



Smartphone Use and Depression in Adolescents– Behavioural Patterns, Gene–Environment Interactions, and Directions for Prevention Research

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Abstract – In high-income countries, almost all teens have a smartphone, and in low and middle-income countries, youth ownership is on the rise. Objective tracking studies indicate that teens spend approximately 5 hours a day on their phones, of which almost 50% is spent on social media and messaging. The literature on this association between excessive smartphone use and depression among youth is reviewed, based on peer-reviewed studies, meta-analyses, and public health reports up to 2026. The review includes usage patterns, psychological mechanisms including social comparison and fear of missing out, sleep disruption, cyberbullying and habit-forming design. It focuses especially on biological aspects, such as genetic vulnerability to depression, gene-environment interaction with digital stressors, circadian and neurotransmitter genes, epigenetic modifications, and future application of polygenic risk scores. Results indicate mostly small but consistent correlations between screen time and depressive symptoms, but stronger associations were found for problematic use of screens and between nighttime screen use and depressive symptoms, and clear associations between cyberbullying victimization and suicidality were found. Current research is still unclear on causal direction. The article describes prevention strategies for school, family and government, discusses the economics of advertising that influence the design of platforms, and identifies areas where longitudinal and genetically informed studies are needed to inform policy.

Keywords: Adolescent mental health, Smartphone use, Depression, Gene-environment interaction, Circadian rhythm, Cyberbullying, Polygenic risk score, Digital wellbeing.

1. INTRODUCTION

Since a teenager born after 2008 has never lived a life without touch screens, it is no surprise that he or she has become a master at using them. The national survey, released by a leading research centre in December 2024, found that 95 percent of U.S. adolescents 13-17 have a smartphone or access to one. Almost half of them, 46%, say they are online nearly all the time, which is about double the 2014 figure. The picture is even starker when it comes to passive sensing research, which captures device activity in real time, as opposed to relying on memory. Phones were used for an average of five hours a day, which is two hours more than the same teens estimated using the phone in a 2024 study of approximately 1,400 teens in the U.S. in a large longitudinal study. Nearly half of all activity was on social media or messaging apps and most activity occurred between 8 and 10 p.m. when the adolescent brain should be winding down for sleep.

These numbers are significant because they correspond to an unfortunate public health trend. According

to the World Health Organization, approximately 1 in 7 young people 10–19 years suffer from a mental health disorder, with depression being one of the top disorders that contributes to morbidity and mortality in this age group. Suicide is one of the leading causes of death for 15–29 year olds. One of the most controversial topics in psychology is whether smartphones lead to depression, exacerbate depression, accompany depression or alleviate depression in some cases. There is some research that suggests that an increase in depressive symptoms among young people after 2012, when smartphones were ubiquitous, may be the reason for the increase. Others respond that the statistical links between screen time and wellbeing are modest, that it's possible for there to be reverse causation that lonely or depressed teens grab their phones because they are already struggling, and that the figures are not large enough to warrant worrying about.

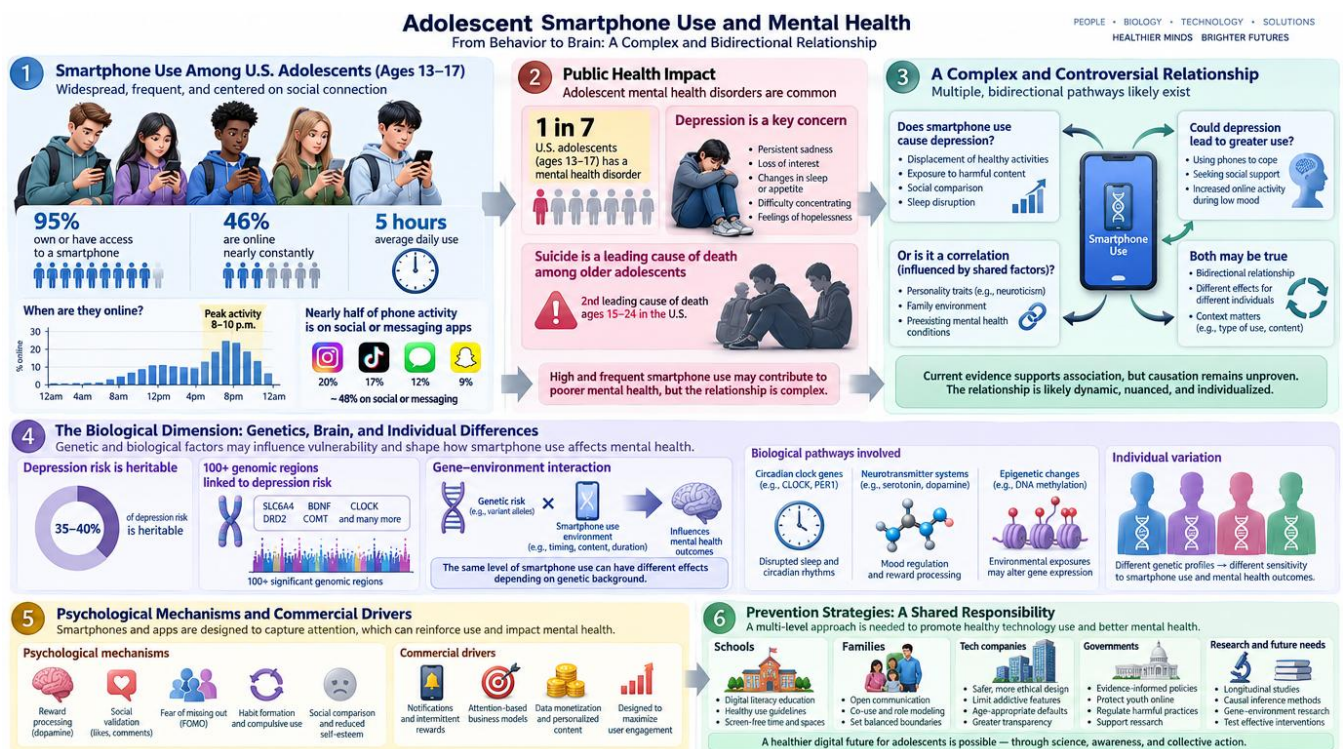


Fig -1: Adolescent Smartphone Use and Mental Health

A third dimension has been missing from the debate biology. Depression is familial Twin studies that indicate that about 35–40% of the risk for depression is due to inherited factors. Over one hundred genetic regions have been found to be associated with the condition by genome-wide studies. If genes are important in determining how susceptible a person is to stressors, and if their heavy smartphone use is creating new stressors for young people, then the same five hours of scrolling can be harmless for one adolescent and corrosive for another. Studies on gene–environment interaction, circadian clock genes, neurotransmitter systems, epigenetic change, and polygenetic risk scores provide an opportunity to transition away from the simplistic good, bad phone paradigm to a more productive good, bad phone for who under what conditions and how.

This article is an attempt to integrate the behavioural, social, economic, and biological aspects in an educated general audience. Readers will learn about how young people really use their devices, the psychological and commercial mechanisms that drive their use, the current state of the evidence on depression, the genetic and epigenetic factors that make some people more vulnerable to depression, and a survey of some of the prevention strategies that schools, families, companies and governments



are starting to test.

2. OBJECTIVE

The article aims to provide a true and balanced picture of the link between excessive smartphone use and depression in youth for researchers, students, policy makers, and the public. It seeks to clarify the behavioural patterns and psychological mechanisms at play, to capture the evidence of genetic and epigenetic factors that the popular media typically fails to mention, to assess the empirical evidence, and to outline the possibilities for prevention and policy options that benefit individuals, families, national economies, and future generations.

3. METHODOLOGY

The content herein has been collected via a systematic review of literature identified in public biomedical databases and includes systematic reviews and meta analyses of problematic smartphone use, cohort studies with objective tracking of smartphone use, genome wide association studies of depression, and laboratory studies of light exposure and circadian timing. Population level data were provided from reports from the World Health Organization, national statistical surveys of adolescent technology use and an international education monitoring report on phones in schools. The accuracy of each of the numerical claims was verified with the main source. When results are contradictory, such as with the serotonin transporter gene-environment interaction both are presented. Where figures were not verifiable, they were not included and where there is doubt this is indicated.

4. WHAT YOUNG PEOPLE ACTUALLY USE THEIR PHONES

Self-report has always been the downfall of screen time research and now there is objective evidence to prove it. In a large cohort of adolescents in the United States, those who carried phones equipped with research software for three weeks had a mean of 5 hours of daily phone use compared with a mean of 3 hours of daily phone use in their self-reports. Individuals are bad reporters of their own behaviour and two decades of survey based data are probably based on undercounts.

What that time consists of is telling. Almost half of the use of social media was in combination with text messaging. Video platforms are the biggest. As mentioned in the national survey above, roughly three quarters of teens, 73% visit a major video sharing platform every day, and about six in ten open a short video app every day, with about one in six saying they do so almost daily. Some 50% of teens use photo sharing and disappearing message apps daily. By contrast, older social networking sites have lost their appeal with teens, as just one in five teens visits them every day. There is no place to escape at school. In 2026, a study was published in one of the top medical journals that showed that the average American teen was spending 1.16 hours per day on their phone during the school day, with social media being their top use followed by video and games. This is one of the reasons why school phone restrictions have become the policy in just a couple of years.

While recreational use far outweighs academic use, the line between the two is not clear. It's the same device that contains the calculator, the textbook, the group chat on a class project and the infinite scroll. It is this duality that makes it hard to control the use of drugs by blunt prohibition and makes it more informative to assess the quality of use, rather than the quantity. Screen time for a teen who video calls for an hour with a grandparent is the same as screen time for a teen who spends an hour looking at

social media images of strangers.

WHAT YOUNG PEOPLE ACTUALLY USE THEIR PHONES

Objective data shows teens use their phones more than they report – and what they do, when they do it, and why it matters is complicated.

**SAME DEVICE.
MANY ROLES.
A COMPLEX REALITY.**

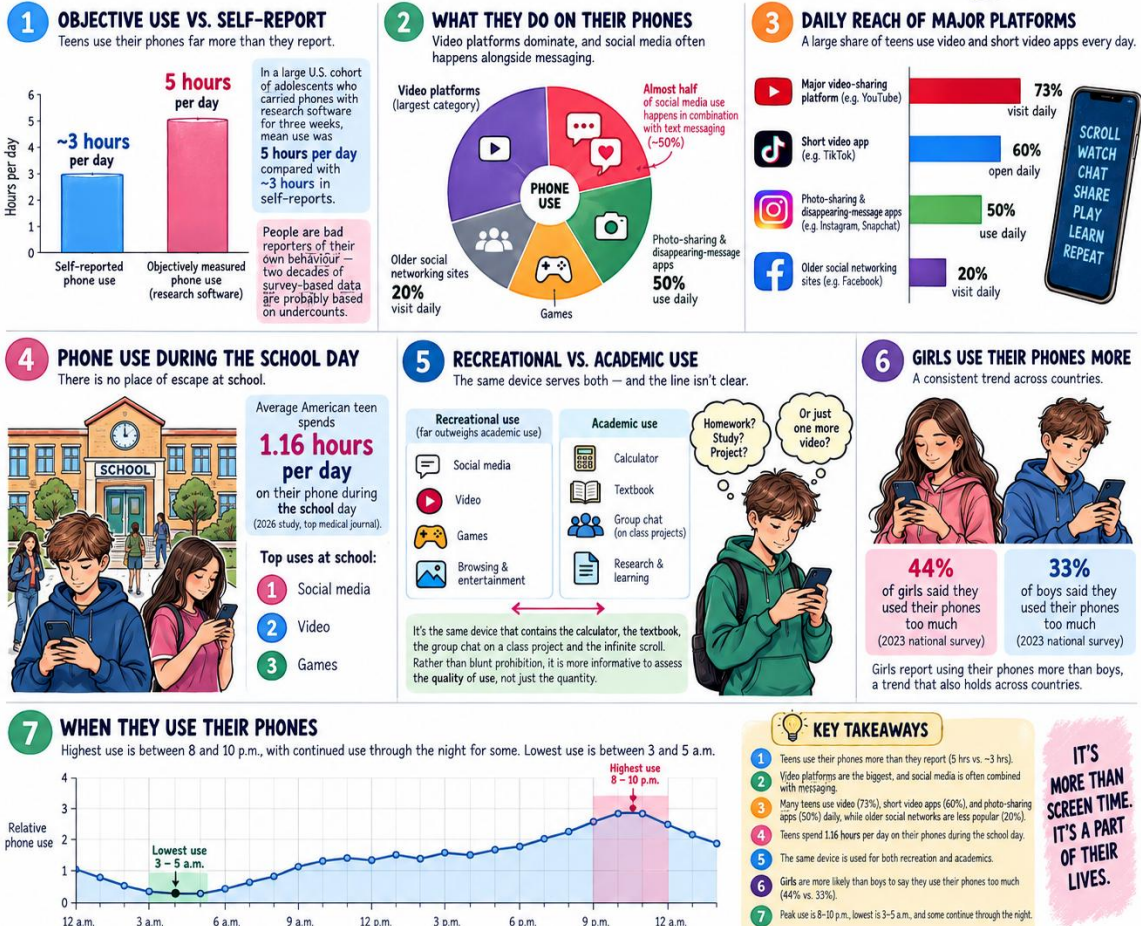


Fig -2: Young People Actually use their Phones

As important as what you post is when you post it. The highest recorded use was between 8 and 10 p.m., and it continued through the night for some minority users, with the lowest use between 3 and 5 a.m., and girls reported using their phones more than boys, a trend that also holds across countries and will be explored later in this article a national survey from 2023 found that 44 percent of girls said they used their phones too much, compared to 33 percent of boys.

5. THE ADVERTISING ECONOMICS BEHIND THE SCREEN

The social networks are all free for teens, and yet they make a ton of money off them. It's an advertising business and the raw material is attention. By the mid-2020s, spending on digital ads had surpassed \$600 billion worldwide, and platforms are vying for that money by maximizing screen time and the amount of behavioral data that can be gathered from it.

Young users are commercially hot in an out of proportion manner. In 2022, an estimated eleven billion US dollars in advertising revenue was generated by the six major social media platforms from under-18 users in the United States. Minors have an impact on household buying, develop brand connections early and

provide years of future involvement. One recent kids' media study revealed that most of the children aged 2-12 could remember a video ad that they saw and asked their parents to purchase.

This article's design decisions are all based on the revenue logic. Autoplay eliminates the end of video stopping point. Infinite scroll doesn't have a bottom of the page. Turn idle moments into sessions with push notifications. Streak counters are a consequence for not coming to school. Recommendation algorithms know, based on billions of data points, what will keep a particular 14-year-old from stopping his or her scroll. And the truth is, it's often content that evokes a strong reaction. This is not malicious in any way, just a result of optimizing one indicator, engagement, in a world where the competition is just a tap away.



Fig -3: Advertising Economics behind the Screen

This manuscript informs readers in a very practical manner about this economy. When parents understand that an app is designed to be hard to stop, they can avoid blaming their child for being unable to quit. Policymakers can control the design, and not the content, and several jurisdictions have started to do so by introducing age appropriate design codes to limit the time at which notifications are made, autoplay, and data profiling of minors. Investors and advertisers on their side will also be increasingly exposed to reputational and legal risks, providing an incentive for them to invest in healthier design. The advertising model has constructed the modern web and is the reason that services billions of individuals use for free exist. The issue is whether the same model can be made to work for a 13 year old's developmental needs and this will be determined by regulation and market forces, not one or the other.

6. NIGHT-TIME USE, SLEEP LOSS, AND MOOD

Sleep is the strongest mechanism for which there is evidence linking phones to mood. Although most adolescents require 8-10 hours of sleep per night, most adolescents in several countries are not getting that amount of sleep, according to large national surveys. Where some of the missing sleep goes can be

seen from the data from the devices, which show peak usage from 8–10pm and usage recorded at every hour of the night.

There are three mechanisms in action. The first is displacement the most obvious minutes spent scrolling are minutes not spent sleeping. The second one is physiological. Cells in the retina that are sensitive to short wavelengths of light provide information to the brain's master clock that is important in signaling daytime. In 2015, a scientific journal published the results of lab studies that showed using light-emitting devices in the evening depressed melatonin levels, shifted the timing of the body clock by more than an hour, and decreased alertness the following morning, compared to reading a printed book. Screens that are close to the face and in a dark bedroom provide this signal at the worst possible hour. Third mechanism is arousal. When the body needs to relax, it is a hostile comment, a cliffhanger video, or an unresolved group chat argument that activates the mind and the body.

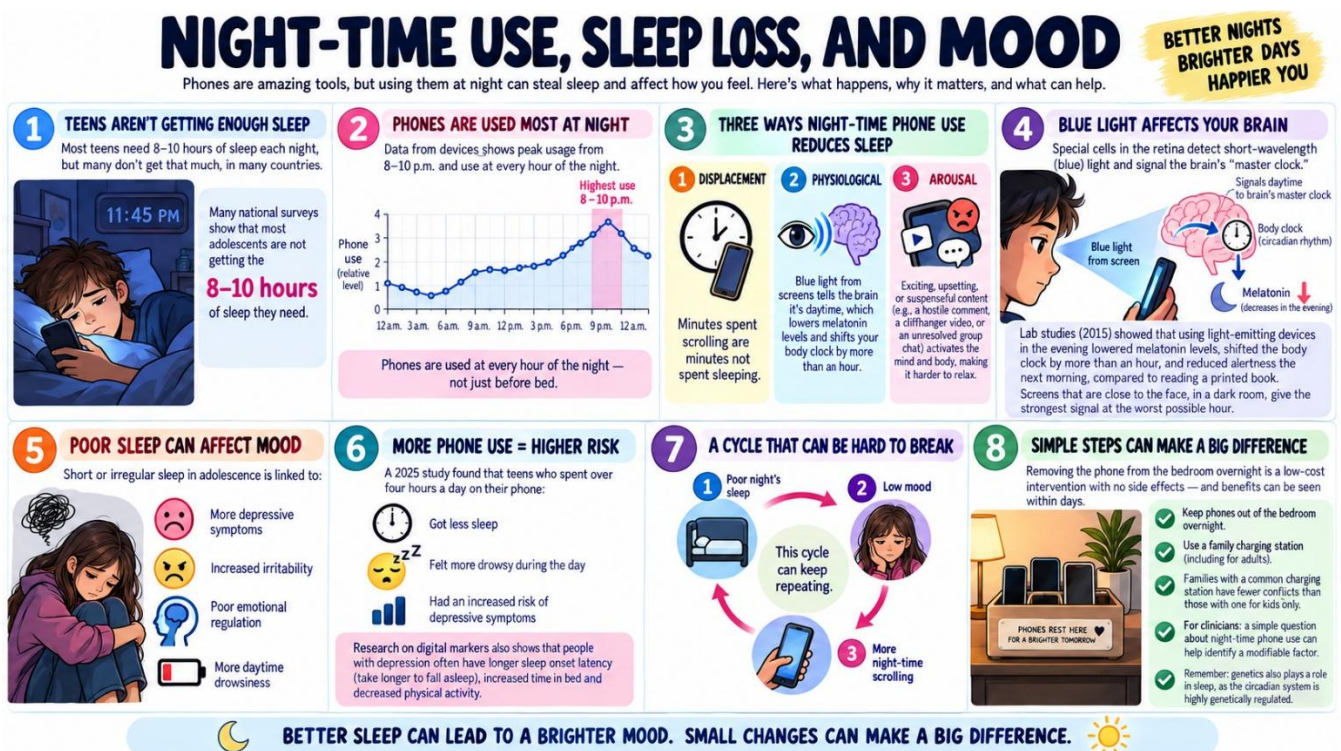


Fig -4: Nighttime Use Sleep Loss and Mood

The mood ramifications are well established. Adolescent sleep disturbances, short and irregular sleep are associated with subsequent depressive symptoms, irritability, and poor emotional regulation. A study of teens published in a peer-reviewed paper in 2025 showed that those who spent over four hours a day on their phone got less sleep, felt drowsier during the day, and had an increased risk of depressive symptoms. Research on digital markers of depression reveals that individuals with depression tend to have longer sleep onset latency, increased time in bed and decreased physical activity, which demonstrates how the cycle can become a vicious one a poor night's sleep leads to low mood, low mood leads to more night-time scrolling and scrolling leads to a poor night's sleep. The practical ramifications are very clear, for a field that is replete with ambiguity. The phone can be removed from the bedroom overnight, is a low cost intervention, has no side effects, and has benefits which occur within days. Families with a common charging station including adults find there are fewer conflicts than families with a charging station for kids only. For clinicians, it is a one question inquiry that can help identify a

modifiable factor that is untouchable by medication, and that is a low mood teen's nighttime phone use. Genetics also plays a role in sleep as the circadian system is highly genetically regulated, as discussed in the biology sections below.

7. SOCIAL COMPARISON AND THE FEAR OF MISSING OUT

People have always been measuring themselves up against other people and the pool of people they compared themselves with was the village. Today's teenager's body, vacation, friends, and accomplishments are juxtaposed against a filtered global feed of people who seem to be doing well. The images are edited, the failures are cut out, and the viewers' statistics are made public. The resulting bias is known as upward social comparison and in experimental studies it has been found that exposure to idealised images of others leads to a decrease in state self-esteem and body satisfaction, with the sample of adolescent girls being the most vulnerable in most studies. The quantified approval accentuates the impact. Numbers of followers and counts turn social status from something nebulous and negotiable into a real-time score that's public. A photo that doesn't get as many likes as a friend's isn't just a disappointment, it's a data point that is easily seen by the entire peer group. Scanning of the brain in teens reveals that the measures are far from insignificant looking at one's own favorite pictures triggers the reward system of the brain.



Fig -5: Social Comparison and the Fear of Missing Out (FOMO)

The compulsive part comes from the FOMO (fear of missing out). The social cost of being away from the group chat is that it is on 24/7. Teenagers say that they check their phones not for fun, but to ease the discomfort of being oblivious to what's going on, which is more like obsessive checking than fun. Survey research reveals that the more one uses social media, the higher their FOMO score is, and that the lower their mood is; and that this is true across countries. Young people's self-awareness is more than adults sometimes think. The national survey referred to above found that 38% of teens felt that they spent too much time on their phones and that girls were more likely to identify this issue and try to reduce their phone usage than boys. However, recognition is not controlling the design elements outlined in the economics section are in direct opposition to the unaided moderation. There are two caveats to maintain

the picture honest. Comparing is not something new and for some youth, especially for those who feel cut off from others in the offline world because of their geographical position, disability or minority status, online communities offer comparison points that are like them and offer them support that they are not receiving in the offline world. Research on small rural communities and on the marginalised youth can be seen to have measurable benefits in terms of online connection. The research challenge is to distinguish the circumstances that promote the motivational effects of comparison from the ones that promote corrosive effects of comparison, as well as the individual-difference factors including genetic factors that tip the scales.

8. CYBERBULLYING AND ONLINE HARASSMENT

Although bullying is not new to the smartphone, it changed the physics of bullying. What used to be confined to the school gate is now extended to the victim's bedroom, works around the clock, reaches hundreds of people in an instant and is recorded for posterity. Anonymity reduces the inhibition of the aggressor, and lack of reaction reduces the empathy cue which inhibits some face-to-face aggression.

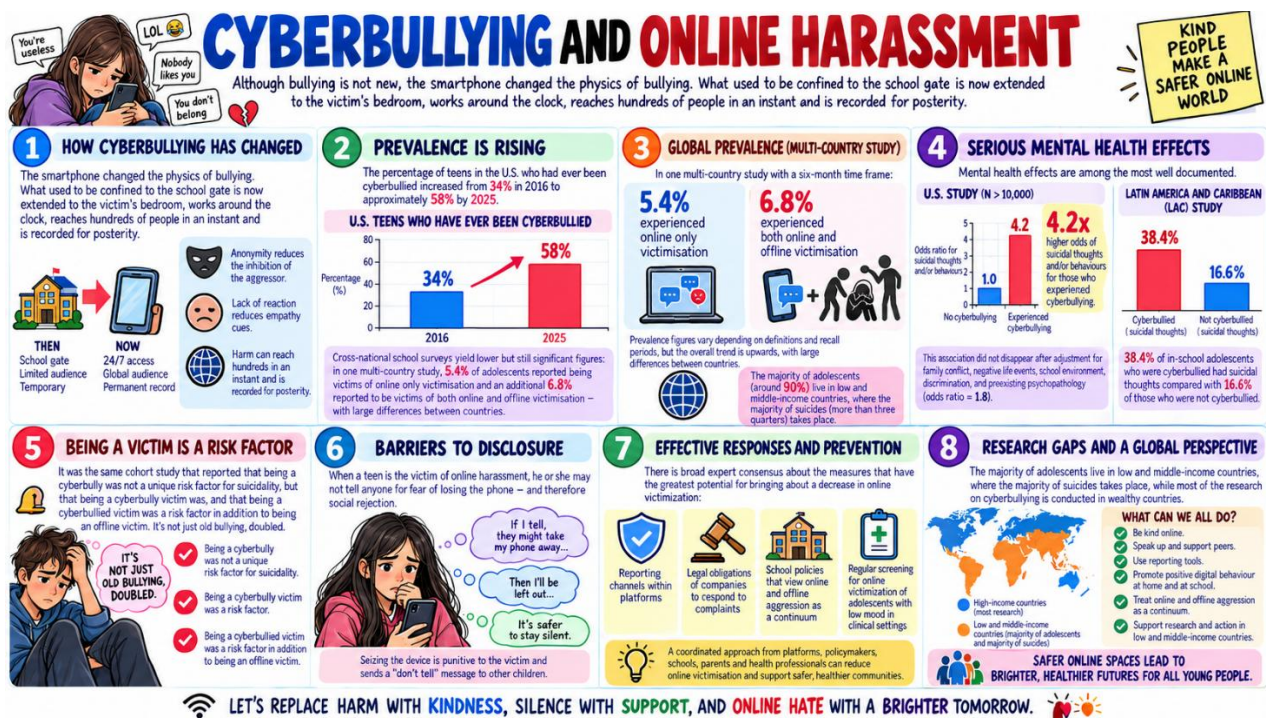


Fig –6: Cyberbullying and Online Harassment

The numbers of prevalence fluctuate depending on how prevalence is defined and on the recall period, but the trend is upwards. The percentage of teens in the U.S. who had ever been cyberbullied increased from 34 percent in 2016 to approximately 58 percent by 2025, according to the research centre that specializes in the issue. Cross national school surveys with a six month time frame yield lower but still significant figures in one multi country study, 5.4 per cent of adolescents reported being victims of online only victimization and an additional 6.8 per cent reported to be victims of both online and offline victimization with large differences between countries.

The mental health effects are among the most well documented of all effects. Among a large sample of early adolescents more than 10,000 in the USA, the odds of suicidal thoughts and or behaviours were 4.2



times higher for those who experienced cyberbullying compared to those who did not, and this association did not disappear after adjustment for family conflict, negative life events, school environment, discrimination, and preexisting psychopathology odds ratio = 1.8. A study conducted in three countries in Latin America and the Caribbean LAC revealed that 38.4 percent of school adolescents who were cyberbullied had suicidal thoughts compared with 16.6 percent of those who were not cyberbullied. Interestingly, it was the same cohort study that reported that being a cyberbully was not a unique risk factor for suicidality, but that being a cyberbully victim was and that being a cyberbully victim was a risk factor in addition to being an offline victim. It's not just old bullying, doubled.

When a teen is the victim of online harassment, he or she may not tell anyone for fear of losing the phone and therefore social rejection. This situation provides a real world lesson for parents and schools that when a disclosure is made, seizing the device is punitive to the victim and sends a don't tell message to other children. There is the broadest expert consensus about the measures that have the greatest potential for bringing about a decrease in online victimization reporting channels within platforms, legal obligations of companies to respond to complaints, school policies that view online and offline aggression as a continuum, and regular screening for online victimization of adolescents who present with low mood in clinical settings. Most adolescents around 90% live in low and middle income countries, where most suicides, more than three quarters, takes place, while most of the research on cyberbullying is conducted in wealthy countries, as is discussed in the research gap section.

9. HABIT-FORMING DESIGN AND THE REWARD SYSTEM

While it is debatable whether there is an addiction problem with phone usage, there is no dispute that there is behavioural machinery in effect. It is not reward per se that is most stimulating to the dopamine system in the midbrain, but unpredictable reward. Experimental psychology in the middle of the 20th century demonstrated that variable-ratio schedules (VR), where the number of responses required for a reward is not consistent, are the best schedules to produce the most persistent behaviour and are the most resistant to extinction. This is the schedule that is used by slot machines. Pulling down to refresh a feed is the same, as it can bring a like, a message, an outrage or nothing, in an unknown sequence.

The difference between problematic use and ordinary heavy use is the ability to control one's use, the presence of craving, the use of a substance despite its harmful effects, and the presence of functional impairments. One systematic review and meta-analysis that included children and youth found that the prevalence of problematic smartphone use was 23 percent, with some samples in East Asia showing prevalence rates ranging from 23 to 53 percent. The strongest and most consistent associations with depression, anxiety, poor sleep, and stress throughout literature are problematic use, not hours. In 2025, a network analysis of the symptoms of Chinese adolescents over time revealed that fatigue acts as a link between problematic use and depressive symptoms, suggesting that fatigue may be a fulcrum on which the two conditions pivot.

This is a matter of controversy whether it is clinically addictive. While international diagnostic manuals do acknowledge gaming disorder, they do not acknowledge smartphone or social media addiction in part, because the device is not a substance, but also because it's not possible to abstain from a device that contains schoolwork or family contact. Those who oppose the addiction label say that it medicalizes normal adolescent sociality, while those who support it say that the behavioural signatures of tolerance, withdrawal-like distress, and failed attempts to reduce use are clearly evident in a small proportion of users.

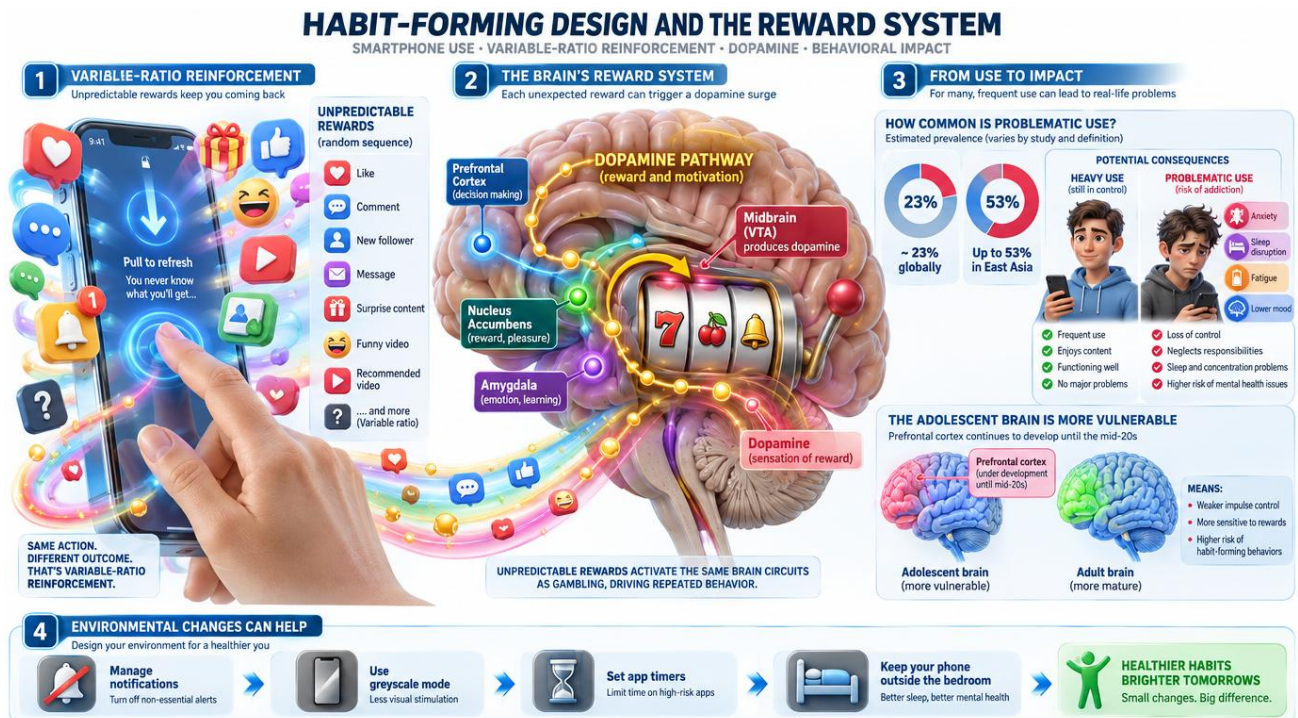


Fig -7: Habit Forming Design and The Reward Systems

The bottom line for the general reader is that the pull of the phone is designed, tested, and honed by some of the most highly resourced experimental projects in commercial history, and that these tests are ongoing, on billions of people. The prefrontal cortex of an adolescent is no match for an adult, and it will not be fully developed until the mid-20s. This re-framing has practical implications environmental changes such as notifying, greyscale displays, app timers and phones outside bedrooms are more effective than appeals to willpower, and design regulation that focuses on the reinforcement schedule rather than the content targets where it resides.

10. WHAT POPULATION STUDIES SHOW ABOUT DEPRESSION

It's time for an honest summary of the empirical record, which has been outstripped in both directions by public debate. Studies from South Korea, Japan, China, and the U.S. all report that heavier use of the smartphone and social media are correlated with more symptoms of depression in adolescents. Disagreement is about the size and direction. In terms of size, several large meta-analyses and systematic reviews have found that the typical link between digital technology use and adolescent wellbeing is small, and several large analyses of data have found that digital technology use accounted for less than one percent of the variation in wellbeing. A recent review of trends in depressive symptoms in a prominent medical journal 2024 concluded that the overall findings of meta-analyses have been small or null for digital media, but that crude exposure measures typically hours spent on digital media may mask actual effects about specific activities, users, and times of day. Averages can mask damage done to a minority that is vulnerable, and in this article, the genetic parts indicate that we should expect such damage.

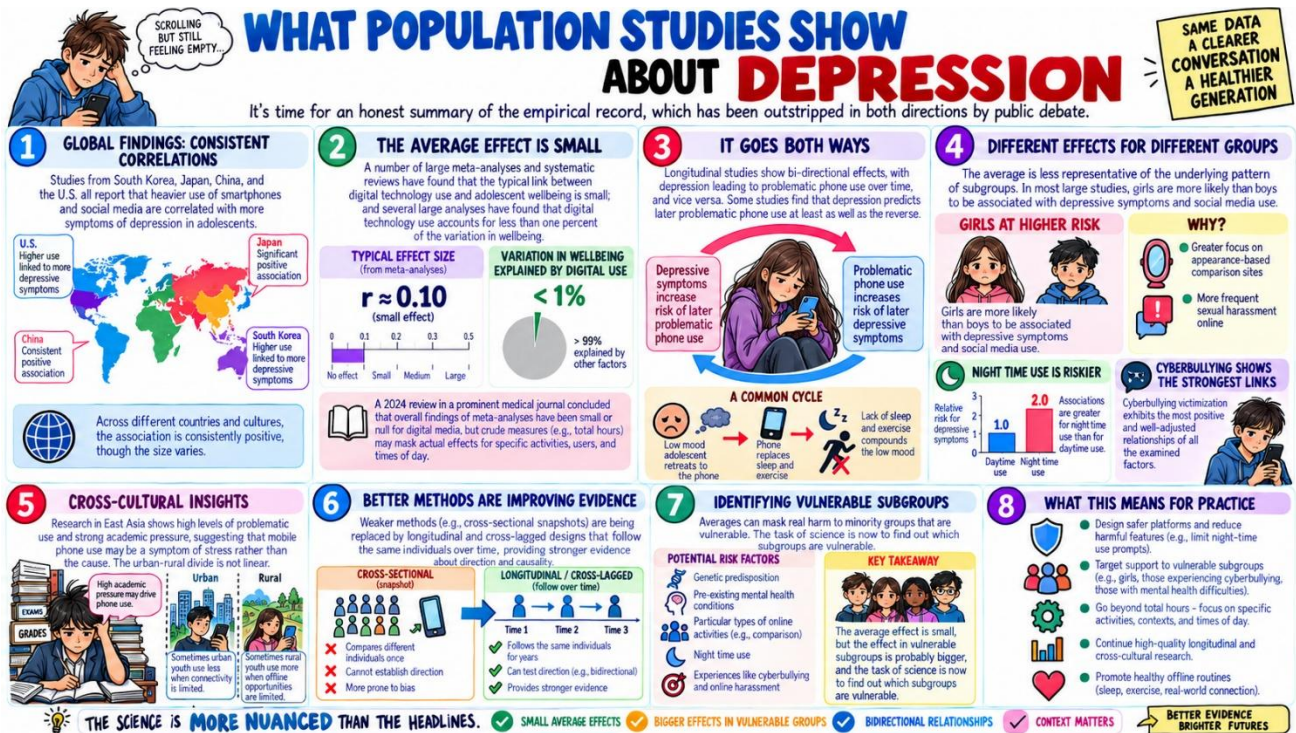


Fig -8: Population Studies Show About Depression

The simple story is complicated by one direction, longitudinal work. Several of the cohort studies report bi-directional effects, with depression leading to problematic phone use over time, and vice versa, as well as some studies that report that depression predicts later problematic phone use at least as well as the reverse. A low mood adolescent retreats to the phone, the phone replaces sleep and exercise the lack of these compounds the low mood. The weaker methods are slowly being replaced by cross lagged designs in which individuals are followed over years, instead of snapshots which compare individuals once. The average is less representative of the underlying pattern of subgroups. In most large studies, girls are more likely than boys to be associated with depressive symptoms and social media use, which may be due to greater focus of their social media use on appearance-based comparison sites, as well as more frequent sexual harassment online. The associations are greater for nighttime use than for daytime use. Total hours are less associated with problematic use than are associations with problematic use. As described above, cyberbullying victimization exhibits the most positive and well-adjusted relationships of all.

Findings are enriched with cross cultural findings. Research in East Asia shows that prevalence of problematic use is high and that there is a great deal of pressure on students' academic performance, indicating that the use of the mobile phone may be a symptom of stress rather than the cause of it. The urban-rural divide in youth is not a linear continuum sometimes, it is the rural youth who use more when offline opportunities are limited and sometimes the urban youth who use less when connectivity is limited. The best summary of this field is that the average effect is small, the effect in vulnerable subgroups is probably bigger, and the task of science is now to find out which subgroups are vulnerable.

11. GENETIC PREDISPOSITION WHY THE SAME SCREEN AFFECTS TWO TEENAGERS DIFFERENTLY

Depression is heritable. Twin studies in various countries have all estimated that about 35-40% of the risk for major depression is attributable to genetic differences, more for severe, recurrent, and early onset

depression. From speculation to inventory, genome-wide association studies have been identifying hundreds of thousands of participants for their genetic variants associated with depression, with the number increasing with larger studies, including a 2019 analysis of hundreds of thousands of participants that identified 102 independent genetic variants. The risk of depression is polygenic that is, the risk is spread out amongst thousands of common variants, each of which makes only a small contribution.

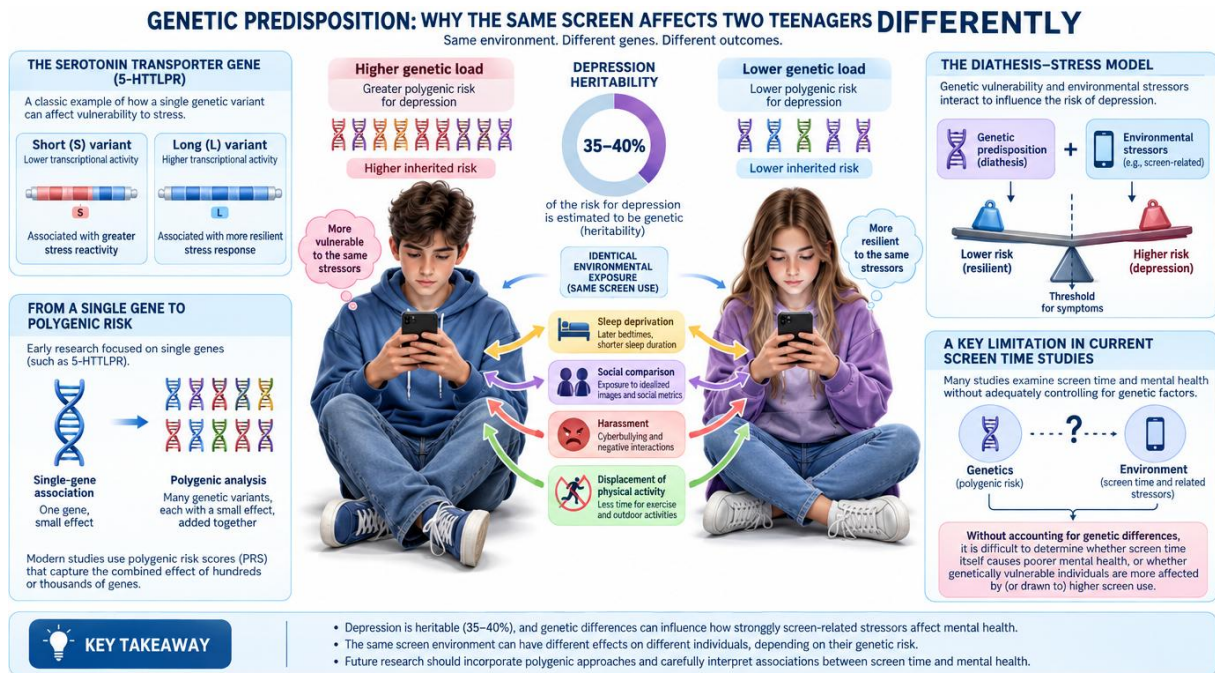


Fig –9: Genetic Predisposition

With heritability of this magnitude, it is certain that adolescents aren't entering the digital environment as equals. Two 14 year olds with the same screen habits have different inherited loads, and the diathesis stress model of psychiatry states that the environment will cause illness primarily in those who have a high predisposition. The stressors of smartphones, such as sleep deprivation, social comparison, harassment and displacement of physical activity and face-to-face interactions, are all chronic and low grade stressors as described in this model.

The most well-known test case is the serotonin transporter gene. In a 2003 study, individuals with the short version of 5-HTTLPR promoter variant were found to be more likely to develop depression following stressful life events than were individuals with the long version. The interaction was confirmed by a 2011 meta-analysis of 54 studies which included over 40,000 participants. However, a larger collaborative re analysis published in 2018 demonstrated little evidence of this and the episode has served as a cautionary tale in the fields of small samples, flexible analysis, and publication bias in candidate gene research. The true take-home message is not that gene-environment interaction is bunk, but that single gene studies were too underpowered to detect effects of this magnitude, and that the true way forward is through modern methods of polygeny.

The following of the smartphone research is straight. Nearly all screen time and depression studies do not account for genetic risk, and thus cannot differentiate between a small average effect, and a large effect limited to a genetically vulnerable minority. It can't rule out gene-environment correlation, either, where the same genetic predispositions such as high neuroticism or low self-control may lead to both high phone use and depression, and there's no causal link between the behaviours whatsoever. Until then, it is

unclear whether the alarmed or reassuring reading of the correlational literature is correct. This is not a technical footnote, but a policy choice – either population-wide restriction or targeted protection of those most at risk.

12. CIRCADIAN GENES, NEUROTRANSMITTERS, AND EPIGENETIC MARKS

DNA codes for the body's day night rhythm. Near-24 hour cycles are seen in nearly every cell and controlled by a master clock in the hypothalamus which is **set** by light hitting specialised retinal cells in a molecular loop including the genes CLOCK, BMAL1, PER1-3 and CRY1-2. Variants in these genes influence chronotype morningness/eveningness and a study in 2017 found a variant in CRY1 that was linked to delayed sleep phase disorder **DSPD**, in which the internal clock is set hours behind the social clock. Evidence from large genetic studies suggests that the evening chronotype is linked to an increased risk of depression and the fact that adolescence itself pushes the clock later means that teens are more likely to stay up late, even before a phone goes to bed with them.

CIRCADIAN GENES, NEUROTRANSMITTERS, AND EPIGENETIC MARKS

Your body's clock, mood and environment are connected — and they all talk to your genes.

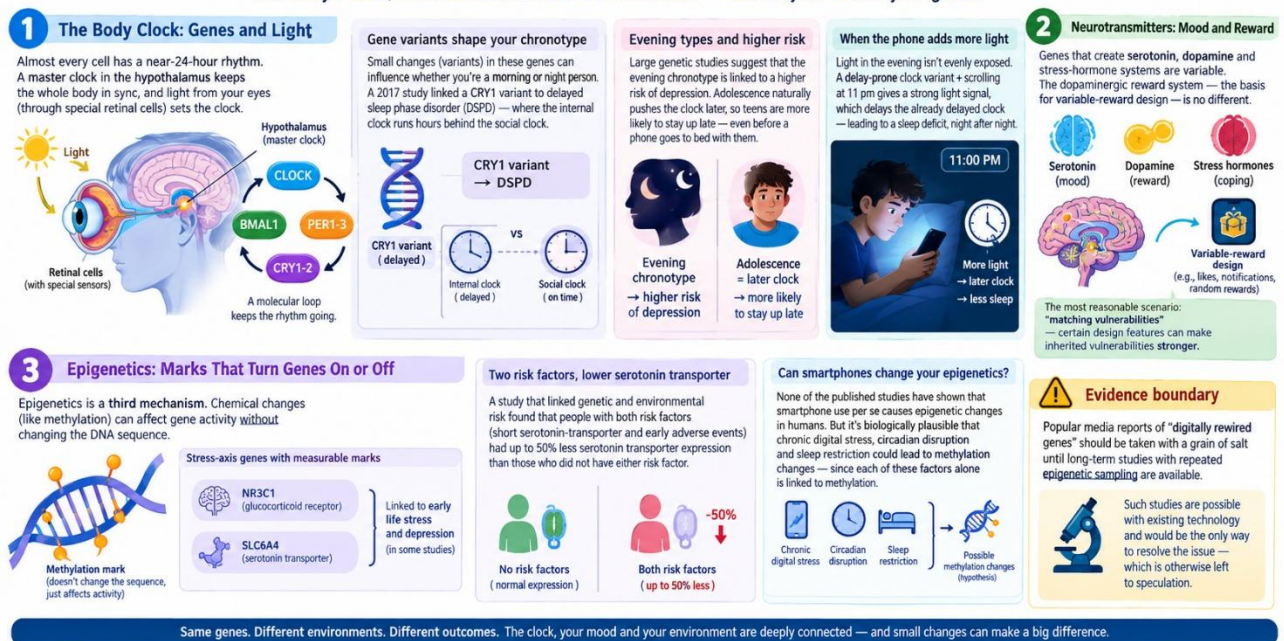


Fig -10: Circadian Genes Neurotransmitters and Epigenetic Marks

This genetic material is not evenly exposed to light in the evening. An adolescent with a delay prone clock variant who scrolls at 11 pm gets a light signal that further delays his or her already delayed clock, leading to a sleep deficit night after night. There is a second level genes that create serotonin, dopamine, and stress-hormone systems, which are responsible for mood and reward, are all variable, and the dopaminergic reward system that is the basis for variable reward design is no different. The most reasonable scenario is of a kind of matching vulnerabilities where certain design characteristics exacerbate certain inherited vulnerabilities.

Epigenetics is a third mechanism, whereby chemical changes in the DNA, like methylation, affect the activity of the gene without altering the DNA sequence. Stress-axis genes such as NR3C1, the gene for the glucocorticoid receptor and SLC6A4, the gene for the serotonin transporter have measurable methylation

marks related to early life stress, and these marks have been linked to depression in some studies. The study that linked genetic and environmental risk revealed that people with both risk factors short serotonin-transporter and early adverse events had up to 50% less serotonin transporter expression than those who did not have either risk factor. Here a forthright expression of the evidence boundary is needed. None of the published studies so far have demonstrated that the use of a smartphone per se causes epigenetic changes in humans. This might occur due to chronic digital stress, circadian disruption and sleep restriction is biologically plausible, given that each of these factors alone is associated with methylation changes but remains a hypothesis. Popular media reports of "digitally rewired genes" should be taken with a grain of salt until such longitudinal studies with repetitive epigenetic sampling are available. Such studies are possible with existing technology and would be the only way to resolve the issue which is otherwise left to speculation.

13. POLYGENIC RISK SCORES AND THE FUTURE OF PERSONALISED PREVENTION

A polygen risk score is a number that reflects an individual's inherited susceptibility to a condition and combines the thousands of small genetic effects that are found in genome wide studies. In the case of depression, the current scores account for just a few percent of the variation in risk, too small to use to diagnose an individual, but large enough to divide large samples of research subjects into high and low genetic risk groups. That's a relatively simple ability that could revolutionize the smartphone-depression industry.

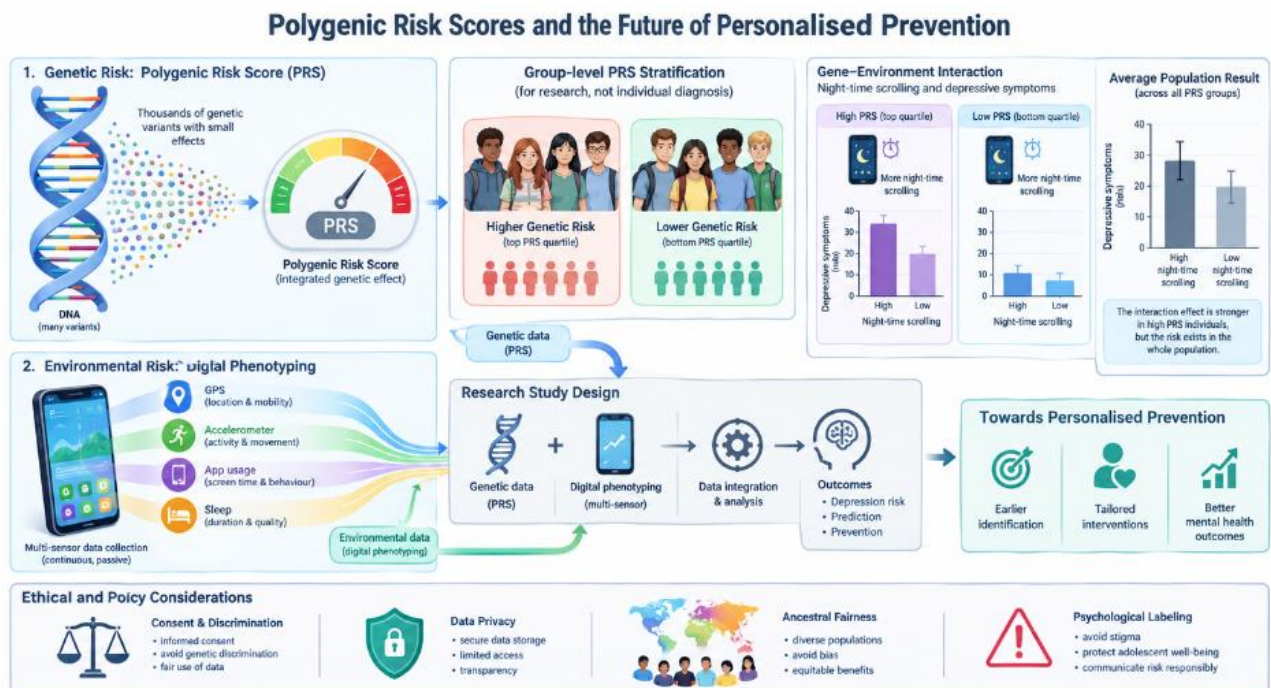


Fig -11: Polygenic Risk Scores and the Future of Personalised Prevention

Think about the study design it can be used for. A group of 10,000 teens, each with a single genotype, has passive sensing software on their device to track the actual use of the device, sleep times, and activity. Researchers can then determine if this relationship between night-time scrolling and depressive symptoms is greater in the highest quartile of polygenetic risk than the lowest quartile of polygenetic risk. If it is, the evidence for gene-environment interaction is not just anecdotal but strong and prevention can



be targeted appropriately. If it isn't, then the population average results are credible and blanket policies are justified. Both answers are good and no study has been published to date that provides it.

Digital phenotyping provides the other half of the equation to the environmental part. In 2024, a scoping review was published of 35 studies, which demonstrated that combining data from multiple smartphones' sensors GPS, accelerometer, and smartphone usage logs is more effective at detecting and predicting depression and anxiety in individuals aged 12 to 25 years than relying on individual sensors alone, but all studies included in the review were at moderate to high risk of bias and a call for standardised reporting was made. Combining these objective measures of exposure with genetic data would provide a single design to replace the two lowest quality instruments in the field, self-reported screen time and family history proxies.

Ethical landscape needs to be charted first, then science. Questions of consent arise when it comes to genetic risk information on minors as they cannot consent to uses that their adult selves may reject. In countries where there are no laws against genetic discrimination, issues of insurance and education discrimination based on polygenetic scores are real-life issues. Scores based primarily on samples from populations of European ancestry do not perform well in other populations and would thus benefit primarily populations already at an advantage. A labeling danger exists as well informing a teen that he or she is genetically predisposed to depression may be a stressful message in and of itself. The right thing to do is to use polygen scores now as a research tool at the group level, where they can answer the causal questions raised in this article, but to restrict individual level screening to a time when they are proven to provide benefit, are legally protected, and are ancestrally fair, which is not right now.

14. FAMILY, PEERS, AND THE MAKING OF A DIGITAL IDENTITY

The phone has become the primary mirror for the assembly of identity in adolescence from social feedback. A teen's online profile is a self that is created, curated, and acted out for an audience which responds in the form of numbers. Peer pressure, which has been traditionally a tool of the hallway and playground, is now also found in group chats that remind you of missed days, streaks that make it difficult to miss a day, and simply the fact that you don't use a platform means that you don't get the social information that everyone else is sharing. Influencer culture is an added layer of commercialization to the normal peer influence. Adolescents' role models are likely to be professional broadcasters of a desired lifestyle, sponsored and paid for, who need to maintain a parasocial relationship with the audience. Recent surveys have shown that children overwhelmingly have seen ads that led to requests to buy products and younger children do not always understand that ads are sponsored. To help students recognize sponsored content, media literacy curricula are increasingly providing students with a skill that will be useful for their entire lives as consumers.

The Internet community is dangerous, particularly if you're on the receiving end. Communities of likeminded people are where isolated young people find a sense of belonging where they are not in the immediate community, whether in rural areas, people with rare medical conditions or young people trying to discover minority identities. But it's the same architecture that serves communities that normalize self-harm, disordered eating and conspiratorial thinking, and recommendation systems have been seen to push vulnerable users towards increasingly extreme forms of whatever they linger on, in journalistic and regulatory investigations.

All of this is tempered by the family environment. Parenting factors like parental monitoring, family conflict, and school connectedness are all identified in studies with a socio-ecological perspective as

influencing the co-occurrence of heavy phone use and good or poor mental health.

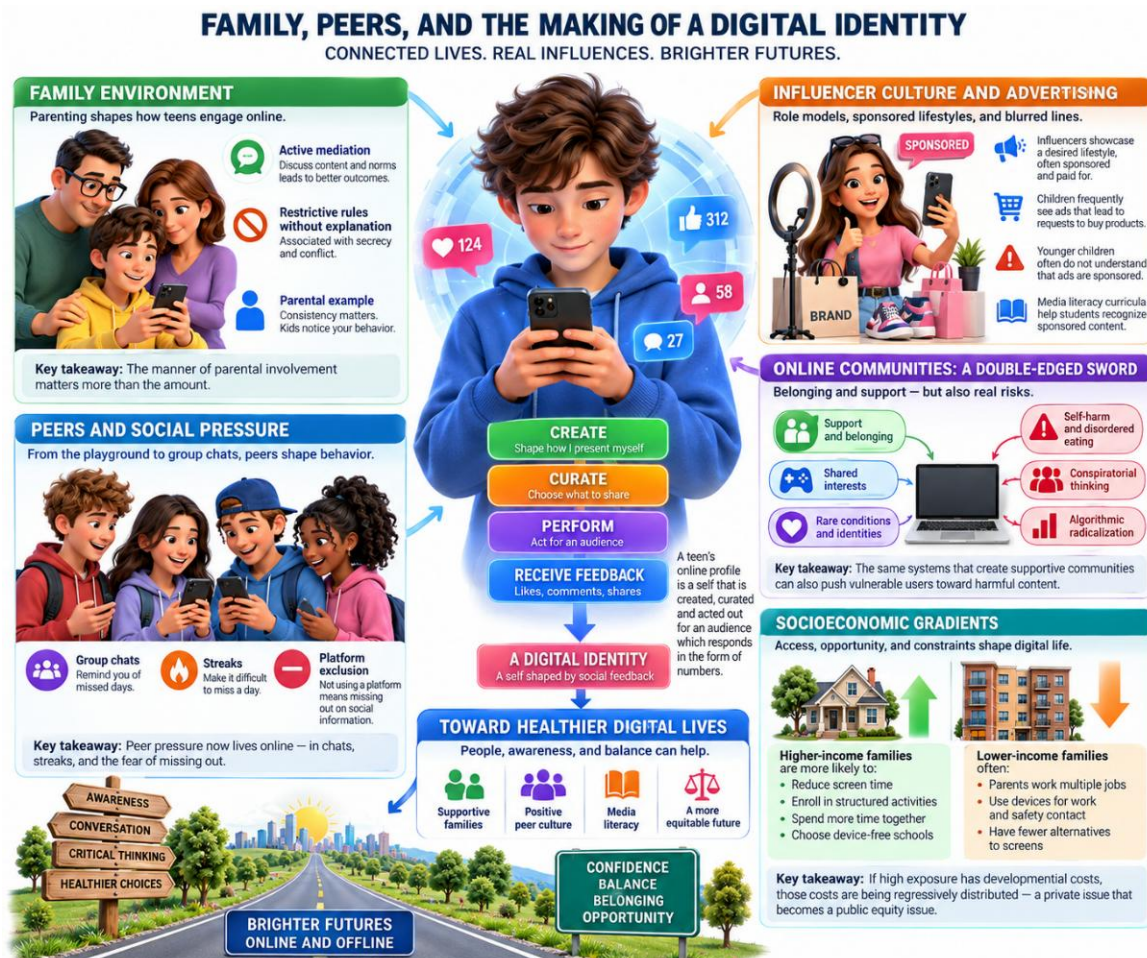


Fig -12: Family Peers and the Making of Digital Identity

The manner of parental involvement is more important than the amount studies in different countries show that parental restrictions with no explanation or discussion is associated with secrecy and conflict, while parental active mediation discussion of content and norms is associated with better outcomes. But parental example is important, as well if you say you're not going to let the kids use the phone, but you're in the back of the room on yours, they know you're not being consistent. It is worth noting of socioeconomic gradients. As families' income rises, they are more likely to take steps to reduce the number of screens in their children's lives, such as creating a device free school, engaging in structured activities, and spending time with their parents and lower income families, in which parents often work multiple jobs, are more likely to use devices for work and safety contact. If there is developmental cost associated with high exposure, this cost is being regressively distributed, thus turning a private parenting issue into a public equity issue.

15. BRAIN DEVELOPMENT, ATTENTION, AND STRESS HORMONES

The teen brain is a building site. Cutting back on grey matter enhances white matter connections and the prefrontal cortex, home to planning and impulse control, is the last to mature, up until the mid-twenties. The reward sensitive striatum, however, is very sensitive during the teenage years. It is this maturational

gap this reward system that is ahead of the control system that is the one that is exploited by habit forming design and why age based protections are not just morally motivated.

BRAIN DEVELOPMENT, ATTENTION, AND STRESS HORMONES IN ADOLESCENTS

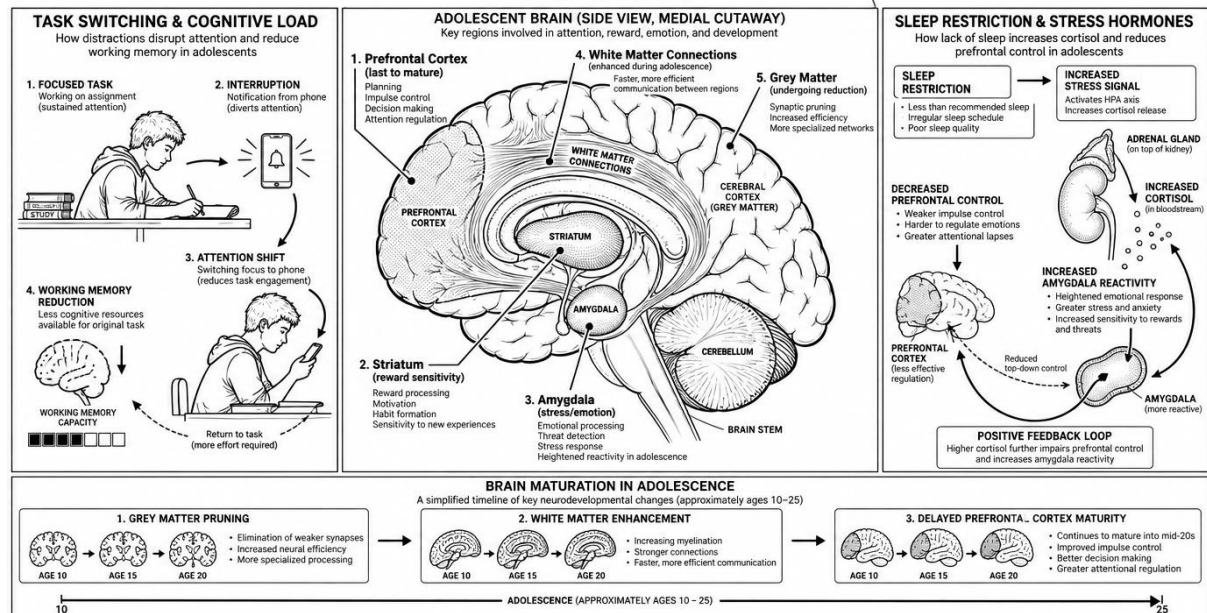


Fig -13: Brain Development Attention And Stress Hormones

The findings of structural brain change in response to heavy phone use are preliminary and need to be interpreted with caution. There are some imaging studies that report differences in grey matter volume and connectivity in adolescents who meet criteria for problematic use, but these studies have small samples, cross-sectional designs and pre-existing differences can't be ruled out. Better answers will be provided by large longitudinal cohorts with repeated imaging, which are currently being undertaken in several countries, in this decade. What is known is that what has been set up is working task-switching studies have shown that there is a measurable cost of interruptions each time you are interrupted, you are forced to switch attention and recover from it, and some laboratory attention tasks have shown that self-described heavy media multitaskers do worse on some of the tasks.

Cognitive load theory provides a less complicated explanation of what happens on a day to day basis. Working memory can only keep a few items at a time, and the researchers have dubbed a cell phone within reach of a brain drain an experiment showed that the presence of a participant's own phone, face down and silent on the desk, decreased working memory capacity, compared to the phone being in another room. The simple study intervention that this finding alone provides for students is the most valid of all study interventions.

Stress physiology is in line with the mood results. Sleep restriction increases evening cortisol and increases the amygdala's response to negative stimuli and decreases the prefrontal control of the amygdala in other words, a sleep deprived teen feels the setbacks more intensely and is less able to control the amygdala's response. The chronic social evaluation of the kind that the metrics economy provides is one of the most reliable experimental systems to induce an increase in cortisol in humans. The biological and behavioural aspects of this article are one story, and the epigenetic mechanisms described above are expected to work via the stress axis which is repeatedly activated during a developmental window. None of this proves that phones harm brains, but that the onus is on the

platforms to prove that they are safe for growing brains.

16. WHAT SCHOOLS, PARENTS, AND HEALTH SYSTEMS CAN DO

Evidence for prevention has developed to a point where they can be ranked. Start with schools. In 2023, almost one in four countries around the world implemented a ban or restriction on smartphones in schools, and the number of these countries has increased since one large European country banned phones in primary and middle schools as early as 2018. Initial findings show improvements in classroom behavior and fewer bullying incidents reported, with mixed findings on academic outcomes, and evidence of impacts is still emerging. With the 2026 finding that students use an average of over an hour of their phones in the school day, mostly on social media, there is an empirical target for restriction policies. But restriction alone is not enough the more successful school programmes combine this with digital literacy training, where the phone is regarded as akin to road traffic in school, a constant danger that kids need to learn how to deal with.

Preventing Problematic Smartphone Use in Adolescents

Shared responsibility. Healthier adolescents. Brighter futures.

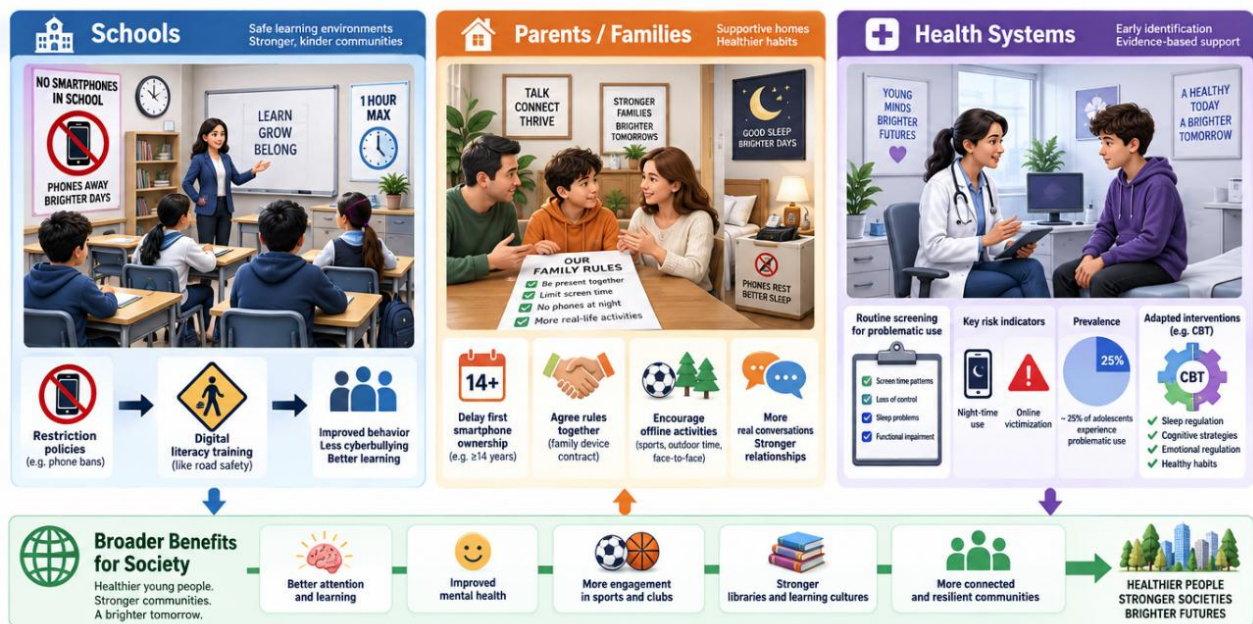


Fig -14: Preventing Problematic Smartphone Use in Adolescents

Behavioural and environmental interventions are the highest ratio evidence to cost interventions for the family. Overnight removal of devices from bedroom helps to tackle the sleep pathway directly. The delay of the first personally owned smartphone, a decision that is often made in concert with parent groups, so that no one child is the social loser, speaks to the developmental-timing question. Rules that are agreed upon by the adolescent, enforced for the entire family, and adjusted as the child grows and develops, are more effective than rules that are imposed by the adult. What we should be saying to our children isn't less phone, it's more of what the phone takes away sleep, sport, unstructured face to face time, and outdoor activity all of which have been shown independently to have antidepressant effects.

Health systems are in a screening position. Health care providers who encounter an adolescent who are presented with low mood, sleep difficulties, and declining school performance should routinely inquire



about night-time use, problematic use symptoms, and victimization online, just as they would ask about substance use. There are brief validated instruments to measure problematic smartphone use which last only a few minutes. In the global meta-analytic estimate, for the approximately 25% of youth that meet problematic use criteria, adapted cognitive behavioural treatments, based on the treatment of behavioural addictions, are beneficial in preliminary studies. This prevention agenda has beneficiaries other than the child themselves. Employers get what they get from each school, cohort attention habits and mental health. Untreated adolescent depression has a cost to the health system in the form of the cost of treating adult depression. Reclaimed hours are put into sports clubs, libraries, and community organisations, creating an opportunity for them to gain participants. Early learning to control attention becomes a public good as a generation learns to do so in their household, and as it applies to work, citizenship and parenting.

17. THE PHONE AS A CLINIC DIGITAL ROUTES TO MENTAL HEALTH CARE

It is the same device that has been blamed for adolescent distress, and the most widely used mental health device ever constructed. By 2024, around 4.9 billion people had access to the internet, primarily via smartphones, and the World Health Organization WHO mental health atlas shows that there are less than one psychiatrist per 100,000 people in low-income countries. For a rural 16 year old, the phone may not be one of the several choices in accessing care. It is the only one.

Real evidence has been gathered for three of the uses. One of these is remote consultation. The number of video and text based therapies has increased many times over in the pandemic years and this growth has largely continued since then, with randomized trials showing video based cognitive behavioural therapy (CBT) to be equally effective as face-to-face CBT for depression and anxiety. The second is self-help that is structured. Meta-analyses of app delivered depression interventions suggest small to moderate improvements, with greater improvements when a human coach is involved with the app than when it is used without a coach. The third one is crisis contact. Crisis services now receive millions of conversations annually through text in multiple countries, among adolescents who report they would not make a voice call and volume data indicate that there is increased use of the services at night, when in-person services are closed and as mentioned above, when distressed phone use is highest.

With passive sensing, a fourth, more tentative, use is added. As mentioned in the scoping review from 2024, mobility, sleep and usage patterns from phone sensors can be used to detect depression in individuals between 12 and 25 years of age but the quality of the studies is inconsistent. The device, if developed, could indicate a decline weeks before a patient's next doctor's visit.

A necessary element of honesty is to communicate the boundaries. There are thousands of products in the app stores that are marketed as mental health support and only a very small proportion of these have been evaluated in any trial. There is a wide range of privacy practices and some of the most popular wellness apps have been penalized by regulators for disclosing sensitive information to advertisers. The problem is that engagement is the one thing that most of these users fail to achieve with self-help apps the tricks that would make them stick around are the same ones this article has lambasted. Digital care also has the potential to exacerbate inequity, if it is a low-cost alternative provided to low-income communities, but not to wealthier patients.

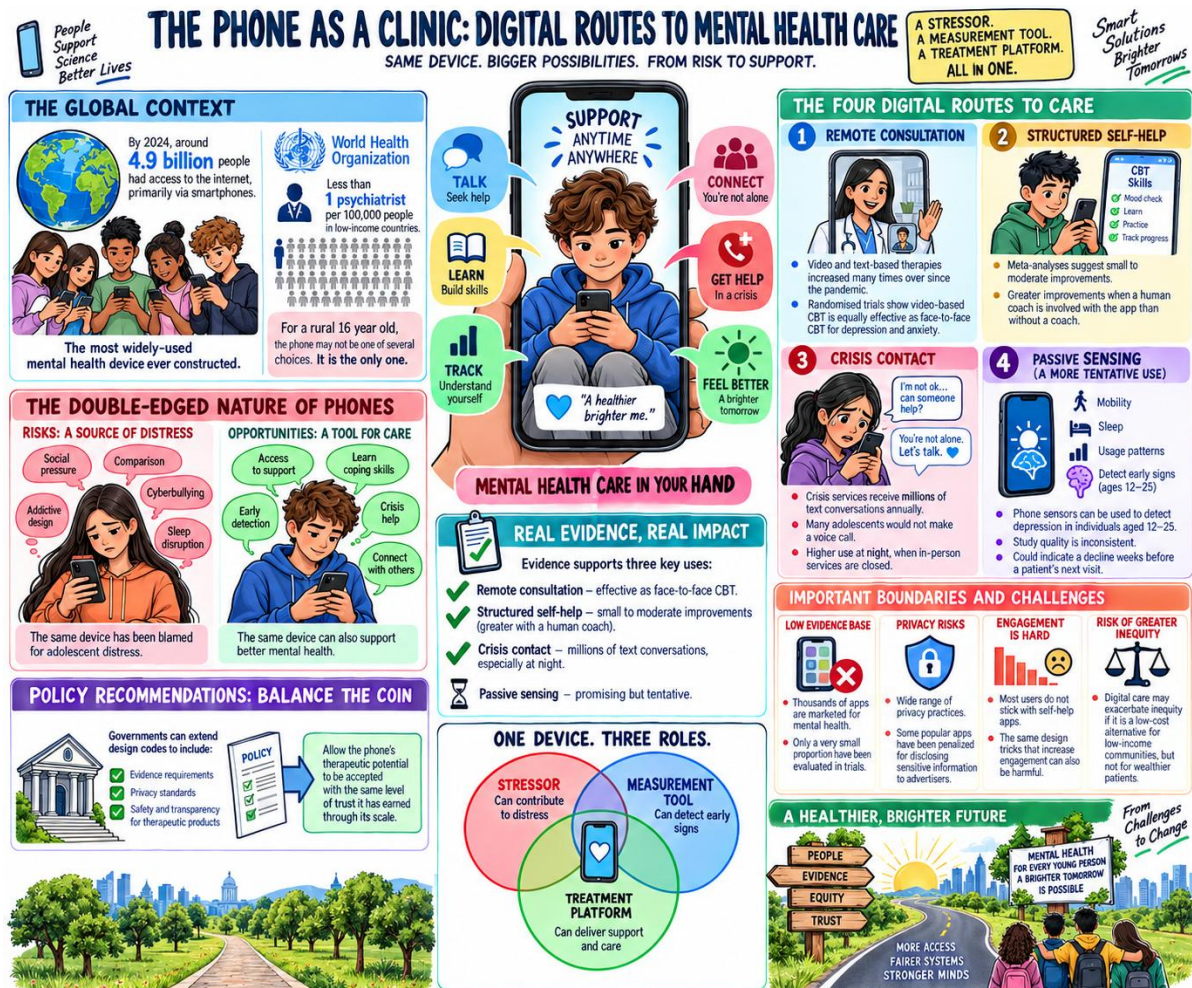


Fig -15: The Phone as a Clinic Digital routes to Mental Health Care

Symmetry is the policy implication. As governments are already working on design codes to limit harmful attributes, they could also include evidence and privacy requirements for products claiming to be therapeutic for mental health, allowing the phone's therapeutic channel to become accepted on the level of trust it has garnered based on its scale. This is the other side of the coin of smartphones and youth depression. It is a stressor, a measurement tool, and a treatment platform all in one and policy which only deals with the first of the three will waste the other two.

18. POLICY, CORPORATE DUTY, AND THE ECONOMICS OF PREVENTION

From discussion to legislation, governments have gone. One country passed a law in late 2024 to raise the minimum age to have a social media account to 16 the law will be enforced at the end of 2025 and is being observed globally as a natural experiment. Other jurisdictions have followed the design-regulation path with age-appropriate design codes that mandate high default settings for privacy on minors, limit nighttime notifications and reduce the amount of profiling that can be used to power recommendation engines. A third approach is based on a duty of care platforms that are legally accountable for the systemic risks to children, and there is a regulator that has audit powers. The three models go hand in hand age restrictions are about when to be exposed, design codes are about 'how' to be exposed, and

duty of care regimes are about WHO is responsible for the exposure.

There is a stronger than is often realized economic case for action. According to the World Health Organization, the cost to the world economy from depression and anxiety is estimated to be approximately one trillion US dollars annually, and the WHO analysis of scale-up of treatment revealed a 4:1 ratio of improved health and work capacity to cost. Prevention in the teenage years was a cost multiplier for adolescent onset depression, which has lifelong impacts on education, income, and physical health, so that prevention provides greater discounted benefits than intervention. The issue of youth depression is not just a health ministry issue, but one that can have measurable returns in countries that reduce the incidence of depression, in workforce participation, reductions in health expenditure, and in human capital.

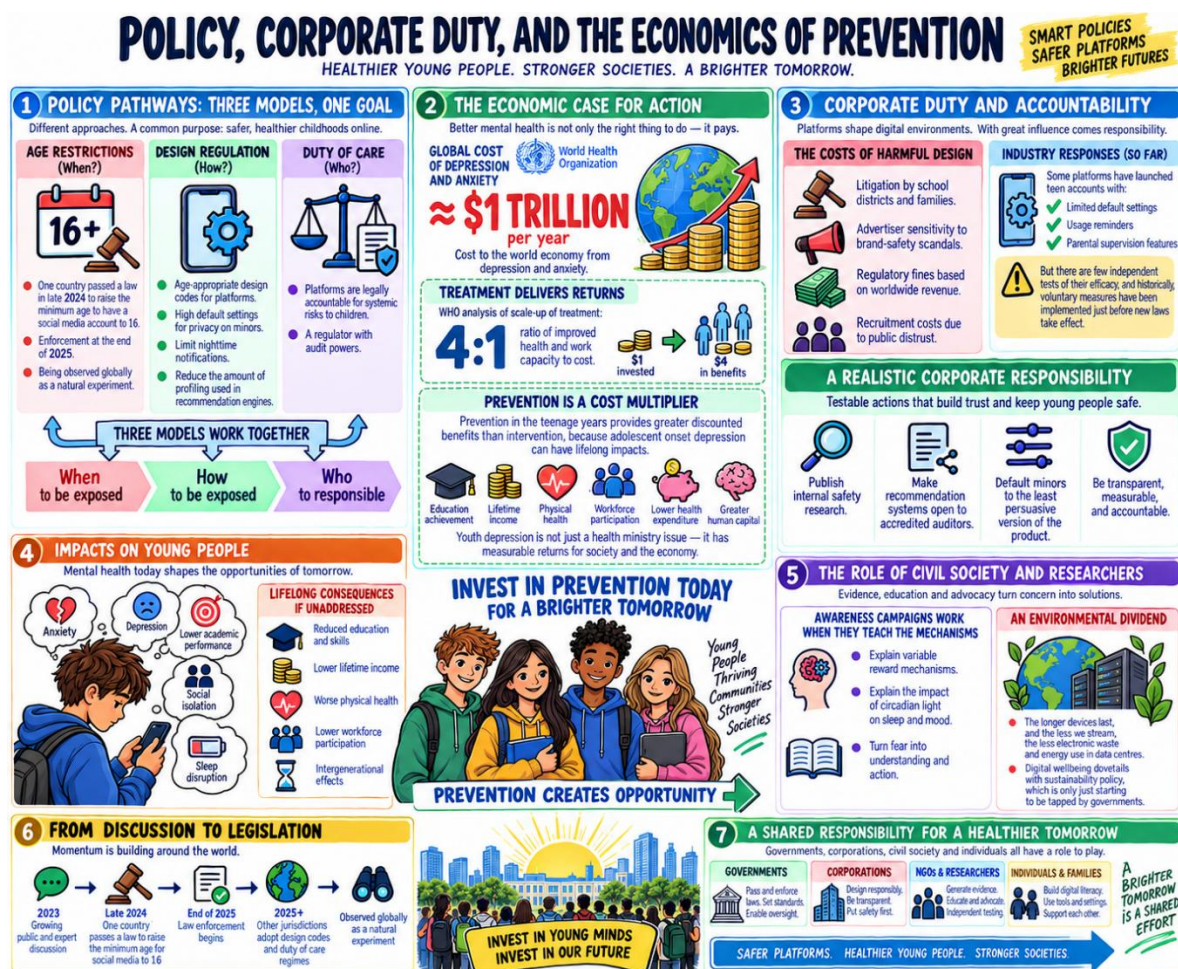


Fig -16: Policy, Corporate Duty, and the Economics of Prevention

But corporations are by no means impervious, as incentives are changing. The costs of harmful design include litigation by school districts and families, advertiser sensitivity to brand-safety scandals, regulatory fines based on worldwide revenue and recruitment costs due to public distrust. Several sites have launched teen accounts that come with limited default settings, usage reminders, and parental supervision features, but there are few independent tests of their efficacy and historically, voluntary measures have been implemented just before new laws take effect. The realistic corporate responsibility is testable: publishing internal safety research, and making recommendation systems open to accredited



auditors, and defaulting minors to the least persuasive version of the product.

The rest of the keys are with non-governmental organisations and researchers. Awareness campaigns are most effective when they change fear to mechanism when they teach the public about the mechanism of variable reward and circadian light, it is less fearsome. There is an environmental dividend, too the longer devices last, and the less we stream, the less electronic waste and energy use in data centres and the more digital wellbeing dovetails with sustainability policy, which is only just starting to be tapped by governments.

19. RESEARCH GAP

The main weakness of the field is the lack of causal inference. Nearly all studies have been cross sectional, and used self-reported screen time, which objective sensing has revealed to underestimate actual screen time by about two hours per day. There are few studies that can determine if depression causes cell phone use, if cell phone use causes depression or if there are common factors that lead to both. There are repeated objective measurements in longitudinal cohorts, although they are uncommon, and the length of the trials, the sample size, and the risk of drop-out are short in the case of the randomized reduction trials. There is a genetic divide of almost 100%. Although depression is heritable 35-40 percent and over a hundred risk loci have been identified, very little research in the field of smart phones stratifies individuals by genetic risk, uses polygenetic methods to test for gene-environment interaction, or controls for gene-environment correlation. The single-gene candidate literature was thrown out the window, as evidenced by the contradictory 2011 and 2018 serotonin transporter meta-analyses, but no one has yet constructed anything on its basis. There is no human study that has measured the epigenetic change that is due to digital stress and the moderation of the effect of digital screens at night by circadian genes has yet to be tested.

There is bias in coverage of the population. Although a large proportion of adolescents more than 3/4 live in low and middle-income countries, where most suicides are likely to occur, most of the evidence is from North America, Europe, and East Asia. Rural youth, minority ancestry genetic samples as well as children under 13, who are increasingly owning devices are all under-represented. Unless sampling practices change, polygenetic scores derived from data from people of European ancestry will not perform well in other populations. Evaluation is behind policy. Natural experiments, in the form of national age limits, school bans and design codes are being implemented without built in evaluation designs, and thus without the opportunity to answer key questions. Lastly, industry possesses behavioural data of an order of magnitude greater resolution than any other source and virtually none of it is made available to independent researchers, a grant programme with the obligation to make such data accessible to researchers would be more effective in this field than any single programme.

20. CONCLUSION

The facts gathered here are neither to be interpreted as panic nor complacency. In many countries, adolescents use a device designed to resist being put down and spend about five hours a day using it almost half of them consider themselves to be online almost all the time. The magnitude of that association to depression is only moderate on average. The associations that emerge from the sea of noise are specific nighttime use that reduces sleep, problematic use that is associated with loss of control, appearance based comparison, which is more detrimental for girls, and cyberbullying victimization, which increases the likelihood of suicidal thoughts even when all the usual factors are

accounted for.

Biology provides an explanation as to why averages can be misleading. Depression risk is heritable to about 35–40%, distributed over hundreds of known genetic sites and circadian timing is genetically regulated, as is stress, with epigenetic signatures on the genes controlling mood. Different force of the same feed on different genomes. Until research studies that integrate objective usage with polygenic risk measurement can be done, the field doesn't know whether it is describing a small harm to everyone or a large harm to an identifiable few, which dictates the right response universal restriction or targeted protection. There are some actions that can be done without waiting. Phones out of bedrooms overnight, rules of design that turn off the most manipulative features for minors, restrictions during school hours, and clinical screening for online victimization all are based on solid evidence and have a negligible cost. The economics are in the same direction depression, and anxiety cost the world economy about a trillion dollars a year, and prevention in adolescence is a decades-long return on investment in education, earnings and health.

The tasks that need to be accomplished are obvious. Passively sense cohorts that are funded longitudinally with genetics. Expand research into countries where 9 out of 10 adolescents live in low and middle income countries. Tie assessment to each new age restriction and school ban to enable policy to teach something. Force researcher access data on the platform in a privacy protected manner. Defer polygenic screening of people to a level of benefit and legal protection that it has yet to achieve. This is a smartphone that's proven to be a valuable tool, but it's been given free rein for a huge uncontrolled experiment on the developing brain. This is work for this decade to close that experiment down and replace it with controlled experiments.

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