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**Cascading bidirectional influences of digital media use and mental health in
adolescence**

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Abstract

A substantial portion of critical adolescent development is occurring within digital environments. However, certain individual differences may lead adolescents to use digital media in diverse ways. In this chapter we suggest that the way teens use digital media influences how digital media affects their mental health. Further, we propose a model in which these influences, in the context of on-going development, may have feedback effects on how digital media is subsequently used, thus resulting in a self-perpetuating cycle. Our model suggests that certain developmental risk/protective factors and maladaptive/adaptive digital media behaviors likely perpetuate each other in a cyclical manner each serving to maintain and/or escalate the other. We discuss existing evidence of these processes in psychosocial, identity, incentive processing, and physical health development. Future research focusing on individual differences and self-reinforcing digital media behaviors that manifest these feedback loops may portray a more complete picture of cascading digital media influences across adolescent development.

1. INTRODUCTION

1.1. Digital media use among adolescents. The context in which development takes place has drastically and pervasively changed over the past two decades. Technological innovations and society's ever-increasing reliance on internet connected devices (e.g., smartphones, laptops, gaming consoles) has led to significantly less face-to-face social interactions than ever before (Twenge et al., 2019). This decrease in offline interactions is largely seen among adolescents and younger adults (Twenge & Spitzberg, 2020). Data over the last decade has shown that adolescents spend significantly less time getting together with friends and going to parties, malls, and the movies than previous generations. Meanwhile, adolescents are spending significantly more time using digital media. The 2021 Common Sense Census report indicated that on average adolescents in the United States engaged with digital media for 8 hours and 39 minutes a day, and social media specifically for 1 hour and 27 minutes a day (Rideout et al., 2022). Further, 53% of 14- to 22-year-olds reported that social media was "very important" for staying connected with family and friends during the pandemic (Rideout et al., 2022). As these statistics attest, a significant portion of critical social learning during the transition from childhood to adulthood is occurring within digital environments. Accordingly, emerging evidence suggests that adolescents' use of digital media may have more substantial links to their mental health than that of other age groups (Orben et al., 2022). Thus, understanding the complex and cascading relationships between media use and mental health across adolescent development has arisen as an important public health concern. In this chapter, we discuss how individual differences in psychosocial development, identity development, health behaviors, and incentive processing may both

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influence and be influenced by adolescents' navigation of digital media environments. We posit that these self-perpetuating, bidirectional influences between media use and mental health can cascade and progress across development, ultimately worsening or improving developmental outcomes.

1.2. Defining and Measuring Digital Media Use. Attempts to define digital media often quickly become outdated as media is ever evolving within a society that is both constructing it while also being heavily influenced by it (Nesi et al., 2022). For the purposes of this chapter, we will use the term “digital media” to refer to both hardware and software media components, whereas “social media” refers more specifically to digital media tools that allow for social interaction and selective self-presentation (Nesi et al., 2022). We will largely adhere to Carr & Hayes' (2015; p.51) definition of social media as “internet-based platforms that allow users to selectively interact and self-present, either in real-time or asynchronously, with both broad and narrow audiences who are exposed to user-generated content and the perception of interaction with others” (Carr & Hayes, 2015). Under this definition, social media can include, but is not limited to: social networking sites (e.g., Instagram, Snapchat, Facebook), messaging tools (e.g., text messaging, messaging apps), online forums and communities, video and image-sharing platforms (e.g., YouTube, TikTok), and video games with a social component (Nesi et al., 2022).

Much of the limited existing research on digital media and mental health is cross-sectional and correlational in nature, and thus cannot determine causal relations or directionality of effects. Additionally, it is worth noting that much of existing work focuses on quantity of time spent on digital media which may not be as predictive of health

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outcomes as other more informative metrics like motivations for use, socioemotional reactions to use, types of media used, how media is used (active vs. passive) and other use features (e.g., Selfhout et al., 2009). Additionally, given that digital media experiences can be highly interactive and largely self-selected, their effects on development may differ across individuals. As such, associations between digital media use and developmental outcomes may vary as a function of individual differences. In sum, because digital media is a tool that can be used in various ways, it is important to understand that its effects on development are largely dictated by how it is used.

1.3. Adolescence as a sensitive window. While digital media has profound and significant influences on society, adolescents may be uniquely impacted by it. Adolescence is a critical developmental period characterized by a heightened neurobiological and behavioral sensitivity to peer influence and social feedback, as well as a prioritization of social connection and peer acceptance (Somerville, 2013). Additionally, adolescence is characterized by a peak in sensation, novelty, and reward seeking behaviors that are thought to support exploration and learning during this developmental period and stem from normative changes in brain structure and function, beginning around the onset of puberty (Padmanabhan et al., 2011). Given these sensitivities, it is unsurprising that people under the age of 30 report using digital media more than other ages groups (Perrin & Atske, 2021). Concurrently, adolescence is also a period during which many mental health disorders, including depression, anxiety, eating disorders, substance abuse, sleep problems, and psychosis, often first arise (Blakemore, 2019). As such, digital media use behaviors may have self-enforcing, cascading effects on psychosocial development, identity development, incentive processing mechanisms,

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and health behaviors across this developmental period with critical implications for mental health outcomes.

1.4. Digital media use and mental health: Evidence for a bidirectional relationship. Research has delineated important links between digital media use and mental health. While much of the focus has been directed at how digital media impacts mental health, these relationships are likely bidirectional and covary across development. Digital media exposure begins very early in life with use tendencies emerging alongside other vital neuropsychological developmental trajectories (Yadav & Chakraborty, 2021). While digital media use can impact mental health, we argue that certain preexisting lifestyle features, social behaviors, personality traits, and psychopathological symptoms may also lead one to engage with digital media in certain ways over the course of development. In turn, these individual differences in use tendencies/motivations may cascade across adolescence and ultimately perpetuate or prevent mental health outcomes.

Many important features of digital media use are, to some degree, self-selected. Across childhood and into adolescence, individuals gain more autonomy and control over their amount of digital media engagement (e.g., times checking social media per day, number of accounts, time spent online), type of engagement (e.g., public posting, private messaging, content viewing), type of content created or consumed (e.g., pictures of peers, news articles, music videos), and choice of platform (e.g., TikTok, Snapchat, WhatsApp, Instagram, Reddit). Additionally, many digital media environments are highly interactive in that experience is impacted, either explicitly or indeterminately, based on user input. Moreover, even the same media experiences can be processed differently by

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individuals. As such, youth with risk factors for later progression toward psychopathology (e.g., lack of social support, impulsivity, poor sleep) may interact with digital media in self-reinforcing ways that may impact later mental illness, whereas youth who are resilient or have protective factors for later psychopathology (e.g., supportive social connections, effective emotion regulation, active lifestyles) may also interact with digital media in self-reinforcing ways that may play a part in facilitating their healthy development.

Evidence suggesting bidirectional influences of mental health and digital media use behaviors across development is beginning to accumulate. A recent longitudinal investigation of over 17,000 participants across the lifespan demonstrated a bidirectional relationship between social media use and life satisfaction such that decreased life satisfaction predicted subsequent increases in social media use, while higher social media use also predicted decreased life satisfaction one year later (Orben et al., 2022). Additionally, evidence from cross-sectional data found that loneliness and poor social skills may be both a cause and effect of internet use (Kim et al., 2009). Together, these results suggest that the impact of digital media use on mental health may cascade such that subsequent mental health affects future digital media use in a self-perpetuating fashion across adolescence.

Overall evidence suggests that certain preexisting aspects of mental health may influence the way adolescents' use, perceive, and respond to digital media, which could, in turn, cascade toward either worsened or improved mental health within a self-perpetuating feedback loop. This cascading, self-perpetuating feedback loop model of adolescent mental health and digital media use behaviors is depicted in **Figure 1**. In this model we suggest that individual differences in adolescents' psychosocial development,

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identity development, incentive processing mechanisms, and health behaviors all influence, and are influenced by, how adolescents incorporate digital media into their lives. As such, this self-perpetuating feedback-loop between digital media use tendencies and aspects of mental health could potentially accelerate or intensify certain developmental trajectories. More longitudinal research is needed to understand these potentially complicated, cascading relationships. Over the course of this chapter, we aim to review current research examining various mechanisms by which aspects of mental health and digital media use behaviors may bidirectionally influence each other across adolescent development.

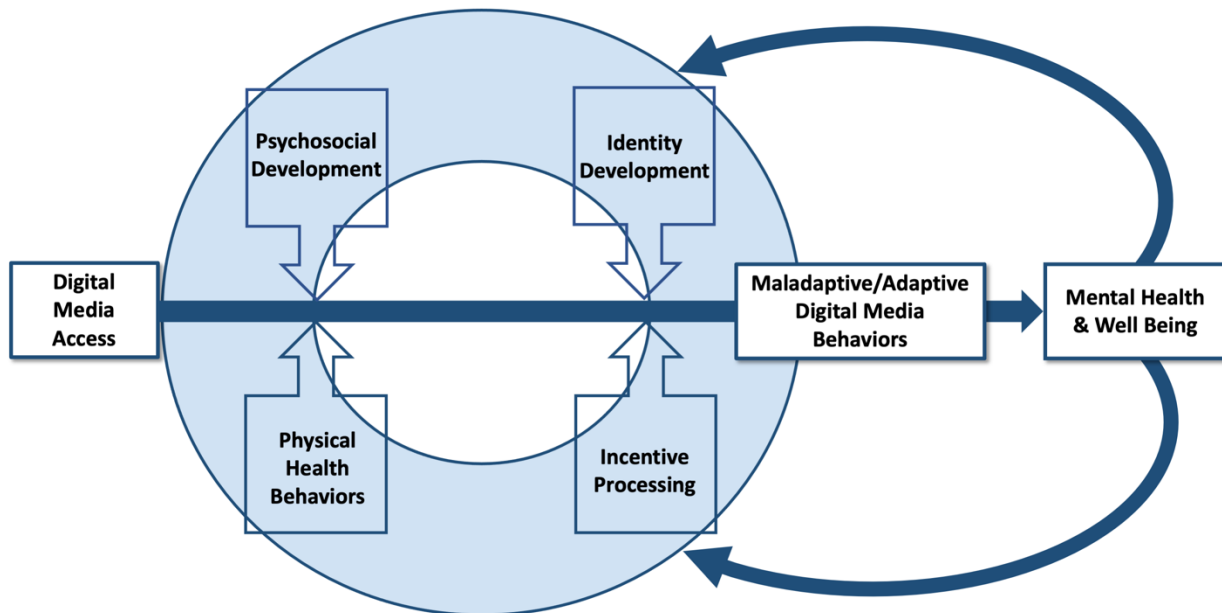


Figure 1. Self-perpetuating feedback loop model of adolescent mental health and digital media use. Individual differences in psychosocial development, identity development, physical health behaviors, and incentive processing may influence and be influenced by how adolescents navigate digital media environments. In turn, these

cascading and self-perpetuating relationships across development could serve to worsen or improve developmental outcomes.

2. PSYCHOSOCIAL DEVELOPMENT & DIGITAL MEDIA

Across development, social support helps protect against psychological distress and is especially imperative during adolescence (Lee & Goldstein, 2016). Research has repeatedly highlighted the importance of peer connections for adolescent development and mental health (e.g., Lombardi et al., 2019). Digital media use can facilitate or hamper social connectedness (Hoge et al., 2017). While some teens may be able to harness digital media to protect against loneliness and strengthen their social connections (Erwin et al., 2004), there are also indications that preexisting social vulnerabilities (i.e., loneliness, low social skills, social anxiety) may lead to maladaptive digital media use behaviors (Caplan, 2007) that ultimately reinforce or even worsen social problems among users. Accumulating findings suggest that individual differences in psychosocial resources, abilities, and propensities (**Figure 1: Psychosocial Development**) may alter how adolescents use digital media (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**), which ultimately impacts developmental outcomes (**Figure 1: Mental Health & Wellbeing**), and, in turn, can perpetuate certain social and digital media use relationships (**Figure 1: Feedback loop**). Below we discuss multiple psychosocial mechanisms that may enable and perpetuate a cascading feedback loop between psychosocial development and digital media behaviors across development.

2.1. Psychosocial precursors and self-perpetuating digital media use.

Researchers have long acknowledged that, to gain a full picture of how digital media use

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impacts social outcomes, it is important to not only consider how digital media influences the social lives of teens, but also consider psychosocial individual differences that may be precursors to digital media use motivations. Specifically, loneliness and social anxiety may impact the degree and way in which adolescents engage in online vs. in-person communication. There are two hypotheses regarding psychosocial predictors of social media use behaviors: the social compensation and the rich-get-richer hypotheses (Valkenburg & Peter, 2007). The social compensation hypothesis proposes that lonely and/or socially anxious adolescents may turn to online communication as it provides either perceived or actual decreases in audio and visual social cues that could help these individuals overcome the shyness or inhibition that they experience in in-person interactions (McKenna et al., 2002). In contrast, the rich-get-richer hypothesis proposes that nonlonely adolescents with strong social skills may engage in more online social interactions than others and use it to strengthen or expand their peer connections (Kraut et al., 2002). However, research suggests that these two hypotheses may not be mutually exclusive and, in fact, may both be at play (Poley & Luo, 2012). Consistent with the rich-get-richer hypothesis, one study demonstrated that non-socially anxious adolescents communicate online more often than socially anxious adolescents (Valkenburg & Peter, 2007). However, consistent with the social compensation hypothesis, digital media also provides a social environment that is less aversive to socially anxious or socially unskilled adolescents (McKenna et al., 2002) and thus might be used as a substitute for in-person interactions. Although, during the COVID-19 pandemic, when there were barriers to socializing in-person, all adolescents had to increasingly substitute in-person interactions for social connection via digital media (Ellis et al., 2020). More research is needed to

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delineate the cascading effects the pandemic had on how adolescents use digital media for social connection. However, emerging findings suggest that critical individual differences in how teens digitally socialized during the pandemic ultimately determined cascading effects on loneliness and mental health outcomes (Cauberghe et al., 2021; Hamilton et al., 2022; Maheux et al., 2021). Taken together, evidence suggests that the ways adolescents incorporate digital media into their social life can determine beneficial and/or harmful cascades across development.

2.2. Using digital media as a distraction or coping mechanism. Some findings have suggested that digital media may perpetuate social problems among adolescents with poor social skills and social anxiety by enabling avoidance of or distraction from in-person social interactions (Hoge et al., 2017). For example, anxiety severity among socially anxious adolescents is associated with a preference for digital media vs. face-to-face interactions (Erwin et al., 2004) and perceiving digital media to be more valuable for intimate self-disclosure, and this perception is, in turn, related to more online communication (Valkenburg & Peter, 2007). While not discounting the various benefits of online social interactions for socially vulnerable individuals, there is growing evidence that long-term replacement of in-person socializing over time might result in socially unskilled adolescents not having as many opportunities to hone their social skills or overcome their social anxieties (Spada et al., 2008). Further, evidence has shown that digital media use can increase anxious individuals' belief that others will be critical and reject them (Erwin et al., 2004). As adolescence is a critical time for social learning and forming relationships, if digital media enables avoidance of in-person interactions among socially anxious

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adolescents, it could exacerbate their symptoms and possibly delay treatment-seeking (Gámez-Guadix, 2014).

Digital media may also be used as a distraction or coping mechanism to relieve social discomfort and anxiety in the short-term. One study found that social discomfort prompted phone use among college students and that most reported that their phones helped them alleviate social discomfort and avoid the people they wish to avoid (Beasley et al., 2016). Other work has shown that using devices for emotional coping is associated with anxiety and depression (Panova & Lleras, 2016). During adolescence significant development of coping strategies occurs in a relatively short amount of time (Williams & McGillicuddy-De Lisi, 1999). Indeed, a recent study demonstrated increases in adaptive coping strategies like social support seeking, and problem solving, across early to mid-adolescence, while avoidant coping strategies decreased (Eschenbeck et al., 2018). Interestingly, digital media use as a coping strategy also increased with age and was used more often when coping with an argument with a friend than with an academic homework stressor. Using digital media to escape negative feelings or avoid in-person social interactions may have cascading influences on adolescents' development of both helpful and unhealthy coping habits that could persist into adulthood.

2.3. Digital media use hindering in-person interactions (phubbing). Given the ubiquity of digital media and that it can be used to cope with social distress, using one's phone while engaged in an in-person social situation is becoming increasingly common and normalized (Procentese et al., 2019). The term "phubbing" has been used in the digital media literature to describe the act of snubbing someone during in-person interactions by using digital media instead of paying attention to them

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(Chotpitayasunondh & Douglas, 2016). Findings suggest that teens who may already be at risk for social difficulties are phubbing more (Sun & Samp, 2021) and that this behavior may also hinder the quality of their in-person communication by lowering self-esteem, feelings of well-being, and relationship satisfaction of those involved (Chatterjee, 2020). As such, social impacts of phubbing might have self-perpetuating and cascading influences across adolescence.

Research among young adults has shown that certain individual characteristics are associated with phubbing behavior specifically, depression, social anxiety, stress, neuroticism (Sun & Samp, 2021), fear of missing out and a lack of self-control (Chotpitayasunondh & Douglas, 2016). While this accumulating evidence suggests that phubbing behavior is common and even more frequent among anxious and depressed teens, there are also findings that demonstrate the implications of phubbing for social connections and relationships. For example, college students experiencing phone use by their conversation partner reported decreased conversation intimacy (Vanden Abeele et al., 2019). Another study examining phubbing behavior among relationship partners found that partner phubbing was associated with reduced relationship satisfaction (Roberts & David, 2016). These findings are critical as the quality of teens' relationships and the quality of their everyday interactions with relationship partners not only influences their current functioning but can set the foundation for their later psychosocial development (Smetana et al., 2006; Sigurdson et al., 2015). Relationship building during adolescence provides teens with vital opportunities to improve their social skills and social competence (Collins & Steinberg, 2006). Overall, we argue that within a cascading feedback-loop, certain social difficulties (**Figure 1: Psychosocial Development**) may lead to increased

phubbing (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**) and increased phubbing may, in turn, hinder relationships and worsen social functioning (**Figure 1: Feedback Loop**).

2.4. Digital media use for social skill building and protecting against loneliness. The impact of digital media use on social outcomes can vary widely with some adolescents having existing social problems enabled or worsened (George & Odgers, 2015) while others reap benefits like social skill building or decreased loneliness (Deters & Mehl, 2013). Specifically, the social aspects of digital media can promote confidence in face-to-face interactions, new friendships, and health-enhancing strategies, even among socially vulnerable adolescents (Hoge et al., 2017). These findings suggest that there may also be adaptive psychosocial-digital media feedback loops (**Figure 1: Adaptive Digital Media Behaviors**). One study examining participants with social anxiety found that those with the most severe anxiety spent the most time using digital media, but also endorsed positive outcomes, including gaining social support, confidence in real-life interactions, new friendships, and new information and understanding about social anxiety (Erwin et al., 2004). These benefits may, in turn, have cascading effects, promoting the formation of more social connections via digital media and more positive social experiences in the future. Another study revealed that lonely adolescents with low social support found identity experimentation via digital media more gratifying than those who were less lonely, and this value placed on online identity experimentation explained their increased preference for social interactions via digital media (Leung, 2011). One multi-timepoint study found that online-only friendships may be protective among suicidal teens, such that teens reporting one or more online-only friends reported lower relational

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victimization, friendship stress, and prospective suicidal ideation (Massing-Schaffer et al., 2022). Finally, experimental evidence, in which one group of college students increased their public Facebook posting for one week (while a control group did not) showed that increased posting reduced loneliness and increased feelings of connectedness to friends (Deters & Mehl, 2013). Together, these studies underscore that digital platforms can promote social connection if used to form and strengthen adaptive social connections.

3. IDENTITY DEVELOPMENT & DIGITAL MEDIA

Identity development is a key process during the transition from adolescence to adulthood (Erikson, 1968). Prior literature has shown a significant association between components of identity, self-concept and self-esteem, and adolescents' school performance, mental health, and overall well-being (Lee et al., 2018). However, the emergence of digital media has transformed adolescent identity development by providing teens with constant and unprecedented opportunities to explore and develop different aspects of their identity (Sebre & Miltuze, 2021). Individual differences in self-construct and self-esteem (**Figure 1: Identity Development**) can influence adolescents' behaviors on social media, such as self-presentation or social comparisons (**Figure 1: Adaptive/maladaptive digital media behaviors**) such that some adolescents will perceive and react to positive messaging regarding their identity and others will experience negative messaging. While supportive and encouraging experiences can increase adolescents' confidence and sense of belonging, particularly for youth with minoritized identities, rejection or victimization online can diminish confidence and increase feelings of loneliness which can impact mental health outcomes (**Figure 1:**

Mental Health and Wellbeing). In turn, health outcomes can impact adolescents' self-construct, self-esteem, and subsequent digital media use, thereby generating a self-perpetuating cascade across development (**Figure 1: Feedback loop**).

3.1 Adolescent identity development in the digital world. Cognitive maturation during adolescence allows for greater self-awareness and self-reflection (Erikson, 1968) making identity formation a central component of adolescent development. Through an ongoing process of exploration and commitment, adolescents begin to define their self-concept (i.e., concrete, stable, and consistent beliefs of the self) and their self-esteem (i.e., how secure they feel about their self-concept), two key elements of their identity (Baumeister, 1997). Digital media has provided new ways for youth to explore their identity, which may have both positive and negative developmental implications. Distinct features of social media, such as being highly visual, quantifiable, and readily available (Nesi et al., 2018), allow teens unique opportunities to explore, appraise, and engage with different aspects of their identity.

Multiple studies have explored the effects of social media use on adolescents' self-concept and self-esteem. However, while some have found a positive effect (Meeus et al., 2019) others have found null (Košir et al., 2016), or even negative effects (Valkenburg et al., 2021). Longitudinal research demonstrated that higher self-esteem is associated with greater social media use in subsequent years (Valkenburg et al., 2017) and increased social media use was associated with decreased self-esteem over time (Boers et al., 2019). This may suggest a bidirectional association between aspects of identity development such as self-esteem and social media use. As lower self-esteem is associated with increased anxiety, depression, and suicidal ideation among adolescents

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(Nguyen et al., 2019) and these symptoms may impact teens' subsequent identity building behaviors on social media (Chua & Chang, 2016; Jung et al., 2022), there is emerging support for a cascading influences theory in which social media use both influences and is influenced by adolescents' self-esteem and identity development over time.

3.2 Digital Media for youth with minoritized identities. The ways in which adolescents develop group identities (e.g., ethnic/racial identity; gender and sexual identity) has been studied for many years. Digital media provides a medium through which adolescents can explore interpersonal bonds with like-minded individuals and construct a collective identity online (Lee & Lim, 2019). This is especially the case for ethnic and sexual minority youth who may not have access to similar peers in their local communities or networks (Larson et al., 2002).

Youth belonging to a racial or ethnic minoritized group may have less access to individuals they can identify with (i.e., form a cognitive and emotional connection) compared to youth belonging to a majority racial or ethnic group. Digital media provides greater opportunities for youth of color to seek and connect with other people of the same racial or ethnic group. In fact, on social media platforms which are not highly visual (e.g., twitter), Black youth often “signify” or speak in particular ways to project their racial identity to others of the same race (Florini, 2014). As a result, youth who strongly identify with their racial or ethnic group may gravitate towards and select media featuring people who represent their own racial or ethnic identity (Behm-Morawitz, 2020). Indeed, youth of color have reported using social media to explore similarities of their racial and cultural identity and validate their identities through shared experiences (Florini, 2014) which may promote a sense of belonging. Additionally, research found that African American high

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schoolers who identified with popular media characters of color had higher self-esteem (Ward, 2004) indicating a bidirectional and self-perpetuating relationship between racial and ethnic identity and digital media use. A greater sense of belonging can, in turn, give adolescents a sense of purpose, meaning, and worth, which contributes to positive mental health (Newman et al., 2007). Alternatively, the anonymity facilitated through social media platforms can lead to increased racial discrimination or hate speech directed at underrepresented minorities (Mathew et al., 2019). Experiencing online racial discrimination may disaffirm adolescents' identity and lead to increases in depression and anxiety symptoms (Tynes et al., 2008). Ultimately, we see a cascading effect where mental health may determine whether individuals feel a sense of pride or shame regarding their racial identity which, in turn, impacts how adolescents express themselves and their identities online (Maragh, 2018).

Youth with sexual and gender minority identities (e.g., lesbian, gay, bisexual, transgender, queer) similarly face challenges in the process of identity development such as fearing rejection and victimization resulting from their sexual or gender minority status (DeHaan et al., 2013). Sexual and gender minority youth often use digital media to seek resources or information, supportive communities, and safe spaces to allow them to explore their sexual and gender identities (Craig & McInroy, 2014; DeHaan et al., 2013). Online communities contribute to the validation, normalization, and self-acceptance of adolescents' sexual and gender identities (McInroy & Craig, 2020) and help configure various intersecting identities in a harmonious manner (Parmenter et al., 2020) which may subsequently promote further disclosure of these identities to others (Elizur & Mintzer, 2001) potentially on social media. Additionally, digital media campaigns (e.g.,

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#SayHerName) allow youth to engage in social media activism that highlights challenges faced by intersecting identities (Brown et al., 2017). This suggests a bidirectional association where youth's intersecting gender and sexual identities can both impact and be impacted by their social media use. Increased peer support afforded by online environments and greater openness about adolescents' sexual and gender identity has been linked to lower depressive symptoms and better mental health among LGBTQ communities (e.g., Kosciw et al., 2015). However, increasing adolescents' openness about their sexual and gender minority identities may also be associated with greater victimization, discrimination, and abuse online (Kosciw et al., 2015). Exposure to these kinds of negative experiences may cause internalization of stigmas and contribute to poor mental health of LGBTQ youth (Berger et al., 2021). Mental health may, in turn, impact self-critical thoughts and self-esteem (Burwell & Shirk, 2006) and further feelings of pride or shame regarding adolescents' own sexual and gender identity. These feelings may shape how youth subsequently behave and express their identity (Elizur & Mintzer, 2001) including online thereby sparking a self-perpetuating and cascading cycle of events. Notably, intersecting minoritized identities also impact social media use

3.3 Self-presentation on social media. Digital media use during adolescence can also contribute to adolescents' self-exploration and identity formation by providing various platforms for self-presentation (Herring & Kapidzic, 2015). In digital settings, adolescents can receive quantifiable feedback and evaluations from others (Yurdagül et al., 2021) and view and evaluate the content that others post (McLean et al., 2019). The use of likes, comments, and followers has provided adolescents with quantifiable feedback metrics to evaluate themselves and their peers creating a context for certain

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types of peer comparisons that are thought to be especially salient to adolescents (Chua & Chang, 2016). Receiving positive feedback on self-presentations, such as selfies, can lead adolescents to feel more socially accepted (McLean et al., 2019) and promote higher life satisfaction and perceived social support (Mingoia et al., 2019). On the other hand, this environment can also lead adolescents to feel like they must curate or modify their self-presentations to seek positive feedback which, in some cases, results in worse psychological well-being and lower self-confidence (McLean et al., 2019).

Further, positive and negative mental health outcomes impact how teens choose to self-present on social media (Jung et al., 2022). Studies have shown that visually editing and modifying photos is driven by feelings of low self-esteem in girls and presenting selfies online is often used as an attempt to gain positive feedback (Chua & Chang, 2016). Together, these findings suggest that psychological well-being and self-presentation on social media can bidirectionally influence each other such that teenagers with better mental health might use visual platforms to self-present, receive positive feedback and further affirm or strengthen their self-confidence. Whereas teenagers with worse mental health might be prone to upward self-comparison or may be especially sensitive to receiving negative feedback ultimately impacting how they choose to digitally express their identity in the future (e.g., feeling the need to increasingly modify self-presentations to fit expectations of others or reducing self-presentation all together).

3.4 Social comparison on social media. Social comparison, or evaluating one's sense of self relative to others, can help adolescents understand their self-concept across different contexts and is thus another important part of their identity development (Yang et al., 2018). Social media has provided platforms that allow for social comparison on a

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more frequent basis. Social comparison can occur either in an upward direction, comparing oneself to others who are perceived to be better (Collins, 1996), or in a downward direction, comparing oneself to others who are perceived to be worse (Wills, 1981). Given the increased importance placed on peer status and peer comparison in adolescence (Do et al., 2020), it is unsurprising that social media is often used by teens for browsing others' profiles (Wu & Srite, 2021). Upward social comparison, via viewing others' profiles, on which individuals generally present their "best selves," has been shown to induce feelings of being left-out, ostracism, a decreased sense of belonging (Schneider et al., 2017), and disturbances in body image (Yurdagül et al., 2021). In general, using social media passively, avoiding posting, and checking the content on other people's profiles is associated with negative well-being and often results in feelings of loneliness (Verduyn et al., 2015). However, there is also research showing that upward social comparison can sometimes promote inspiration for learning and improvement. Inspiration is one of the strongest motives for following people on social media (Ouwkerk & Johnson, 2016). Further, following content that fits with an individual's specific interests (e.g., working out, traveling, or cooking) can further motivation to pursue similar activities and enhance wellbeing (Meier & Schäfer, 2018).

Notably, how teens engage in upward social comparison relies heavily on their preexisting mental states (Gibbons & Buunk, 1999). For instance, research has also shown that self-esteem can be a protective factor against the negative outcomes of upward social comparison, suggesting that teens with higher self-esteem, can still have a positive experience on social media and choose to express themselves in a confident matter, even if they engage in upward social comparison (Liu et al., 2017). Further, one

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study found that higher social comparison behavior mediates the relationship between psychosocial wellbeing (e.g., depression, anxiety, and loneliness) and social media engagement (Reer et al., 2019). Together these findings suggest that teens' established self-concept can have cascading effects, influencing how they engage with and respond to identity forming and affirming experiences on social media in an adaptive or maladaptive manner. Overall, we suggest that individual differences in self-construct and self-esteem (**Figure 1: Identity Development**) can exacerbate behaviors on social media, such as social comparisons (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**). Further, these digital media behaviors can affect adolescent mental health outcomes (**Figure 1: Mental Health and Wellbeing**) which, in turn, may have a self-reinforcing impact on adolescents' subsequent identity development (**Figure 1: Feedback Loop**).

4. INCENTIVE PROCESSING & DIGITAL MEDIA

4.1. Adolescent susceptibility to digital media use incentivization. In addition to providing a means of social connection, smartphones, social media, and online gaming can deliver streams of highly salient incentives that are thought to be powerful drivers of continued and escalating digital media use. Content typically accessed via digital media is self-selected and thus inherently rewarding. Further, psychologists have noted that attractive aspects of digital media (e.g., finding desired content, receiving a text or email) are often attained at an intermittent, unpredictable frequency and saliency (Greenfield, 2007), operating on a variable ratio reinforcement schedule. Variable ratio schedules are highly resistant to behavior extinction and thus are particularly well-suited for maintaining

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behavior. As such, it is unsurprising that people continue and increase their digital media use overtime and, as some evidence suggests, even trade species-typical rewarding behaviors (e.g., face-to-face social interaction (Twenge et al., 2019), sexual behavior (Ueda et al., 2020), exercise (Mustafaoğlu et al., 2018), etc.) for the immediate, easy-access rewards delivered via digital media.

There may be developmental periods in which people are particularly sensitive to the incentive structures of digital media. In fact, data suggest that digital addiction symptoms may peak during mid-adolescence (16 years old) and diminish with age (18 years old; Stavropoulos et al., 2018). This may be explained in part by the changes in incentive processing mechanisms that preclinical and neuroimaging work has shown during adolescence. Specifically, normative changes in brain structure and function, as well as elevated sensation, novelty, and reward seeking are thought to support exploration and learning during this developmental period (e.g., Ciranka & van den Bos, 2021). Indeed, adolescents display a heightened sensitivity to rewards, particularly in a social context compared to children and adults (Smith et al., 2015) and their decisions may be more heavily influenced by rewards (Galván, 2013).

Adaptive incentive processing development during adolescence is important for healthy transitions to later developmental stages. However, hypersensitive reward processing is linked to externalizing and risk-taking behaviors (Bjork & Pardini, 2015) and blunted reward sensitivity has been linked to depression (O'Callaghan & Stringaris, 2019). In line with our bidirectional feedback model depicted in **Figure 1**, evidence is beginning to suggest that individual differences in incentive sensitivity (**Figure 1: Incentive Processing**) are potentially both a precursor to, and consequence of, how adolescents

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navigate their digital media environments (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**) (Nesi & Prinstein, 2015). Specifically, adolescents with certain reward sensitivities may be particularly apt to seek out digital media incentives and thus are also particularly susceptible to their provocation of continued use (Sherman et al., 2018), creating a self-reinforcing and cascading cycle across development (**Figure 1: Feedback loop**) with potential implications for novelty seeking, reward sensitivity, impulsivity, and habit formation into adulthood (**Figure 1: Mental Health & Wellbeing**).

4.2. Bidirectional influences of digital media and incentive processing mechanisms. Recruitment of incentive processing brain systems when engaging with digital media may have implications for impulse control and future digital media use behavior. For example, functional magnetic resonance imaging (fMRI) research found that ventral striatum responses to Facebook-related stimuli was positively correlated with digital media addiction and viewing these stimuli diminished inhibition performance (Turel et al., 2014). Another fMRI paradigm, simulating social media experiences, demonstrated ventral striatum responsivity to both giving and receiving “likes” among adolescents and young adults (Sherman et al., 2018), while another study observed that ventral striatum responsivity to positive social feedback (but not monetary rewards) predicted real-world Facebook use (Meshi et al., 2013). The ventral striatum is a brain region involved in incentive processing and linked to reward seeking behaviors, suggesting that digital media engagement recruits key neurophysiological systems underlying incentive processing (e.g., Sherman et al., 2016).

Given recruitment of these neurophysiological systems during adolescents’ digital media engagement, and relations with use behaviors, it is possible that excessive digital

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media exposure may alter function in these systems and in turn, further influence use behaviors. Neuroimaging research has shown that repeated exposure to the reinforcement schedules administered via digital media may be associated with altered structure and function of the neurophysiological systems underlying incentive processing (e.g., Reichert et al., 2021; Turel et al., 2014). Indeed, higher frequency of daily Facebook checking was linked with smaller ventral striatum gray matter volumes (Montag et al., 2017). Further work has demonstrated a positive association between adolescent sensation seeking, disinhibition, and maladaptive smartphone use (e.g., Wang et al., 2019). Like individuals with drug dependences, when compared to controls, individuals categorized with certain digital addictions display altered frontal-striatal connectivity (e.g., Weinstein, 2017) that is thought to also be implicated in impulse control, as well as altered function in regions known to be involved in incentive processing including striatal, insular, anterior cingulate, posterior cingulate, and prefrontal regions e.g., (Schmitgen et al., 2020). Additionally, individuals with smartphone addiction, compared to controls, display increased smartphone cue-reactivity in frontal and occipital regions as well as decreased responsivity in regions comprising the default mode network (Schmitgen et al., 2020), potentially indicating increased attention or salience placed on digital media stimuli. Overall, existing fMRI evidence has indicated altered brain function among individuals addicted to digital media similar to that of individuals addicted to drugs however, empirical comparisons of both quality and magnitude of alterations are still needed.

Other evidence also suggests that dysregulated incentive processing, both neural and behavioral, may be a pre-existing risk-factor for compulsive digital media use (Sindermann et al., 2020). Although, most existing work is cross-sectional, findings

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cannot determine whether differential neurobiological incentive processing was caused by heavy digital media exposure or if it is a risk-factor for compulsive digital media use. Our model (**Figure 1**) argues that both directional influences may be at play, cyclically cascading across adolescent development. Specifically, as proposed in our bidirectional feedback model depicted in **Figure 1**, high sensation seeking and impulsivity (**Figure 1: Incentive Processing**) likely lead to certain digital media use behaviors, such as constant checking (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**), but these tendencies may also be exasperated by heavy exposure to digital media environments and self-selected digital media content (**Figure 1: Feedback loop**). Under this line of thinking, the digital media use of particularly disinhibited, sensation seeking teens may result in a self-reinforcing feedback loop across development that could contribute to digital media addiction or other negative health outcomes (**Figure 1: Mental Health & Wellbeing**).

5. PHYSICAL HEALTH BEHAVIORS & DIGITAL MEDIA

5.1. Development of health behaviors during adolescence. During adolescence, young people have increased autonomy and involvement in their own health (Hoyt et al., 2012) and begin to develop health-behavior patterns and habits (Spear & Kulbok, 2001). Development of various health behaviors including nutrition, exercise, hygiene practices, and sleeping patterns, have all been of interest in developmental research. Additionally, researchers have often focused on the prevalence and escalation of maladaptive health behaviors across adolescence including drug use, risky sexual behavior, and car safety. Developmental models of health (Halfon & Hochstein, 2002),

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emphasize the particular importance of health practices and interventions during critical developmental turning points, like the transition to adulthood. Thus, the role digital media plays in health education and development of health-impacting habits may be specifically critical during this developmental period. Further, health behaviors like good sleep habits and regular physical activity, are known to have powerful mental health benefits throughout the lifespan (Milojevich & Lukowski, 2016). As accumulating evidence suggests that physical and mental health are fundamentally linked, digital media's association to certain lifestyle factors may influence the development of physical health habits into young adulthood and, in turn, mental health outcomes. We propose that digital media use tendencies (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**) and certain unhealthy habits and lifestyle risk factors (**Figure 1: Physical Health Behaviors**) may bidirectionally maintain and accelerate each other in a cascading manner across development (**Figure 1: Feedback loop**). Below we discuss health factors and the mechanisms through which they may both influence, and be influenced by, digital media use.

5.2. Digital media use and sleep. Sleep quality is one of the most studied health behaviors among adolescents with wide-ranging implications for their mental health and quality of life (Illingworth, 2020). Poor sleep is a central symptom of many mental health conditions (i.e., depression and anxiety; Milojevich & Lukowski, 2016) while healthy sleep behaviors are associated with positive mental health outcomes (Meijer et al., 2001). Sleep quality is also one of the primary variables considered when trying to explain links between digital media use and mental health. A systematic review found consistently reported associations between excessive social media use, poor sleep quality, and poor

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mental health (Alonzo et al., 2021). Further, some studies have found that sleep outcomes may mediate the relationship between digital media use and mental health (Adams & Kisler, 2013) however, directionality of effects is still debated.

Baumgartner summarized two hypotheses aiming to explain the established association between digital media use and sleep outcomes (Baumgartner, 2022). One hypothesis suggests that digital media use causes sleeplessness by displacing sleeping hours and delaying bedtime (Quante et al., 2019), which in turn causes or exacerbates symptoms of depression or anxiety. This hypothesis is supported by work demonstrating that a reducing screen time after 9 pm is correlated with earlier sleep onset time and increased total sleep duration among adolescents (Perrault et al., 2019). Other work suggests that blue light exposure via digital media use may suppress melatonin and cause wakefulness (Wahnschaffe et al., 2013). In contrast, the second hypothesis proposes that adolescents who are already depressed or anxious are more prone to sleep disruption and use digital media to cope with wakefulness. Indeed, evidence from a longitudinal study indicates that digital media is used as a means of coping with existing sleep problems (Tavernier & Willoughby, 2014) and does not necessarily predict sleep problems or duration, contrary to prior work. Furthermore, a considerable portion of adolescents report watching television (TV) (36.7%) and playing computer games (22.1%) specifically to help them fall asleep (Eggermont & Van den Bulck, 2006). However, evidence suggests that the directionality of these associations may change across the lifespan. Specifically, research has demonstrated that TV watching in adolescence predicts sleep problems in young adulthood (Johnson et al., 2004). However, while reducing TV watching to 1 hour per day at 14 years old, was associated

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with a reduced risk for sleep problems when 16 years old, reducing TV watching when 16 years old was not associated with a reduced risk for sleep problems when 22 years.

Nonetheless, as exposure to digital media and sleep behaviors both begin in the earliest stages of life, distinguishing which initially caused the other may not be particularly relevant from a prevention or intervention standpoint. Ultimately, our model argues that regardless of the initial instigator, sleep disturbances (**Figure 1: Physical Health Behaviors**) and digital media use (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**) likely perpetuate each other in a cascading, cyclical manner each serving to maintain and/or worsen the other (**Figure 1: Feedback loop**). This proposed feedback loop, cascading across development, may help situate incongruent findings regarding the directionality of sleep problems and media use that have been observed at different stages of adolescence and young adulthood.

5.3. Digital media use, sedentary lifestyle, and other health behaviors. There is a substantial body of work linking digital media use to a handful of unhealthy lifestyle factors. There are well-known associations between leisure-time digital media use, sedentary behavior, and obesity in both children and adults (e.g., Fennell et al., 2019). One study found that higher leisure-time internet and computer use was linked with more sedentary behavior and an increased likelihood of being overweight or obese (Vandelanotte et al., 2009). Another study found that multiple unhealthy lifestyle factors were associated with internet addiction, including sedentary behavior, electronic-cigarette use, alcohol use, and daily soda, regular fast food, and inadequate fruit and vegetable consumption (Ying Ying et al., 2020).

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In parallel to observed decreases in health-enhancing physical activity (Dumith et al., 2011), late adolescence is marked by increases in the prevalence of mental health disorders (Blakemore, 2019). There is large body of work exhibiting specific ways in which sedentary behavior may contribute to poor mental health outcomes. Specifically, acute bouts of physical activity have shown to alleviate emotional effects of stressful events (e.g., Beauchamp et al., 2018), while regular physical activity has reliably shown to contribute to positive mental health outcomes (Penedo & Dahn, 2005) and buffer against ill health (Lubans et al., 2016). Further, one meta-analysis reported consistent associations between sedentary behavior, insomnia, and sleep disturbances across studies (Yang et al., 2017). Given these findings, excessive digital media use (**Figure 1: Maladaptive/Adaptive Digital Media Behaviors**) may impact adolescents' mental health (**Figure 1: Mental Health & Wellbeing**) by replacing physical activities, disrupting sleep, and leading to a more sedentary lifestyle (**Figure 1: Physical Health Behaviors**) which in turn, may lead to more digital media use (**Figure 1: Feedback loop**).

6. CONCLUSIONS & FUTURE DIRECTIONS

Individual differences may lead teens to use digital media in diverse ways. In this chapter we suggest that the way teens' use digital media has cascading, bidirectional effects on their behavior and mental health. In the context of on-going development, these influences on behavior and mental health may then have feedback effects on how digital media is subsequently used, thus becoming a self-perpetuating cycle. Specifically, due to user-selected, driven, and tailored digital media experiences, certain risk and protective factors may be reinforced or maintained through certain ways of engaging with digital

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media. We discuss existing evidence of the role these processes have in psychosocial, identity, incentive processing, and physical health development. More targeted work is needed to fully delineate nuances in how digital media interacts with each of these forms of development. We propose that future research address questions that appreciate cascading bidirectional feedback loops between developmental individual differences and digital media use.

Regarding psychosocial development, we discuss multiple mechanisms, through which certain social difficulties/proficiencies may lead to self-enforcing patterns of media use. These mechanisms include an increased likelihood, among socially vulnerable adolescents, to use digital media as a distraction or an escape from negative feelings (maladaptive coping), or as a replacement or way to avoid in-person socializing. These use tendencies are thought to ultimately hinder relationships and worsen social functioning. Contrarily, socially “rich” teens may hone digital media to strengthen and expand their social connections (Valkenburg & Peter, 2007). That said, future research should additionally explore ways teens low in friendship support and/or high in loneliness may also hone digital media in beneficial ways that promote social connection and facilitate social skill building (Massing-Schaffer et al., 2022; Pouwels et al., 2021). Indeed, some emerging evidence has shown that digital media can both mitigate and worsen mental health among lonely teens. As such, understanding drivers of these disparate trajectories will be critical to inform prevention and intervention efforts to improve adolescents’ social and mental health outcomes.

Regarding identity development, we recognize digital media as a powerful tool for adolescent identity exploration and development (Sebre & Miltuze, 2021). Further, we

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propose that, within a self-perpetuating feedback-loop, teens' self-construct and self-esteem can foster certain self-presentation, social comparison, and content selection behaviors on digital media that ultimately reinforce and perpetuate their identity solidification. Further, evidence has shown that online communities are also a source of self-enforcing identity development, normalization of experience, cultural expression, and in-group support for minority group members including the LGBTQ+ community (Baams et al., 2011), members of racial and ethnic minority groups (Florini, 2014), and especially those with intersecting identities. However, moving forward, research examining media practices specific to certain groups is still needed to fully delineate beneficial and/or harmful influences on adolescent identity formation. Moreover, future research that can appreciate individual differences in the ways adolescents process, positive, misleading, stigmatizing, and/or discriminatory digital media messaging into their identity development will be key to understanding these multifaceted digital media use feedback-loops.

Regarding incentive processing, research has clearly demonstrated that digital media use probes neurobiological and behavioral incentive processing mechanisms and is robustly associated with individual differences in impulsivity and sensation seeking. However, future research considering "addictive" digital media use should proceed with caution. At what point digital incentive seeking should be considered diagnosable has clinical implications but is also highly culturally embedded. Whereas digital "addictions" (e.g., internet, social media, online gaming) have yet to be included as official disorders in the latest edition the Diagnostic and Statistical Manual for Mental Disorders (DSM-V) (Aagaard, 2021), researchers still operationalized them based on DSM-V diagnostic

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criteria for substance use disorders (Young, 2009). Some initial research suggests that they may share some of the same characteristics as substance addictions such as consistent patterns of preoccupation, tolerance, withdrawal symptoms, relapse, use for mood modification, and use despite negative impacts on other aspects of life (Kuss et al., 2014). While these similarities between digital and drug addictions have been observed, empirical comparisons of both quality and magnitude of these similarities are still needed. Additionally, as social norms surrounding digital media use shift, what constitutes as pathological digital media behavior will also likely need to shift. Given the sheer ubiquity and necessity of digital media use today, researchers and clinicians alike may find that considering a spectrum of digital media behaviors may be more informative than categorizing individuals with a diagnosis.

Regarding physical health behaviors, we discuss evidence for bidirectional links between digital media use behaviors, certain life-style factors, and physical health. However, we note that the directionality of influence between health behaviors and digital media may shift on a moment to moment, day to day, and/or year to year basis. As most existing evidence speaks to the cascading links between digital media use and health across years, investigating cyclical feedback loops operating on potentially shorter time scales will also be important for future, dense sampling studies to explore.

In sum, our model suggests that individual differences in aspects of mental health and maladaptive/adaptive digital media behaviors likely perpetuate each other in a cyclical manner each serving to maintain and/or strengthen the other. This proposed feedback loop highlights cascading bidirectional influences of digital media and the digital media user across development. Accordingly, we suggest that individual differences in

user-driven digital media behaviors that manifest these self-enforcing feedback loops should be a focus of future research.

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