The effects of social deprivation on adolescent social development and mental health

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Abstract

Adolescence is a period of life characterized by heightened sensitivity to social stimuli and the increased need for peer interaction. The physical distancing measures mandated globally to contain the spread of Covid-19 are radically reducing adolescents' opportunities to engage in face-to-face social contact outside their household. In this interdisciplinary review, we describe recent literature from a variety of domains that highlights how social deprivation in adolescence might have far-reaching consequences. Human studies have demonstrated the importance of peer acceptance and peer influence in adolescence. Animal research has shown that social deprivation and isolation have unique effects on brain and behaviour in adolescence compared with other stages of life. However, the decrease in adolescent face-to-face contact might be less detrimental due to widespread access to digital forms of social interaction through technologies like social media. The findings reviewed highlight how physical distancing might have a disproportionate impact on an age group for whom peer interaction is a vital aspect of development.

Keywords: social deprivation, adolescence, social isolation, social media, development, Covid-19, physical distancing, social distancing, mental health

Social interactions are proposed to be a basic human need, analogous to other fundamental needs such as food consumption or sleep(*1*). Indeed, feeling insufficiently connected to others is associated with profound and lasting negative consequences on physical and mental health, even leading to increased mortality(*2*). Current efforts to contain the spread of the coronavirus have required sudden and commonly mandated 'physical distancing' (also termed 'social distancing'), removing many regular sources of social connection from people's lives. Such measures are likely to have a substantial impact, not only on the economy and society, but also on individuals' mental health and well-being through factors such as reduced contact with other people. It is possible that the impact of such deprivation of social contact will extend beyond the period of physical distancing and might affect the population for years to come.

The negative effects of physical distancing and social deprivation might be particularly profound for adolescents. Adolescence, defined as 10-24 years(*3*), represents a sensitive period for social interaction(*4*). In the following sections, we discuss evidence that human adolescents are hypersensitive to social stimuli and to the negative effects of social exclusion(*4*) and animal models that demonstrate that extreme forms of social deprivation including complete social isolation during adolescence have damaging effects on brain and behavioural development. This global crisis has, however, struck at a time when many adolescents are relatively well positioned to mitigate some of these social shortfalls using digital means of connection(*5*). This review therefore synthesises interdisciplinary scientific findings relating to adolescent social processing, social isolation and digital social behaviours. We highlight how adolescents might be particularly affected by social deprivation, especially the reduction of peer contact, and how this must be taken into account when considering the long-term consequences of global Covid-19 prevention measures.

Adolescence is a sensitive period of social development

In parallel with the hormonal and biological changes associated with puberty, adolescence is a time of profound psychological and social transformation. During adolescence, the social world and the peer interactions it enables become increasingly important. Compared with children, adolescents spend more time with peers than with family and form more complex peer relationships(*6*). The importance of obtaining peer social approval increases and peer influence is

heightened in adolescence(*7–10*). Indeed, adolescents are markedly more sensitive to peer acceptance, rejection and approval than are children or adults(*11–13*). This reorientation towards peers facilitates young people's development into independent adults, enabling them to foster a more complete sense of social self-identity, at the same time as building stronger affiliations with their peer group(*14*). Simultaneously, cognitive abilities such as self-referential processing(*15*), executive control(*16*) and mentalising, improve across adolescence, enabling young people to better understand other people's minds and take others' perspectives(*16*). The development of high-level cognitive processes provides adolescents with the mental machinery to reflect on themselves and other people and to navigate social networks that start out as unstable and less reciprocal and gradually become more refined and reciprocal throughout adolescence(*17*).

Indeed, adolescence can be considered a sensitive period for social development(*4*), which might be partly dependent on the development of the social brain: the network of brain areas involved in social perception and cognition that allows us to understand others(*18*). As with most regions within the human cortex, the structure of the social brain also develops substantially throughout adolescence(*19*). Multiple longitudinal MRI studies have shown that, across the cortex, the volume of grey matter, mostly consisting of cell bodies and synapses, declines from late childhood to the mid-twenties(*20*, *21*), whereas the volume of white matter, consisting of myelinated axons, gradually increases(*21*). These macrostructural changes are thought to correspond to neurodevelopmental mechanisms at the microstructural level, including the myelination and growth of axons and synaptic reorganisation, which are partly dependent on environmental input and represent mechanisms of developmental neuroplasticity(*22*, *23*). Thus, the heightened neuroplasticity that characterises early development(*24*) is proposed to continue into adolescence(*20*, *21*, *23*). While parental or care-giver input is a critical environmental component in early development, the influence of peers becomes an additional important element of the social environment(*25*).

Adolescence is also a period of heightened vulnerability to mental health problems, with 75% of adults who have ever had a mental health condition reporting that they first experienced symptoms before the age of 24(*26*). There is evidence that problems with peer relationships, peer rejection, bullying and loneliness are risk factors for the development of affective conditions

such as depression in adolescence(*27*, *28*). Conversely, high quality peer relationships appear to protect against mental health problems and strengthen adolescent resilience(*29*). It follows then that widespread changes in the social environment, such as enforced physical distancing and reduced face-to-face social contact with peers, might have a significant impact on brain and behavioural development during adolescence.

It is important to note, however, that physical distancing might not affect all adolescents in the same way. For example, adolescents who are living with high functioning families and who have positive relationships with parents or caregivers and siblings might be less affected by physical distancing than adolescents who do not have positive family relationships or who are living alone. Furthermore, as physical distancing rules vary by country, region and time, limited face-to-face contact with non-household members might be permitted for certain adolescents. Nevertheless, many young people around the world currently have significantly fewer opportunities to interact face-to-face with peers in their social network, putting their social needs at risk of not being met at a crucial time of social development.

The effects of social deprivation on adolescent brain and behaviour: evidence from animal models

There is little research on the effects of social deprivation or isolation on human adolescent development, or on adult humans in general. A number of studies have focused on loneliness in humans, and have reported a connection between self-reported loneliness and mental health problems(*40*). However, such studies do not clearly establish whether loneliness results in mental illness or vice versa. Furthermore, human loneliness is not straightforward to study experimentally as loneliness is not a simple product of objective social deprivation: people can be alone without feeling lonely, or feel lonely even in a crowd(*40*). In contrast, there is a long history of animal research documenting the causal effects of social deprivation, including complete isolation, on brain and behavioural development during animal adolescence(*31*). These animal models usually involve depriving animals of any form of social contact with their own species and studying changes in brain and behaviour both during and after social isolation. Although these experimental studies involve more extreme forms of social deprivation than the physical distancing experienced during Covid-19, the animal research literature provides

valuable insights into the effects of depriving the developing animal of social contact during a sensitive period for social interaction.

Many animal studies have used rodents as their preferred animal model as these are innately social creatures and fare better in social rather than isolated housing(*32*). This rodent research has demonstrated that social isolation causes significant changes in brain and behaviour(*31*), especially if isolation occurs during development(*8*, *9*). The effects of social isolation are considered to be twofold. First, social isolation is a stressor, and some of the effects of isolation can be attributed to general stress effects (engagement of the hypothalamus pituitary adrenal, HPA, axis)(*34*, *45*). Second, social isolation also has impacts that go beyond such general stress effects and can be attributed to the deprivation of stimuli critical for the maintenance of neurobiological mechanisms and development(*35*).

An advantage of rodent animal models such as mice and rats is that their development progresses through similar stages as human development(*36*). To investigate the effects of social deprivation or isolation on adolescent development, rodent studies have focused on the time period between weaning and adult maturity (corresponding to the time period from around postnatal days 21 to 60)(*34–37*). Similar to adolescent humans, after weaning, rodents show a strong orientation towards their peers(*38*). The animals actively seek out peer interaction and these interactions are considered to be important social input for healthy development(*39*) and specifically for social learning(*37*).

Behavioural effects of social deprivation in animal models

Many animal studies have investigated the effects of complete social isolation at different stages of development. While the negative effects of social isolation in very early development are mainly linked to a lack of maternal care(*34*, *35*), it is specifically interaction with peers that is important for adolescent animals(*39*). On a behavioural level, even a brief duration (e.g. 24 hours) of isolation in adolescent rodents can cause increased anxiety(*40*), hyperactivity(*41*) and heightened sensitivity to social rewards(*42*). The latter behaviour extends to the seeking of food or drug rewards, making these animals particularly prone to developing addictions(*43*, *44*). While re-introducing acutely isolated animals to social contact can alleviate some of the negative

effects of short-term isolation, such as anxiety(*40*), there are long-lasting negative consequences that are not easily remedied. For example, increased alcohol consumption in animals after social isolation persists even after re-introduction to social housing(*45*). When rodent adolescent isolation occurs chronically, over one week or longer, it has even more profound effects. Chronically isolated adolescent rodents (isolated throughout the whole adolescent period) have shown abnormal behaviours such as hyper-reactivity to stressful situations(*46*) and increased aggression(*47*). Isolation-induced changes additionally occur for cognitive processes such as learning and attention and result in diminished performance on tasks that involve these processes. In particular, isolation during adolescence results in cognitive flexibility deficits that impair reward learning(*48*), reversal learning(*49*) and attention shifting(*50*).

Other studies have deprived animals of social contact with peers during their peak social play periods, rather than complete isolation throughout adolescence. In most of these studies, animals were isolated from peers from around postnatal days 21 to 43, corresponding roughly to early- (10-13 years) and mid- (14-16 years) adolescence in humans(*37*). Such studies show similar effects to those investigating isolation throughout the whole adolescent period, including increased anxiety-like behaviours, depression-like behaviours, and reward seeking, but impaired reward learning and habituation to novel stimuli(*34*). Furthermore, increased aggression is also observed when rodents are raised with genetically modified conspecifics that show reduced social interaction(*52*), suggesting that behavioural changes also occur under less extreme forms of social deprivation.

Brain effects of social deprivation in animal models

Complete social isolation in adolescent rodents evokes widespread structural and functional changes in the brain, most prominently in neuromodulatory dopamine and serotonin systems and particularly within cortical and striatal targets (*34–36*). Thus, complete social deprivation during rodent adolescence impacts brain development, mainly affecting motivation and reward processes(*34*, *35*). Importantly, these effects are specific to isolation during rodent adolescence and do not occur in such ways when isolation occurs before or after adolescence(*34*, *35*). More specifically, while some divergent effects have been observed, the most consistent findings report that dopamine release in reward regions such as the nucleus accumbens increases

following adolescent isolation, but dopamine activity in the prefrontal cortex decreases(*34–36*). These changes result in dysregulation of dopaminergic signaling in distinct brain structures responsible for processing salient stimuli(*53*). Additional neurochemical changes include alterations to serotonin levels, with the direction of the effects differing between brain regions. For example, the prefrontal cortex shows increased serotonin levels, while other brain areas, such as the hippocampus, show decreased levels. These have been proposed to underlie observed behavioural changes such as increased anxiety and hyperactivity(*35*, *37*). Even if not completely isolated, but instead deprived of peer contact by being reared solely with an adult animal, adolescent rodents show brain-level changes including reduced synaptic pruning in the prefrontal cortex(*54*).

There are a number of studies that have investigated the effects of social deprivation at different stages of development in other species. Many studies have investigated deprivation of peer contact in adult animals(*55*) and have found that, across species, deprivation of contact with peers resulted in negative behavioural and physiological effects in animals, suggesting that the need for peer to peer contact is a universal phenomenon of social species (*56*). While much scarcer, research on the effects of social deprivation in adolescent non-human primates has shown effects in line the rodent research: deprivation of contact with peers for 1-3 weeks results in anxiety-like behaviours and a reduction in cell proliferation and neurogenesis in the hippocampus (a brain region involved in learning and memory)(*57*).

Relating animal and human studies of isolation

In sum, social deprivation and isolation have significant effects on adolescent animals, ranging from neurobiology to cognition and behaviour, which extend well beyond the period of isolation and can have long-term consequences. However, it remains unclear how well the social needs of rodents map onto the social needs of humans(*55*). The social world of rodents differs in many ways from the complexity of human sociality, so social deprivation might have differing effects between species. Most animal studies focus predominately on males, with female rodents included in only a few studies, and therefore fail to represent the constellation of the human population. Furthermore, while the sequence of developmental stages is fairly consistent between

species, the different time intervals of development in rodents compared to humans open up additional questions about homology across species.

Comparable research on social deprivation in humans is scarce, but a small number of studies have investigated the effects of extreme forms of isolation like solitary confinement. They suggest that such isolation in prison leads to increased distress, depression and aggression as well as increased prevalence of self-harm in adults(*58*). These detrimental effects are amplified in adolescent prisoners: one study showed that being younger than 19 and assignment to solitary confinement were the two strongest predictors of self-harm in prisoners(*59*). However, the nature of these studies means that they relate to non-representative groups and are therefore difficult to interpret due to many confounding factors.

Beyond these extreme forms of isolation in non-representative groups, recent evidence on experimentally-induced acute social isolation in adult humans shows that isolation results in increased feelings of loneliness, craving for social contact and decreased happiness(*60*). In the human brain, isolation alters neural patterns in ways similar to food deprivation(*57*): brain activity in the substantia nigra (the core of the brain's dopaminergic motivation centre) when people crave social contact after acute isolation mimics the activity exhibited there when they crave food after fasting. There is, therefore, evidence that at least some of the effects of social isolation observed in animal models can be extended to humans. However, more research is urgently needed to understand how social deprivation affects human development and mental health.

The animal studies reviewed above suggest that consequences of deprivation of social needs during adolescence can have negative effects resembling features of human neuropsychiatric disorders, and on social cognitive development more broadly, due to lack of experiences for social learning. Specifically, it appears that it is particularly the lack of social interaction with peers that elicits behavioural and brain-level changes. The physical distancing measures that are currently in place across the globe in response to Covid-19 will likely reduce many adolescents' ability to fulfil their social needs: while they might still have contact with household members and with people beyond their home via virtual forms of communication, opportunities for face-to-face interaction with peers will be drastically reduced or completely eliminated. While for

some adolescents, social interactions at home might meet their social needs, physical distancing will challenge many teenagers' capacity to connect with peers. Research is therefore needed to understand whether the effects of social deprivation found in animal studies can be extended to apply to human adolescents. However, such research will need to investigate the possibility that virtual social connection might mitigate these effects, and that is what we turn to in the next section.

Digital sources of social connection

Young people have been some of the first large-scale adopters of communicative digital technologies such as social media and smartphones(*5*, *61*). Almost three quarters of British young adolescents (12-15 years-old)(*62*), and 97% of American 13-17 year-olds have a social media profile(*63*). The majority of US teenagers spend more than four hours a day on social media sites(*61*), and almost half report they are 'almost constantly' engaging online(*63*)[1]. While physical distancing measures would have stopped all adolescent peer contact except the landline phone and letter writing just three decades ago, active social contact can now be mediated by digital applications, whether that be social media, video chatting/conferencing, blogging or online gaming(*62*). Digitally mediated interactions challenge our traditional conceptualisations of what socialising entails(*64*) as they can be asynchronous, one-to-many, click-based or audio-video-reliant. This raises the possibility that digitalised social contact can mitigate the potentially harmful effects of physical distancing in young people.

Adolescents routinely report using digital technologies for actively social means(*65*). In particular, 13- to 17-year-olds indicate that technologies like social media make them feel more connected with their friends (81% of respondents), help them interact with more diverse groups of people (69%) and allow them to access social support during tough times (68%)(*63*). Studies

[1] It is important to note that income and education gaps between those who use smartphones and social media and those who do not are still substantial in both developed and emerging economies. There is a 15% gap in smartphone ownership between lower- and higher-income teenagers in the USA(*61*) and 58% of Nigerians with secondary education or more have a social media account compared to 10% of Nigerians without secondary education(*5*).

on adolescent social behaviour show that core components and qualities of adolescents' face-to-face interactions, including information disclosure, interactivity, social reward and social support, are present when communicating online(*66*). Online communication has been shown to remediate negative feelings after social exclusion(*67*). Evidence for the ability of digital communication to mirror face-to-face contact effects extends to neuroimaging studies of human brain correlates of social processing. Due to the physical constraints of the MRI scanner, all neuroimaging studies focusing on the "social brain" and social cognition are limited to digitally-mediated social interactions instead of their face-to-face counterpart. fMRI studies have shown that experiencing partial components of positive social interactions such as real-time sharing of eye-gaze(*68*), hearing someone laugh after a telling a joke(*69*) and observing videos from someone who has a shared intention(*70*) activate neural reward systems in similar ways as do non-social rewards (e.g. monetary rewards). While these studies were conducted in adults, research in children and young adolescents (8-12 years) similarly show that positive chat messages(*71*) evoke neural reward activity akin to activation resulting from monetary reward.

Digital interactions can be mediated via many different technologies ranging from interactive video games to social media. These can encourage a wide variety of activities ranging from popular pastimes such as connecting with friends or engaging with social media 'influencers'(*72*) to less common activities such as accessing digital mental health interventions or exposure to harmful content (e.g. online gambling and grooming (*73*)). Social media especially has become popular in the adolescent age group over the last decade(*62*). To gauge the effect of social media on personal relationships and well-being it is necessary to differentiate between its different uses (*74*). Specifically, 'active' uses of social media, for example engaging in directed communication (e.g. messaging) or posting directly on another person's 'wall', have been shown to increase well-being(*75*) and help maintain personal relationships(*76*). However, social media also allows for other activities less akin to the digital communication described above, e.g. 'passive' uses such as scrolling through social media newsfeeds. These have routinely not been linked to positive outcomes(*77*). There is initial experimental evidence that such 'passive' uses could even negatively influence well-being, possibly by increasing social comparison and envy(*78*). To understand how digital technologies impact adolescents experiencing physical distancing, we need to differentiate between 'connection promoting' (i.e. active and

communicative) and ‘non-connection promoting’ (i.e. passive) uses of social media(*74*) instead of focusing solely on time spent using this medium(*79*).

Furthermore, there is growing consensus that the consequences of social media use will be dependent on individual differences(*79*). Some studies have supported the ‘rich-get-richer’ view of online communication, i.e. those who already have strong offline friendships might benefit most from digital interaction, while those with a liability to mental health issues might be more susceptible to the negative effects(*79*). For example, those who have been victimised in person are more likely to be victimized or bullied online(*80*).

It is difficult to parse the unique effects of social media and digital technology from the noisy background of adolescent life, making it challenging to give accurate and evidence-based recommendations in times of physical distancing that go further than promoting common sense approaches(*81*). However, the existing evidence demonstrates that certain aspects of digital communication can engender social connection and might, therefore, mitigate the consequences of physical distancing, and research should focus on this possibility.

Discussion and conclusion

With physical distancing being enforced by governments around the world, society is at the start of a period of intense and widespread reduction of face-to-face social contact. This review highlights the urgent need to consider the well-being and development of adolescents. Adolescents are at a unique period in their lives when the social environment performs crucial functions in brain development, self-concept construction, and mental health. This review highlights animal studies that demonstrate significant and potentially long-term effects of social deprivation and isolation in rodent adolescence on neurochemistry, structural brain development and behaviours associated with mental health problems. This research has almost entirely been conducted in animal models, and little is known about how social deprivation affects human development. The review considers the potential of social media and other digital technologies to mitigate the severity of social deprivation effects on human adolescents, but more research focused on this precise question is needed.

There are many questions that remain unanswered. It is unknown how long the physical distancing measures will be in place, and whether or how they will affect development and mental health in the longer term. Even if physical distancing measures are temporary, several months of physical distancing represents a relatively large proportion of a young person's life during a sensitive period of development, so it is possible that the effects will be more potent than for adults. Furthermore, there is little understanding how the consequences of physical distancing compare with other stressors experienced by adolescents during the COVID-19 crisis, including economic pressures, uncertainty and loss of public events marking key life stages and rites of passage. Adolescent physical distancing should therefore be given urgent consideration by policymakers and the opening of schools and other social environments should be a priority once physical distancing can be loosened. There needs to be more information provided about the potential merits (and harms) of digital connection, and governments need to address the 'digital divide' by supporting access to digital connection in families irrespective of income or location. Finally, there is an urgent need to understand the short- and longer-term effects of social deprivation and physical distancing, reduced face-to-face social interaction, and increased use of digital means of connection, on human adolescent development and mental health.

Search strategy and selection criteria

We searched Scopus (which includes PubMed and Medline) for peer-reviewed articles on social behaviour in human adolescence, social isolation and deprivation in adolescent rodent models that included measures of brain or behaviour, and social media, adolescence and mental health. We only searched for articles published in English, or those translated into English.

Key messages

- Physical distancing measures to contain the spread of the Covid-19 virus have removed many sources of face-to-face social connection from people's lives. This might affect people's mental health, particularly in adolescence, a period of life characterized by heightened need for peer interaction.
- Animal research suggests there are unique effects of social isolation and social deprivation on brain and behaviour in adolescence. Although the isolation in these studies is

more extreme than the reduced social interaction associated with physical distancing, this literature suggests that adolescents might be particularly affected by deprivation of their social needs.

- Adolescents' use of digital technologies and social media might mitigate some of the negative effects of social distancing.
- We call for an increased sensitivity during the Covid-19 response to the needs of adolescents, for whom peer interaction is a vital aspect of development.

Disclosures

The authors have no conflicts of interest to declare.

Authors' contributions

All authors contributed equally to this manuscript.

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