusion is that many studies have focused on exploring the hypothetical idea of addiction to technology, instead of exploring why some children spend a lot of time using digital technology and when this might impact their lives and well-being positively or negatively (Kardefelt-Winther, 2014).

This second aspect seems more relevant in response to the growing societal concerns around children's increasing use of digital technology.

In this paper these two perspectives will be kept separate, despite researchers' tendencies to conflate them. This division is justified because of the need to separate research concerned with the impact of time spent using digital technology on children - an area where more research is urgently called for by many (Palmer et al., 2016; Etchells et al., 2017) - from the hypothetical idea that technology can be addictive. The main part of the paper will thus review the available body of evidence on the impact of time spent using digital technology on children's well-being. The second part will critically appraise what we know about the idea of addiction to technology and the popular science notion that digital technology might hijack or re-wire children's brains.

2.2 Methodology

To respond to the main research question, an evidence-focused literature review was undertaken by drawing on some of the core principles of a systematic review (Khan et al., 2003), while still leaving room for reflection and interpretation.

The review encompassed literature published between 2005 and 2017. This time frame covers the period when digital technology became available for everyday use by children in Western societies and regular use became the norm. The search strategy involved three step-by-step processes:

- 1) An academic literature search for peer-reviewed journal articles using the databases PubMed, PsycINFO and Google Scholar;
- 2) The identification of three experts working in the field followed by an email exchange to ascertain their knowledge of and access to further literature, and recommendations for other sources (snowballing technique); and
- 3) Browsing the reference list of empirical articles found through processes 1 and 2 for additional relevant articles.

Search strings based on the three areas of interest were used for the database search. Search strings used were: (children digital technology AND (wellbeing OR well-being)), (children digital media AND (wellbeing OR well-being)), (digital* OR "digital technology" AND child*), (digital* OR "digital technology" AND (well-being OR wellbeing OR physical* OR social* OR relationship*)), (digital* OR "digital technology" AND (child* OR adolescent*)) AND (well-being OR wellbeing OR physical* OR social* OR relationship*)).

The results for each search string were sorted by relevance where possible, otherwise they were sorted by date, and screened for relevance to the three sub-questions. Results from the first ten pages of each search engine were included. If selected, the article was categorized according to theme (mental well-being, social relationships, physical activity). Cross-sectional studies, longitudinal studies and meta-analyses were included. Non-empirical papers including literature reviews were excluded to avoid relying on secondary data sources. Only studies of children (age 0-18 inclusive) were included in the final corpus. Studies that used addiction measurements or lacked an indicator for time use were excluded.

A total of 301 unique peer-reviewed journal articles were identified in the literature search. Of these, 226 were excluded as they covered the wrong subject or lacked indicators for time use; 10 articles were excluded for being reviews of the literature; and 45 articles were excluded as they

studied the adult population. A total of 20 articles were retained based on the database search, corresponding to 6.6% of the total number of articles found in the search.

While every effort was made to capture a broad spectrum of material of possible relevance to the research questions, it was expected that achieving comprehensive coverage would be unlikely through database searches alone. The experts contributed another 6 articles. Browsing the reference lists of empirical articles from the literature search yielded another 29 relevant articles, making the total number of articles included in this review N=55. One limitation of the literature search was that only studies in English were included.

A secondary aim of the paper was to provide the reader with a critical overview of the hypothetical idea of addiction to technology. This part of the paper is not based on a comprehensive literature search but draws on a selection of studies that have explored this topic in depth.

2.3 Limitations

Before presenting the results of the literature review, limitations to research studying the impact of digital technology on people, sometimes referred to as 'media effect' research, are highlighted. These limitations are highlighted because they generalize across most studies included in this literature review. Therefore even the most rigorous studies presented in this paper should be interpreted with some caution.

First, many studies are correlational in nature and use cross-sectional data, which means that they cannot establish what is cause and effect or establish long-term consequences. In other words, the data collected cannot be used to determine whether an effect, for instance increased levels of depression, is the cause or the consequence of using digital technology. Both may be plausible – a person could feel more depressed after spending a lot of time online, or someone who is feeling depressed might spend a lot of time online to cope with these feelings. Longitudinal studies are needed to tell us more about causality and whether any effect is persistent over time. This is important for determining whether the time spent on digital technology has an effect on well-being in the long term.

Second, it is likely that individual differences influence how use of digital technology impacts a child. Such differences include age, gender, personality, life situation, social and cultural environment and other factors (Livingstone et al., 2011; Kardefelt-Winther, 2014; Byrne et al., 2016; Livingstone, 2016; Banaji, 2016). Most studies tend to account only for a limited number of background variables for practical reasons, such as survey cost and length. Traditionally, it has been more common to investigate only the psychological characteristics of a child and what they do online, without considering their broader life context. This means that studies may a) overestimate the effect of digital technology on children, or b) assume that digital technology has an effect, when the effect is due to another cause.

Third, it seems likely that the activities and content children engage in via digital technology is equally or more relevant to any of the positive or negative outcomes experienced, compared to time use (Etchells et al., 2017; Przybylski and Weinstein, 2017). Focusing on time use alone without considering what a child is actually doing online, limits the scope of the inquiry and the value of the conclusions drawn.

Fourth, most research on media effects do not have pre-registered study protocols, which means that the studies may suffer from confirmation bias or selective reporting of results. Pre-registering research protocols is part of a recent movement towards reproducible science, where researchers are encouraged to publicly register a study and its hypotheses prior to data collection to be transparent about the foundation for their analysis. The importance of pre-registration was recently advocated in *Nature*, as a way to combat low reproducibility of research findings and to maximize the efficiency of the research community's use of the public's investment in research (Munafó et al., 2017). While pre-registration of study protocols for randomized controlled trials in clinical medicine has become standard practice, this is not the case in the psychological sciences. Pre-registration is increasingly advocated to reassure the research community that the analysis conducted was planned in advance to avoid 'cherry picking' of results and intentionally or unintentionally highlighting only those relationships that were statistically significant (Munafó et al., 2017).

With these shortcomings in mind, the next sections present the results of the literature review.

3. LITERATURE REVIEW

3.1 Impact of time spent using digital technology on children's mental well-being

Some cross-sectional studies have found a positive association between both internet and mobile phone use and self-reported feelings of depression (Kim et al., 2010; Bezinovic et al., 2015; Ikeda and Nakamura, 2014). However, the effect sizes for the associations found were small²; a finding that has also been observed in larger and more robust studies. For example, Ferguson (2017) in a study of 6000 children aged 12-18, found a small positive association between screen time and depressive symptoms and delinquency. A longitudinal study by Selfhout and colleagues (2009) provides a more nuanced perspective on the relationship between digital technology and depression; for children with low-quality friendships, spending time just surfing seemed to lead to a slight increase in self-reported feelings of depression over time (Selfhout et al., 2009). For children with medium- or high-quality friendships, there was no association between time spent just surfing and self-reported feelings of depression. However, if the children with low-quality friendships spent their time socializing with others online, this led to reduced self-reported feelings of depression, leading the authors to conclude that what children do online is crucial and should be considered in addition to the time they spend online. The authors suggest that reduced feelings of depression might occur because socializing online increases the chance of receiving social support, which may otherwise not be available to children with low-quality friendships.

Ferguson (2017) found a small but significant positive association between time use and feelings of depression and delinquency only for those children who repeatedly reported more than six hours' screen time per day. Given the relatively weak impact even on children who report more than six hours' screen time per day, the author suggests that reducing screen time in efforts to improve youth well-being is unlikely to be effective for most children. Ferguson (2017) suggests

2 In simple terms, the strength of an association between two variables determines how much one variable can be said to influence the other, and its numerical interpretation is referred to as the effect size. While there are no strict rules for interpreting effect sizes, Cohen (1988) has provided what is arguably the most common rule of thumb within psychological sciences: an effect size of $r \leq .1$ represents a 'small' effect size (where the predictor variable only has a minor influence on the outcome), $r \sim .3$ represents a 'medium' effect size and $r \geq .5$ represents a 'large' effect size. However, these conventions should be used with caution, as a small effect in one context might be considered large in another.

based on these findings that youth seem to be quite resilient to screen consumption at much higher levels – up to six hours daily - than is typically recommended by most policy statements.

This perspective is further supported by a recent cross-sectional, large-scale, pre-registered study conducted in the UK with over 120,000 15-year-old children, where Przybylski and Weinstein (2017) found that the time children spend using digital technology only had negligible impacts on mental well-being. In this robust inquiry, Przybylski and Weinstein (2017) studied the impact of a variety of digitally-mediated activities on children's mental well-being, such as watching TV and movies, playing video games, using computers and using smart phones. The activities differed somewhat in their respective impact, but the authors conclude that in general, no use at all was associated with lower mental well-being, while moderate use seemed small positive effect on mental well-being up to a certain point. For example, watching TV and movies or using computers had a small negative impact when use exceeded 4 hours per day, in contrast to smart phones which had a small negative impact when use exceeded 2 hours per day. Prior to reaching these cut-off points, each activity showed a positive impact on mental well-being. The study controlled for gender, ethnicity and economic factors. The negative impacts were somewhat higher when the time spent on digital technology went beyond these cut-off points during weekdays, indicating that screen time might for some children interfere with structured activities during the week, such as homework, but can be used more extensively on weekends. An important point emphasized by the authors was that even though negative effects were found after the time spent online exceeded a certain threshold, these effects were very small, contributing less than 1% towards explaining the overall well-being of the young people in the sample. This led the authors to conclude that "the possible deleterious relation between media use and well-being may not be as practically significant as some researchers have argued" (p. 10).

For very young children, findings from a large cohort study of more than 13,000 children aged 5 in UK show that using screen entertainment for more than 2 hours a day was associated with a small increase in emotional and conduct problems in girls only. The study found no evidence that longer duration of screen usage was associated with any other mental health problems investigated for boys or girls, such as hyperactivity, peer problems or prosocial problems (Griffiths et al., 2010). A qualitative study providing case study evidence from observations and participatory research with more than 50 families and their 3 to 4-year-old children in Scotland found no evidence from parents that technology was having a detrimental effect on their children in terms of behaviour, health or learning (Plowman and McPake, 2013). This was further supported by a longitudinal study that followed UK children from age 5 to 7, finding no negative impact from playing video games on either conduct problems, emotional symptoms, hyperactivity/inattention, peer relationship problems or pro-social behaviour, with no gender differences observed (Parkes et al., 2013). Television viewing however was associated with a small increase in conduct problems over time, if viewing exceeded 3 hours per day. In a study of children aged 10-15, Przybylski (2014) found that low levels of video game playing of less than one hour a day was associated with many benefits, such as higher levels of pro-social behaviour and life satisfaction, as well as lower levels of conduct problems, hyperactivity, peer problems and emotional problems. Children who played between 1-3 hours per day saw no effects on these outcomes, while those who spent more than half of their daily free time on video games saw some small negative effects. This supports the idea that video games can function similarly to traditional forms of play, presenting opportunities for identity development as well as cognitive and social challenges (Przybylski, 2014). However, as stated previously, after time spent on gaming exceeds a certain threshold these positive influences may diminish or disappear. Looking to another popular online activity, use of social networking sites, longitudinal research found that too much time spent on this activity might have some negative impact on mental

well-being (McDool et al., 2016). Exploring the relationship between time spent on social networking sites and mental well-being further, an experimental study found that passive Facebook usage, meaning passively browsing news feeds or looking at friends' pages and pictures without interacting with others, led to a decrease in well-being by enhancing feelings of envy (Verduyn et al., 2015). This might explain why some studies of young adults (e.g. Kross et al., 2013; Chou and Edge, 2012) have found a negative association between using social networking sites and well-being; as profiles on social networking sites are often used to craft and convey a positive image of a person, this might influence our perceptions of other people and their lives and lead to feelings of envy or inadequacy.

Taken together, this review shows that the time spent on digital technology can have both positive and negative effects on child well-being, depending on the activity and how much time is spent. No use and high use tends to be associated with negative effects, while moderate use seems to have positive effects. However, these effects - whether positive or negative - are typically weak and only contribute a small part to explaining overall child mental well-being. As some studies have concluded, if the goal is to improve the mental well-being of children it seems more important to ensure a healthy life style for children in general rather than reducing screen time. As Przybylski (2014), Parkes and colleagues (2013) and Ferguson (2017) suggest in their respective studies, factors shown to have robust and enduring effects on child well-being such as family functioning, social dynamics at school and socioeconomic conditions, are more important than the direct influence of time spent using digital technology. While gender differences were found in relation to how children use digital technology, few significant gender differences in terms of the impact on mental well-being, were found in these studies.

As Przybylski (2014) suggests, even if no direct negative effects result from heavy technology use, it may crowd out other activities that could benefit the child. Longitudinal data and cohort studies are needed to understand the cumulative effects of spending a lot of time on digital technology from a young age.

3.2 Impact of time spent using digital technology on children's social relationships

Research on the impact of digital technology on children's social relationships tend to follow four main hypotheses, some of which predict positive outcomes, others negative ones:

- The displacement hypothesis mentioned previously, suggesting that online social interaction is replacing face-to-face interaction, which could result in lower social capital and fewer personal acquaintances (e.g., Kraut et al., 1998; Putnam, 2000; Turkle, 2011).
- The rich-get-richer hypothesis (Kraut et al., 2002), suggesting that those who already have strong social networks and skills will benefit more from digital technologies in terms of social interaction than those who have weaker social connections.
- An alternative to the rich-get-richer hypothesis, called the social compensation hypothesis, suggesting that online communication will be more beneficial to people who are socially anxious and isolated as they may feel more at ease when developing friendships online in a safe environment (McKenna, Green and Gleason, 2002; Kraut et al., 2002).
- The stimulation hypothesis (Valkenburg and Peter, 2007), suggesting that online communication stimulates communication with existing friends, leading to mostly positive outcomes and stronger friendships overall.
- Studies in this area of research have typically focused on exploring one or several of these hypotheses.

A cross-sectional study of 1300 adolescents aged 12-18 showed that although time spent on digital technology did reduce the amount of time adolescents spent interacting with their parents, it did not actually reduce the quality of the parent-child relationship (Lee, 2009). While time spent using a computer to study was related to spending less time with friends, greater engagement in online communication seemed to strengthen friendships. The positive relationship between online communication and friendship quality or social capital has been found in various cross-sectional studies both of children, adolescents and young adults (Peter et al., 2005; Valkenburg and Peter, 2007; Ellison et al., 2007; Jacobsen and Forste, 2011; Davis, 2013). For example, Peter and colleagues (2005) found that extroverted individuals tended to self-disclose and communicate online more often than others, which improved their online friendships. In other words, there are good grounds to believe that it is easier to talk about personal or sensitive topics online, which would account for some of the positive associations observed between online communication and social relationships. Similar findings also emerged from a qualitative study (Davis, 2012). In addition, Valkenburg and Peter (2007) in a cross-sectional study of Dutch adolescents found that online communication was positively correlated with time spent with friends and that it improved the quality of existing friendships, leading to greater well-being.

Several authors have suggested that those who communicate online more frequently tend to feel more connected to their school environment (Ellison et al., 2007; Lee, 2009), because they have stronger friendships. These findings broadly support the stimulation hypothesis and the rich-get-richer hypothesis, but some of the findings also suggest that the displacement hypothesis might be relevant for relationships that are less prioritized by adolescents. Since peer relationships tend to be prioritized over family relationships during teenage years, this explains why time spent on online communication is associated with a decrease in family time, but not with a decrease in time spent with peers (Lee, 2009).

There is also some support for a social compensation hypothesis; Peter and colleagues (2005) found that introverted adolescents were more motivated to communicate online to compensate for lacking social skills, which increased their chances of making friends online. This might be particularly beneficial for those children who find it easier to self-disclose online compared to offline, which seems to be more common among boys than girls (Valkenburg and Peter, 2009). Also in support of the social compensation hypothesis, a meta-analysis of eight studies on Facebook use and loneliness found that people who feel lonelier tend to use Facebook more often (Song et al., 2014), rather than Facebook use causing people to feel lonely. However, the estimate of the causal direction was based on path modelling of cross-sectional data, which means that the true causal direction is still unclear.

Taken together, the results from this review supports the statement that the internet (or digital technology) by itself is not a main effect cause of anything (McKenna and Bargh, 2000; Peter et al., 2005), but that it is the contextual and individual factors that determine impacts on social interaction and relationships. Valkenburg and Peter (2009) conclude in their review of a decade on research on the social consequences of the internet for adolescents that there has been a clear shift in research findings in this area. While early research from the 1990s tended to report that internet use was detrimental to social interaction and relationships, recent studies tend to report mostly positive impacts, a conclusion also reached in a review by George and Odgers (2015). Valkenburg and Peter (2009) speculate that this is connected with changes in how adolescents used the internet in the 1990s compared to today. In the past, it was difficult to use the internet to maintain existing friendships since the majority of an individual's social network was not yet online, this is not the case today, when most young people have access. This

makes it more likely that digital technology will have positive impacts on friendships and social networks because a large amount of time spent online is spent on strengthening existing bonds of friendship, and not on isolating people in a lonely online space. Today's internet users are far from lonely, which seems to explain the positive impacts of time spent using digital technology on children's social relationships (Valkenburg and Peter, 2009).

3.3 Impact of time spent using digital technology on children's physical activity

Another aspect of children's lives that has received considerable attention under the displacement hypothesis is the relationship between time spent using digital technology and physical activity. Concerns have been raised that as time spent on digital technology increases, time spent on physical activity is reduced, which might be a contributing factor to child and adolescent obesity and physical health problems (Kautiainen et al., 2005). Iannotti and colleagues (2009) drawing on an older cross-sectional sample from the Health Behaviour in School-Aged Children (HBSC) survey implemented in 2000 in Canada and the United States, found that an increase in screen time was associated with small reductions in several health indicators, such as physical health status, quality of life and family relationships.³ Another cross-national study, drawing on a cross-sectional sample of over 5000 9-11 year olds (LeBlanc et al., 2015) found that an increase in screen time was associated with small reductions in physical activity and a slightly less healthy diet. However, in both studies the effect sizes were small. For this reason, Iannotti and colleagues (2009) conclude that interventions targeting screen time alone are unlikely to significantly increase time spent on physical activity. Leblanc and colleagues (2015) suggest that although screen time is an important aspect of sedentary behaviour, it would also be beneficial to consider the positive and negative effects of non-screen based sedentary behaviour, to gain a better understanding of their relative impacts.

The two studies cited here used aggregate estimates of screen time without considering the differences between digital devices, activities or content. This is a weakness that several authors acknowledge (e.g. Kautiainen et al., 2005; Sisson et al., 2010; Straker et al., 2013). Straker and colleagues (2013) showed empirically that different screen-time activities relate differently to physical activity and health indicators. Their findings build on an early cross-sectional study of a representative sample of Finnish youth (14-18 year-olds) that found that only certain forms of technology were associated with higher obesity rates; watching television was associated with a small increase in the likelihood of being overweight for girls only, while playing digital games had no such effect (Kautiainen et al., 2005). Kautiainen and colleagues noted that when accounting for biological maturation and weekly physical activity, the statistical associations were weaker and non-significant for some of the age groups. This might suggest that it is the lack of physical activity rather than screen time that increases the risk of being overweight.

The fact that digital technologies differ in their impact is corroborated by several cross-sectional studies included in this review; television viewing has been linked to a reduction in physical activity (e.g. Devis-Devis et al., 2012; Tolbert Kimbro et al., 2011), while time spent on mobile phones was linked to a reduction in physical activity in one study (Lepp et al., 2013) but to an increase in physical activity in another, though only as far as weekday use is concerned (Devis-Devis et al., 2012). Devis-Devis and colleagues speculate that the increase in physical activity could be explained by the fact that children use their mobile phones while moving around or engaging in other activities. However, few control variables were included in the analysis. These mixed results also appear in studies that use aggregate screen time measures, where

³ Screen time was, however, also associated with a positive increase in peer relationships.

differences in terms of activities or devices are not considered. Some studies find no association between screen time and physical activity (Laurson et al., 2014) while others report a negative association (Sisson et al., 2010).

A large cross-national study drawing on survey data from over 200,000 adolescents aged 11-15 found that the relationship between time spent using digital technology and spare time physical activity also seems to differ depending on age, gender and nationality (Melkevik et al., 2010). Broadly speaking, the study found that spending two hours or more per day on screen-based activities resulted on average in half an hour less per week spent on leisure-type physical activity. Again, the form of screen-based activity adolescents engaged in mattered for the outcome; regular computer use was associated with an increase in physical activity, while gaming and watching television was associated with a decrease. However, these patterns were not stable across all countries. For example, in Eastern and Southern Europe gaming, watching television and general computer use were associated with increases in spare time physical activity. The authors conclude that physical inactivity is unlikely to be a direct consequence of adolescents spending too much time on screen-based activities, but rather suggests that already-inactive adolescents have more time to spend in front of screens. This conclusion is supported by findings from a separate longitudinal study of 11-13- year olds, demonstrating that increased engagement in computer use or video gaming was not directly associated with leisure-time physical activity, and indicating that screen-based activity and physical activity should be addressed separately in health promotion activities (Gebremariam et al., 2013). The authors suggest that factors other than computer use or gaming might better determine whether children spend more or less time on physical activity. Moreover, the association between screen time and obesity found in some studies may be due to dietary behaviours rather than a lack of physical activity. This claim was supported by a systematic review of studies on sedentary behaviour and dietary intake for children, adolescents and adults (Pearson and Biddle, 2011).

In summary, evidence on the impact of time spent using digital technology on physical activity is mixed and inconclusive. While a number of longitudinal and cross-sectional studies have found a link between time spent using digital technology and reduced physical activity, other studies report no such associations. Explanations for reduced physical activity seem to depend on multiple factors beyond the time spent on digital technology, some of which have yet to be examined. Researchers do seem to broadly agree that the link between screen time and physical activity is unlikely to be direct. For example, Tolbert Kimbro and colleagues (2011) suggest that perceptions of neighbourhood safety and the residential environment (e.g. access to parks or playgrounds) might influence the time spent both on digital technology and physical activity. It has been suggested that indoor play offers a compelling alternative to outdoor play in less affluent neighbourhoods and in families where parents have less time available to supervise their children (Tandon et al., 2012). This claim is supported by studies showing that individuals who live in more disadvantaged neighbourhoods tend to have less access to portable play equipment and report lower levels of physical activity and higher rates of obesity, though the causal nature of these relationships is unclear (Tolbert Kimbro et al., 2011; Tandon et al., 2012). The finding that screen-based activity and physical activity seem to be independent behaviours is particularly important for health promotion policies and should be underlined. Longitudinal data suggests that reducing the amount of time spent on digital devices will not automatically increase the time spent on physical activities (Gebremariam et al., 2013). Some authors argue that promoting physical activity independently may be a more useful strategy. This argument is supported by previous longitudinal studies on television viewing and physical activity in adolescence (Taveras et al., 2007).

4. CAN THE USE OF DIGITAL TECHNOLOGY BE ADDICTIVE?

Do some people have problems with spending too much time online? Yes, and some people also spend too much time reading, watching television, and working and ignore family, friendships, and social activities. (Grohol, 1999, p. 400)

Some researchers have suggested that a small group of people spend so much time using digital technology that they experience severe problems in life as a result. This behaviour has been given different labels, such as ‘addictive use’, ‘pathological use’, ‘compulsive use’, or ‘disordered use’, applied to digital devices or online applications or activities (Widyanto and Griffiths, 2006; Smahel et al., 2012). In addition to the different labels, there is no consensus on the problems that such activities are assumed to cause. Few studies have explored in-depth which problems may occur as a direct consequence of a hypothetically addictive use of technology, reflecting the relative immaturity of the evidence base. At present, no consensus exists on how to define this behaviour or how to measure it (Griffiths et al., 2016), though most researchers would agree that the behaviour should, at the very minimum, represent a pattern of use that leads to significant functional impairment or distress for the individual and persistence over a considerable period of time. Some believe that ‘addiction’ is a useful term to describe this behaviour, while others prefer different terminology that does not draw parallels with substance use behaviours (e.g. Smahel et al., 2012; Kardefelt-Winther, 2016).⁴

Most people who read this paper will never encounter an individual who uses digital technology in a way that might be labelled ‘addictive behaviour’. Addicted in a clinical sense means that the consequences of the behaviour are so severe that normal functioning in society is no longer possible. To justifiably describe a child as ‘addicted to digital technology’, their use should lead to clear functional impairment and impact negatively on multiple domains of life. Researchers have not yet been able to present convincing evidence that excessive engagement with digital technology is followed by severe life impairment over time (Thege et al., 2015; Kardefelt-Winther et al., 2017).

Unfortunately, addiction terminology which strictly belongs in a clinical setting is often used in relation to children’s everyday usage of digital technology, based on the assumption that some children’s digital engagement mirrors the behaviour of a substance addict. This is a deeply unfortunate and inaccurate comparison. There is plenty of disagreement among researchers as to whether digital technology should be considered addictive or not, outlined, in part, above. However, most people working in this area agree that careless use of addiction terminology, extended to children’s everyday engagement with digital technology, downplays the very real consequences of the behaviour for those who are seriously affected, while overstating the risk of harm for those who at times engage in somewhat excessive, but ultimately not harmful use. While no consensus exists on the causal factors for addiction in general, there is broad agreement that addiction is not directly caused by a substance or an activity. Rather, addiction seems to be a consequence of multiple interacting individual and environmental factors. In light of this, the popular science claim that time spent on digital technology alone could cause children to become addicted, is a misrepresentation of existing knowledge.

4 A common criticism leveraged against studies in this area is that they fail to capture whether the outcomes of the excessive use are truly severe in a clinical sense. This makes it unclear if the populations studied so far include people who experience a true problem behaviour, or whether studies have unintentionally captured people who experience an intense but ultimately positive engagement in a hobby or leisure activity (Billieux et al., 2015; Kardefelt-Winther et al., 2017).

4.1. What do we know about those who spend so much time using digital technology that they experience severe negative outcomes in life?

No consensus exists on whether excessive use followed by severe negative outcomes might usefully be thought of as addiction or not, nor whether the outcomes of such behaviour truly mirror outcomes of substance addiction (Griffiths et al., 2016). Despite these disagreements, researchers have been tentatively exploring risk-factors for nearly two decades. While these studies suffer from the same shortcomings as studies on media effects (see p. 14), they have provided some initial insights into factors that may be relevant in understanding why some people keep using digital technology excessively despite suffering negative outcomes as a result.

Some of the factors found to be associated with such behaviour are low psychosocial well-being (e.g. Caplan, Williams and Yee, 2009; Lemmens, Valkenburg and Peter, 2011), low self-esteem (e.g. Armstrong, Philips and Saling, 2000), loneliness and shyness (e.g. Caplan, 2002, 2003, 2005, 2007; Whang, Lee and Chang, 2003), stress (Lam et al., 2009), boredom (Lin, Lin and Wu, 2009) and family conflict (Lam et al., 2009). However, it remains unclear whether these indicators are causes or consequences of the behaviour. Furthermore, most research in this area has been survey-based and conducted with largely healthy populations who do not meet the designated cut-offs for clinically relevant problems (Kardefelt-Winther et al., 2017; Aarseth et al., 2017), because it is rare to find individuals who experience severe negative outcomes caused by their engagement with digital technology in the wider population (Van Rooij, Schoenmakers and Van de Mheen, 2017). It is therefore unclear how much we can learn from these studies. Calls have been made for less survey-based research and more clinical patient-focused research to address this issue (Kardefelt-Winther et al., 2017).

In addition to studies on risk-factors, many studies on excessive use followed by severe negative outcomes have implicitly or explicitly suggested that this behaviour might be a consequence of attempts to cope with difficult real-life situations through digital technology (e.g. Young, 1996; Griffiths, 2000; Armstrong, Phillips and Saling, 2000; Whang, Lee and Chang, 2003; Caplan, Williams and Yee, 2009; Lemmens, Valkenburg and Peter, 2011; Smahel et al., 2012; Kuss, Louws, and Wiers, 2012; Kardefelt-Winther, 2014, 2016; Wang et al., 2015). This is similar to the social compensation hypothesis mentioned previously (p. 17). For example, if an individual is feeling sad, they might go online and use an application that distracts them from the sadness, such as an online game or a social networking site. The consequences can be positive and negative; positive because the individual might feel better temporarily, but also negative because the real cause of the sadness may not be addressed (Kardefelt-Winther, 2014). In the long run, this might make the coping behaviour a recurring habit unless the underlying problem is resolved, which could lead to severe negative outcomes due to the time spent on the coping activity. In this sense, use of digital technology can be seen as a form of self-medication, though it remains unclear when and for whom it is positive and helpful and when it becomes maladaptive and harmful. Griffiths (2000) speculated that for individuals with permanent real-life difficulties such as physical or mental disability, the need for compensation might be constant which would explain persistent excessive use followed by severe negative outcomes, though this might still be preferable to other alternatives. Many researchers agree that it is the underlying problems which prompt excessive screen time that need to be addressed to successfully overcome this problem behaviour, whereas a forced reduction in screen-time would represent a surface intervention that is unlikely to serve its purpose (Griffiths et al., 2016).

This body of research should not be interpreted in relation to children's everyday interaction with digital technology, nor should parents or teachers attempt to diagnose children if they

encounter those who use technology in a way that appears to be excessive to the adult in question. As Bax writes (2014), young people tend to see online activities as a welcome escape from the pressures of life. Bax (2014) suggests based on interviews with parents and children in China that the real problem may rather lie with figures of authority who put pressure on children to conform to their own values, without considering what the children want for themselves. In this respect, it is not surprising that although disagreements around children's use of digital technology sometimes occur in the home, the causes may be found both in parents' attitudes to digital technology and in the children's use of it.

4.2. Can digital technologies hijack or rewire children's brains and make them addicted?

While substance use has been linked to changes in brain structure, which in turn has been linked to reported problems in life (e.g. Leshner, 1997), this is likely due to the direct physiological impact of substances on the brain. Some authors - including journalists from mass media and the popular science press - occasionally claim that harmful structural brain changes can occur also from using digital technology. Media reports sometimes claim that internet use and new technology can 're-wire' children's brains and make them addicted (e.g. Ferranti, 2016). However, while some behaviours may certainly change brain structure and its function, this cannot, in itself, be taken as evidence for the development of addiction, nor can it even be considered a harmful outcome *per se*. Brain changes are part of a normal development process, in particular during adolescence (Blakemore and Mills, 2014). Changes in brain structure, as measured by magnetic resonance imaging (MRI) studies, seem to be subject to strong genetic control between late childhood and adolescence and are thus unlikely to be affected in any major way by subtle environmental influences such as technology (Mills, 2014). As Mills (2014) concludes in a recent review of the neuroscience literature on the effects of internet use on the adolescent brain, "Major brain changes, akin to what is suggested by the phrase 'rewiring the brain' are unlikely" (p. 385).

Another popular claim sometimes found in media reports (e.g. Ferranti, 2016; Kardaras, 2016), which draw on neuroscience literature though do not necessarily reflect the body of evidence accurately, is that internet can 'hijack the brain' by interfering with its reward system to the point where a behaviour becomes encoded as habit. This idea draws on the dopamine theory of addiction (see Nutt et al., 2015 for a review), which reached some prominence in neuroscience as an explanation of why addiction occurs. Dopamine is a neurotransmitter which has been shown to play a major role in reward and learning (Di Chiara and Imperato, 1988). The dopamine theory of addiction suggests in simple terms that drugs cause a dopamine release stronger than that of natural rewards, making drug intake more motivationally important than other activities in life, in the end resulting in uncontrollable drug use and addiction. The idea when applied to digital technology is that as a pleasurable activity, digital technology will stimulate the release of dopamine in the brain and produce feelings of reward similar to a drug. It has been suggested that the individual will find the feelings of reward produced by digital technology so desirable that they are unable to control or stop the behaviour, thus leading to addiction.

This claim has received plenty of attention both in mass media and research, but draws on somewhat outdated and misunderstood perspectives on the link between reward and addiction. A recent review by Nutt et al., (2015), accounting for evidence from 40 years of research on the dopamine theory of addiction, concludes that dopamine release is not responsible for the euphoric effect of all abused substances (p. 307) and that the relationship between dopamine and addiction is likely to be more complex than the dopamine theory of addiction suggests. This effectively debunks the claim that dopamine release and feelings of reward resulting from use

of digital technology alone could cause addiction. The same review states that dopamine might even have a role in resilience against becoming dependent on some substances, turning the dopamine theory of addiction on its head (p. 308). The dopamine theory of addiction has been further challenged for either excluding relevant studies that do not support the link between reward and addiction or for relying too much on evidence from animal models that do not necessarily generalize to humans (Nutt et al., 2015). Release of dopamine is not problematic in itself, but a natural function that serves many important roles in normal brain functioning, such as influencing attention, working memory, motivational salience and fluent motor function. From a logical standpoint, if using digital technology could hijack the brain (or the dopamine system) and cause addiction, simply by being pleasurable, it stands to reason that most people would be addicted to it. This is clearly not the case, suggesting that dopamine release and feelings of reward alone do not cause addiction. This is supported by recent thinking in the neuroscience literature on substance addiction, as only a minority of drug users develop addiction (Nutt et al., 2015).

To conclude, the neurobiological mechanisms that may contribute to excessive use of digital technology are, so far, largely unknown. However, it is unlikely that digital technology can cause addiction by directly impacting the brain. Furthermore, claims that the brain might be hijacked or re-wired by digital technology are not supported by neuroscience evidence and should be treated with skepticism. Brain imaging methodologies are still in a very early stage and although studies that report links between brain structure and behaviour tend to receive much attention in science and the media, recent findings show that many such links fail to replicate in follow-up studies (Boekel et al., 2015). Unfortunately, both mass media and researchers sometimes misuse, misunderstand or exaggerate neuroscience findings, which leads to unhelpful narratives about hijacked brains, causing fear and confusion among the public.

5. DISCUSSION

Research on how digital technology impacts children's well-being has been ongoing for almost two decades, with research conducted between 2005 and 2017 reviewed here. While some high-quality studies are now emerging, in particular in recent years, research in this area still suffers from theoretical and methodological weaknesses that makes the evidence collected so far unreliable and inconclusive. Four issues need to be addressed to produce more conclusive evidence:

- Many studies use aggregate screen time measures where the self-reported total time spent with screens per day or per week is used to predict well-being outcomes. The assumption that all screen time is equal has been criticized and it would be beneficial for future studies to measure the effects of specific instances of screen time separately, such as mobile phone use, video gaming or using social networking sites (e.g. Przybylski and Weinstein, 2017). This would also enable an examination of how the content of children's digital experiences influences the outcomes, providing necessary granularity to screen time research.
- There is a need for more longitudinal studies in this area; cross-sectional research has been useful as a starting point for hypothesis-generation and initial theory-building, yet to advance theory and arrive at firm conclusions, we need longitudinal evidence that looks at how digital technology impacts children over time. It is possible that digital technology may not have immediate positive or negative effects on children - which would explain the small effect sizes found in some studies - but there may be cumulative outcomes that can only be captured in long-term studies.
- Researchers can help to promote age- and context-specific policies by collecting data over time, from children of all age groups and genders, taking their life context and socio-demographics into account to the greatest extent possible (see Byrne et al., 2016 or Livingstone, 2016 for a useful research framework). More background variables need to be included as controls in quantitative studies, to ensure we do not exclude variables that have known effects on child well-being outcomes. Children's online experiences cannot be studied in isolation from their lives in general. Qualitative data from children and parents could be particularly beneficial to understand the circumstances under which children's use of digital technology has positive or negative impacts on their lives. Qualitative data has an advantage in that it allows participants to freely express themselves, which can generate new knowledge and insights driven by children's own voices and experiences.
- The research community needs to strengthen reproducibility of research and the reliability of findings. Researchers may wish to register their hypotheses before collecting data and then share the raw data and analysis code attached to each publication, so that every policy-relevant research finding is produced in a transparent way, is computationally reproducible and freely accessible online (for example through the Open Science framework⁵). This would enable stakeholders to vet claims that are being made and enable transparent debate within the research community before evidence is used to inform policy or practice.

A final point concerns the role of media outlets, which should ideally provide evidence-based, balanced reporting on issues relating to children's use of digital technology. As George and Odgers (2015) write in their review of fears around digital technology, media coverage can

5 <https://osf.io/>

both capture and influence societal fears, which emphasizes the importance of providing a nuanced picture. This is not easy to do given that evidence in this area is inconclusive and conflicting, which puts journalists in a difficult spot. Even so, too many news articles share evidence from single studies or studies that are methodologically weak, or exaggerate or misrepresent the evidence provided. This can distract attention from more pressing issues for children, or lead to situations where research and policy seeks to address problems too quickly via interventions that have not been properly evaluated. This is not necessarily the fault of the media outlets or journalists - it also signals that there may be issues with respect to science communication by universities and research institutes. One way to tackle this issue is to write press releases together with researchers, to ensure that both findings and study limitations are communicated properly.⁶ This requires researchers, in turn, to become more aware of the limitations of their studies and use appropriate descriptions of the research conducted, when speaking to journalists; the distinction between *exploratory hypothesis-generating* research and *confirmatory hypothesis-testing* research is critical. Cross-sectional data is too often used to test hypotheses that require longitudinal or experimental data, without the appropriate caveats in place. Such studies dilute the evidence base and contribute to confusion among researchers, the media, the general public and policy makers. More research is not always a good thing; it is only a good thing when it is of sufficient quality. Moving forward, journalists, editors and science communicators have a major role to play in ensuring that policy initiatives or interventions are based on high quality evidence.

6. CONCLUSIONS

An important challenge as research on children's use of digital technology moves forward is to understand where to draw the line between healthy and harmful use, which is likely to require an individual approach where each child and their life context is considered separately. Although few negative impacts have been found in relation to the time children spend using digital technology, in order to maximize the positive impact younger children may require provisions and support of a different nature than older children. Similarly, what is harmful for a very young child to see or do online may be largely unproblematic or even positive for an older child. In this respect, blanket-recommendations and policies are unlikely to be effective.

There is an unanswered question with respect to the activities that children's increased use of digital technology may be crowding out. Research on digital technology and children's well-being rarely asks whether other activities could have had some positive influences on the child if they were practised more regularly. This relates to the displacement hypothesis mentioned previously (p. 17). Although plenty of research has explored this hypothesis, the consequences of an increase in children's use of digital technology and a decrease in other potentially beneficial activities are rarely considered together. We need more comprehensive, large-scale, longitudinal studies that look at children's time use in general in order to be able to truly say whether the time spent using digital technology over time has a positive or negative influence on child well-being, also considering activities that may be crowded out. It is not feasible to investigate the effects of digital technology in isolation from children's lives in a broader sense. The use of digital technology, as a multi-faceted activity, needs to be considered together with other activities that are part of children's lives in order to determine where the trade-offs are, and work towards achieving the best possible life balance for each individual child.

⁶ For a good example of high-quality science communication, see this press release from Bristol University: <http://www.bristol.ac.uk/alspac/news/2016/video-games.html>

Having also reviewed the hypothetical idea of addiction to digital technology, the contrast to time use studies has hopefully been made clear. This distinction helps us avoid misinterpreting children's fascination with digital technology as addiction. Given the popularity, importance and integrated nature of digital technology in children's lives, conflating highly engaged use with addiction is unlikely to contribute to a constructive dialogue around how to achieve a healthy balance and use in moderation for children. In some countries, the idea of addiction to technology has been used to justify the incarceration of children in treatment camps despite a lack of evidence for the efficacy of such approaches (Aarseth et al., 2016). Media reports from these camps suggest that disciplinary methods employed by staff involved physical punishment and electric shocks (Russon, 2016; Ives, 2017). This violates several fundamental rights of children and could cause significant harm. It illustrates the risk of uncritically applying clinical concepts such as addiction to describe children's everyday interaction with digital technology. Media plays an important role in ensuring that such concepts are not misused.

Finally, children use digital technology for specific reasons and are often able to articulate why they do it. Sometimes these reasons may not seem optimal from an adult point of view, but it is important to take their opinions and explanations seriously, even if we disagree.

Adapting to the increased use of digital technology in society will demand some adjustments in how we parent children, carry out research and develop policy, among other things. The current situation is unusual as children are in many ways the pioneers and experts in this area, often the first to try new applications and programmes - sometimes even creating their own. To be able to effectively adjust to this situation and build constructive dialogues around healthy and harmful uses of digital technology in the family, school, and society at large, we will most likely need to rely more on children's voices and experiences.

7. REFERENCES

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