Social Risk in Adolescence

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Signed declaration

I, Jack L. Andrews, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

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Abstract

Adolescence, defined as 10-24 years, is a time of heightened sensitivity to the negative effects of social rejection. Avoiding social risks – decisions or actions that could lead to social rejection - may therefore be important for adolescents, for whom social status and acceptance predicts future mental and physical health. In this thesis, I describe a series of studies that investigated the relationship between social risk and adolescence.

In my first study, I developed a novel self-report measure of concern for health and social risk behaviours. I assessed age-related differences in concern for health and social risk between adolescence and adulthood, and whether these were related to rejection sensitivity and depressive symptomatology. In my second study, I explored the degree to which adolescents' engagement in health risks and illegal behaviours was related to whether or not they perceived these behaviours to increase their likability. I also investigated how this relationship is impacted by adolescents' experience of victimisation. In my third study, I used network analysis to explore the link between sexual minority status, depression, interpersonal relationships and health risk behaviours in a large cohort study of adolescents. In my fourth study, I designed an experiment to measure the extent to which adolescents versus adults show a preference for social versus non-social stimuli within an academic diligence task.

I discuss how my findings suggest adolescence to be a period of heightened sensitivity to social risk, and how this impacts decisions to engage in risk taking behaviour. I consider how my findings relate to legal and policy issues around the minimum age of criminal responsibility, joint enterprise convictions and the use of peer-led approaches for behaviour change.

Impact statement

This thesis examines social risk and social development in adolescence and presents a number of findings that contribute to a growing body of work demonstrating that adolescence is a unique period of social development and sensitivity to the social environment.

The results presented show adolescence to be a period of heightened concern for social risk, and a time when the desire to be liked by others is tightly linked to engagement in health-risk behaviours, when this is the norm. In addition, this thesis highlights the significant relationship between sexual minority status and depression among adolescents, and demonstrates several poor outcomes among this group of young people to be downstream consequences of depression and poor peer relationships. This thesis also shows that adolescence is a time of heightened self-reported preference for social relative to non-social information, but that this does not reliably translate to behaviour.

The work presented here has the potential to confer benefits both inside and outside of academia. In terms of dissemination, this thesis has contributed to the publication of 5 peer-reviewed papers, to date. This thesis offers a novel measure of social risk sensitivity, which is freely available to other academics. This measure has been shown here to have high when validated against measures such as depressed mood and rejection sensitivity. Within this thesis, a novel experimental paradigm to assess individuals' sensitivity to social versus non-social rewards has been developed, and is freely available to other researchers.

Outside of academic research, the work presented here has the potential to contribute to education and health policy. One example is within the context of COVID-19, and a publication resulting from this thesis makes recommendations regarding how public health messages, especially around adherence to social distancing rules, might reach young people. If adolescents are especially motivated by group belonging and by avoiding social rejection, then interventions aimed at promoting positive behaviour

should account for this. Specifically, it is the recommendation here that peer-led interventions are most likely to be effective, relative to adult-led interventions.

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Abbreviations

ACC	anterior cingulate cortex
AIC	Akaike information criterion
CFA	Confirmatory factor analysis
dmPFC	dorsomedial prefrontal cortex
EFA	Exploratory factor analysis
IQ	intelligence quotient
LRT	Likelihood ratio test
M	Mean
MCS	Millennium cohort study
mPFC	medial prefrontal cortex
PFC	Prefrontal Cortex
pSTS	posterior temporal sulcus
SD	Standard deviation
SM	Sexual minority
STS	Superior temporal sulcus
TOM	Theory of mind
vMPFC	ventromedial prefrontal cortex
WASI	Weschler abbreviated scale of intelligence

Chapter 1: Introduction

Parts of this chapter have been published as:

Andrews, J. L., Ahmed, S., & Blakemore, S. J. (2020). Navigating the social environment in adolescence: The role of social brain development. ***Biological Psychiatry*.**

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During the transition to adulthood, adolescents undergo a number of substantial social changes. The amount of time spent with peers increases between childhood and adolescence, and young people's personal and social worth becomes increasingly influenced by what their peers think of them (Blakemore & Mills, 2014; Lam et al., 2014). In the presence of peers, adolescents are also more likely to take health or legal risks, when this is valued by the peer group (Chein et al., 2011; Gardner & Steinberg, 2005; Lundborg, 2006). In this thesis I present the argument that this is, in part, because adolescents are especially socially risk averse: they avoid behaviours, or actions, that could lead to a loss of a face, a reduction in their social status, or social exclusion.

In the first part of this introduction, I describe findings that demonstrate adolescence to be a period of continued brain and behavioural development. I review evidence showing that the brain continues to develop structurally and functionally throughout adolescence, and relate this to the development of social cognition, such as mentalising and perspective taking, during adolescence. I then describe current models of adolescent risk taking, peer influence and social reward before highlighting the negative effects that social rejection has on adolescents' current and future well-being.

1.1. Defining 'adolescence': from BC to today

Born into the discourse of the 15th century, the term "adolescence" owes its origins to the Latin word "adolescere", meaning "to grow up or to grow into maturity" (Lerner & Steinberg, 2004). For centuries, the transition from childhood to adulthood has been conceptualised in ways not too dissimilar to our understanding of adolescence today. In particular, the ancient Greek philosophers, such as Plato and Aristotle, were unafraid to stereotype adolescents as "passionate, irascible and apt to be carried away by their impulses […] the age when people are most devoted to their friends" (Aristotle, 350 BC). Such descriptions are remarkably consistent with current evidence that adolescence is a distinct period of social reorientation, characterised by increased peer affiliation relative to family members (Nelson et al., 2016), a heightened effect of peer influence (Knoll et al., 2015) and risk-taking in the presence of peers (Chein et al., 2011; Gardner & Steinberg, 2005). One contemporary definition of adolescence marks the onset with

the start of puberty and the end of adolescence as the time when adult independence has been achieved (Patton et al., 2016). However, such a definition is open to considerable interpretation. A more recent review has redefined adolescence as starting at 10 years of age and ending at around 24 (Sawyer et al., 2018). This definition serves to capture the biological, psychological and social changes that occur during the transition from childhood to adulthood and has also been proposed as a necessary step forward for the appropriate framing of laws and social policies (Sawyer et al., 2018).

1.2. Structural brain development

During adolescence, the brain undergoes substantial and protracted structural development. Non-invasive brain imaging techniques, such as Magnetic Resonance Imaging (MRI) have been used widely to study the structural properties of the developing brain, such as overall brain volume and grey and white matter volume. The most substantial volumetric changes in the brain occur in the immediate post-natal period. However, one meta-analysis of 56 longitudinal MRI studies of whole brain volume changes found meaningful periods of development at various other points across the lifespan. On average, at around 9 years, a 1% annual increase in brain volume is found, levelling off at 13 years of age, which is followed by a decrease until the early twenties, and then by a period of stability and a subsequent decrease again at around 35 years of age (Hedman et al., 2012). This notable decrease in volume observed during adolescence is also mirrored by the findings from a more recent, large, multi-site (NCD – Neurocognitive Development Study: University of Oslo, CPB – NIH Child Psychiatry Branch, Pittsburgh and Braintime – Leiden University) longitudinal study showing whole brain volume decreases during adolescence (Mills et al., 2016). However, there was variation in the timing of this decline, with data from NCD and CPB showing this decline in whole brain volume beginning in mid-adolescence, whist Pittsburgh and Braintime showed a reduction in volume from late childhood to early adolescence.

1.2.1. Grey and white matter

Across all four samples in the Mills et al., 2016 paper described above, cortical grey matter volume (which largely includes neuronal cell bodies and synapses, as well as

other neural matter such as glia) was highest during childhood, subsequently decreasing during adolescence and levelling out in the early twenties. Across adolescence grey matter decreases by approximately 1.5% each year. Concurrently, cerebral white matter volume (consisting of myelinated axonal tracts) shows a linear increase through childhood and adolescence, at a rate of approximately 1% increase per year (see **Figure 1.1**; Mills et al., 2016). There is also evidence of regional specific variation in structural brain development across adolescence. For example, one study of 147 participants aged 7-24 years old, of whom 53 were scanned multiple times, showed that structures including the caudate, putamen and nucleus accumbens, decreased in grey matter with age, whilst the amygdala, cerebellum, hippocampus, pallidum and thalamus demonstrated an inverted U-shape trajectory (Wierenga et al., 2014). Further work has also shown regional specific changes of the hippocampus in a large sample of adolescents and young adults (8-28 years) (Tamnes et al., 2017). This suggests that brain development develop during adolescence is not uniform, rather it follows distinct, region-specific trajectories.

1.2.2. Individual variation in adolescent brain development

No two individuals' brains develop in the same way and there exists striking heterogeneity between individuals, at both the level of the intercept (overall level e.g. volume) and slope (trajectories) of brain development (Foulkes & Blakemore, 2018). This means that averaging across individuals occludes a more nuanced understanding of brain development; individual variability in brain development is large and is likely driven by a number of factors including genetics, pubertal timing, and environmental factors such as culture, poverty and parenting. For example, grey matter volume is influenced by distinct genetic (Panizzon et al., 2009; Winkler et al., 2010), evolutionary (Rakic, 1995) and cellular (Chenn & Walsh, 2002) processes, which generate a large degree of individual variation.

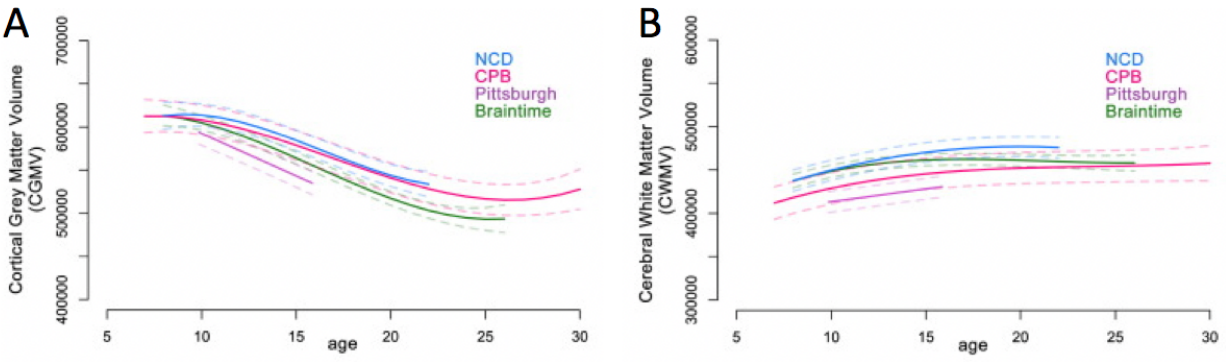

Figure 1.1. Developmental trajectories of grey and white matter. Trajectories of cortical grey matter and cerebral white matter are shown in panel A and B, respectively. Lines depict change over time and colours correspond to each of the four cohorts studied. As depicted by panel A cortical grey matter volume decreases over adolescence, appearing to stabilise from the mid 20's. As depicted in panel B, trajectories of cerebral white matter volume increase over adolescence and appear to stabilise from the mid-twenties. Reprinted from Mills et al., 2016.

In one study, individual variation observed in these trajectories of brain development was explicitly assessed. In this study, 33 participants, who were scanned at least three times between childhood, adolescence and early adulthood, showed averaged trajectories of prefrontal cortex (PFC), amygdala and nucleus accumbens (NAcc) development did not consistently reflect developmental trajectories at an individual level (see **Figure 1.2**). Faster maturation of the amygdala, compared to the PFC, was observed in 27 of the 33 individuals, whilst 17 of the individuals showed faster maturation in the NAcc compared to the PFC. When comparing across all three regions, 46% of individuals (15 participants), showed a developmental mismatch (a difference in the rate of structural maturation) between both the amygdala, the NAcc and the PFC. 36% of individuals (12 participants) showed a mismatch between only the amygdala and the PFC. 6% (2 participants), showed a mismatch between only the NAcc and the PFC. This leaves 12% (4 participants) who revealed no mismatch between either three regions – the rate of maturation did not differ across region (**Figure 1.2**; Mills, Goddings, Clasen, Giedd, & Blakemore, 2014). These findings demonstrate that not all individuals show the same trajectories of brain development, questioning the importance often placed on averages.

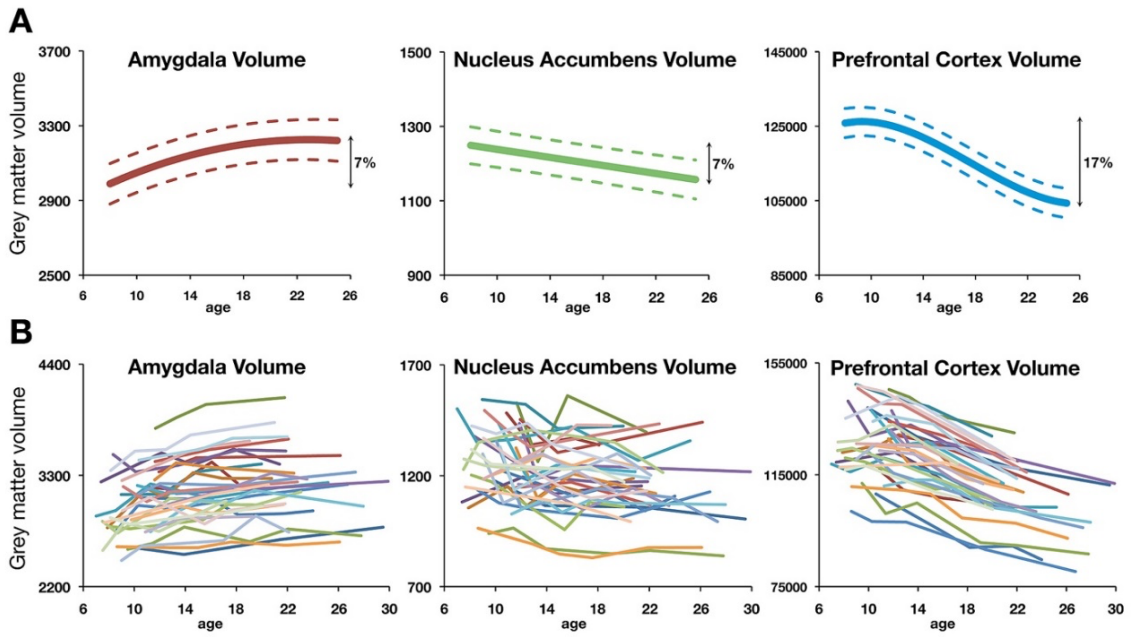

Figure 1.2. Individual variation in brain development. A: The best-fitting group models for average developmental trajectories in grey matter volume in the amygdala, nucleus accumbens and prefrontal cortex from 33 participants scanned at least three times between late childhood and early adulthood; dashed lines indicate 95% confidence intervals. B: Individual data from the 33 participants plotted in A, revealing wide variation across individuals. Reprinted from Mills, Goddings, et al., 2014).

The trajectories of these specific regions were selected in order to test the dual-systems theory of adolescent risk-taking, which attributes increased risk-taking during adolescence to divergent patterns of developing motivational and cognitive control systems (Steinberg, 2010). These models suggest that increased risk-taking during adolescence is a product of faster maturing reward systems in the brain (e.g. NAcc), which motivate adolescents towards sensation seeking, and the slower maturation of pre-frontal, self-regulatory regions (Shulman et al., 2016). Self-regulation is the capacity to pursue goals through the deliberate modulation of one's thoughts, feelings or actions (Smith et al., 2013). However, Mills et al (2014) found no evidence that a developmental mismatch between the structural development of brain regions implicated in reward and self-regulatory processes was associated with risk-taking behaviour. However, this study assessed risk-taking retrospectively, asking participants to self-report their engagement in risk behaviours during adolescence (several years earlier). This presents a limitation as participants may over- or under-estimate their experiences and may be subject to a number of biases in self-reporting. Further evidence in support of and

against the dual systems model of adolescent risk-taking is discussed in **Chapter 1.4**. These findings from Mills et al (2014) do, however, demonstrate that brain development is not consistent across regions and that trajectories of brain development might not directly map onto behaviour.

1.2.3. Social brain development

Some of the latest maturing brain regions are found within the 'social brain', the network of regions involved in recognising, understanding and interpreting cues from others. Brain areas involved in these complex components of social cognition include the medial prefrontal cortex (mPFC), the anterior cingulate cortex (ACC), the inferior frontal gyrus, the superior temporal sulcus (STS), the amygdala and the anterior insula (Blakemore, 2008). Regions of the social brain involved in mentalising, the ability to interpret the mental states, feelings and actions of others (Blakemore, 2008), collectively form the 'mentalising network'. The mentalising network includes the posterior superior temporal sulcus (pSTS), which is involved in the interpretation of social gestures and eye gaze (Pelphrey et al., 2004; Puce & Perrett, 2003), the temporoparietal junction (TPJ) and dorsomedial prefrontal cortex (dmPFC), which are involved in inferring others' mental states (Frith, 2007; Saxe & Kanwisher, 2003; Saxe et al., 2009). Some studies have also implicated the anterior temporal cortex (ATC; for a review see (Olson et al., 2013)), which is involved in representing and retrieving social knowledge (see **Figure 1.3**) (Carter et al., 2012; Olson et al., 2013) and the precuneus, a region often co-activated with the mPFC during perspective taking with mental imagery tasks (Schurz et al., 2014).

Longitudinal structural imaging studies have shown that regions of the social brain which support mentalising undergo substantial and protracted development during adolescence. For example, grey matter volume and cortical thickness in pSTS, TPJ and dmPFC decreases from childhood into the early twenties, whilst in the ATC, cortical thickness increases until early adulthood and grey matter volume increases until adolescence (Mills, et al., 2014). This suggests that regions of the brain involved in social

cognitive processes, including mentalising, are maturing in terms of structure throughout adolescence and into early adulthood.

1.3. Social cognitive development

1.3.1. Mentalising

Mentalising enables us to understand the minds and predict the behaviour of other people (Olsson & Ochsner, 2008). Functional neuroimaging studies have investigated the neural basis of mentalising, frequently by asking participants to think about the mental states of characters in stories. The TPJ, mPFC and precuneus show increased activity when young adolescents (Saxe et al., 2009) and adults (Gweon et al., 2012) listened to sections of a story describing a character's thoughts (requiring mental state attribution) compared to sections of the same story that described the physical environment (not requiring mental state attribution), and this activity correlated with behavioural performance (Gweon et al., 2012). Other studies have found age differences in the activation of the dmPFC and TPJ during mentalising tasks (Blakemore & Mills, 2014). For example, several studies have found that the recruitment of the dmPFC decreases between adolescence and adulthood when individuals perform a variety of mentalising tasks (see review (Blakemore, 2008)). Other studies have also found that adults recruit the TPJ more strongly than do adolescents when responding to scenarios relating to their own intentions versus physical events (Blakemore et al., 2007). Previous work in adults has found that the TPJ is recruited more by tasks requiring reasoning about others' intentions and beliefs (cognitive theory of mind (ToM)) (Schlaffke et al., 2015; Schnell et al., 2011), while the mPFC is recruited more by inferences about emotions and preferences (affective ToM) (Amodio & Frith, 2006; Etkin et al., 2011; Hynes et al., 2006; Leopold et al., 2012; Sebastian et al., 2012; Shamay-Tsoory, 2011; Shamay-Tsoory et al., 2006; Shamay-Tsoory & Aharon-Peretz, 2007). Therefore, these two brain regions may be differentially involved in the development of mentalising skills in adolescence.

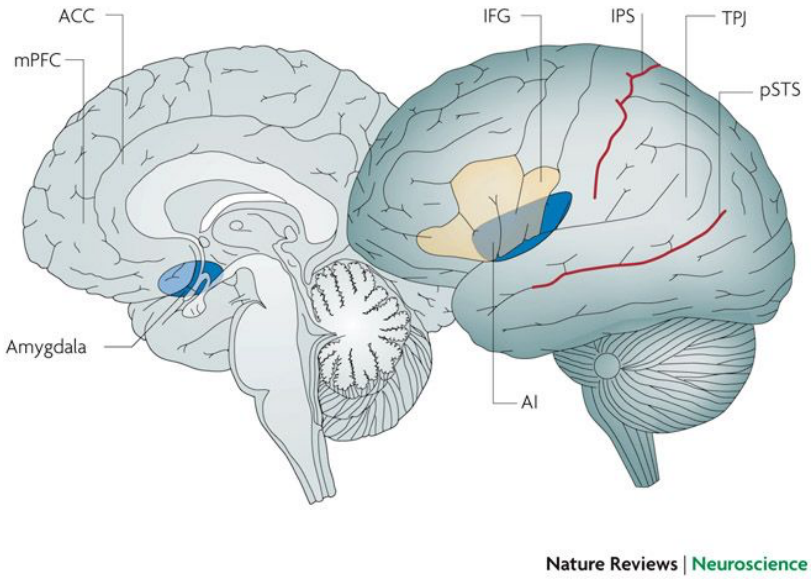

Figure 1.3. Regions of the social brain, including the medial prefrontal cortex (mPFC), the temporoparietal junction (TPJ), the posterior superior temporal sulcus (pSTS), the inferior frontal gyrus (IFG), the interparietal sulcus (IPS), the anterior cingulate cortex (ACC) and the anterior insula (AI). Reprinted from Blakemore (2008).

1.3.2. Perspective taking

Perspective taking is the ability to take another person's point of view into account. Studies exploring the development of perspective taking during adolescence have often employed the Director task, in which a 'Director' stands behind a set of shelves that contains a number of objects, some of which are occluded from the Director's view. Participants are required to move objects according to instructions from the Director, remembering only to move objects that are visible to him, which requires taking his perspective. Performance on this task continues to improve between adolescence and adulthood (Dumontheil et al., 2010; Symeonidou et al., 2016).

Whilst mPFC and pSTS/TPJ are commonly activated during mentalising tasks, perspective taking tasks, in which individuals make visuo-spatial rather than mental state inferences, do not tend to activate these regions (Aichhorn et al., 2006; David et al., 2006; Vogeley et al., 2004). However, in one adaption of the Director task for fMRI, two Directors, one male and one female, were presented on a screen, one in front of and the other behind a set of shelves (Director Present condition; DP; Dumontheil et al.,

2012). On each trial, one director (indicated by a female or male voice) instructed participants which object to move and, as in the behavioural version of the task, some objects were not visible to the Director situated behind the set of shelves. Therefore, moving the correct object in this DP condition required perspective taking. In a non-social control condition, no Directors were present and instead the letters 'M' and 'F' were placed next to the shelves (Director Absent condition; DA). In this condition, the letters indicated whether certain objects could be moved. The two conditions were identical except knowing which object to move was achieved by taking the director's perspective in the DP (social) condition versus following a symbolic rule in the DA (non-social) condition. In the DP condition, adolescents and adults recruited the dmPFC, whilst in the non-social DA condition, adolescents (but not adults) recruited the dmPFC in spite of there being no social cues. These findings suggest that adolescents may be recruiting regions of the brain that underpin mental state attribution in non-social contexts where mentalising is not needed. The authors suggested that adolescents' activation of the dmPFC during the non-social condition might reflect the continued specialisation of brain regions that underpin social cognition.

Together, these findings suggest that adolescents, relative to adults, may be using different cognitive strategies when taking another's perspective. Several studies have further demonstrated that the ability to take someone else's perspective is still maturing during adolescence (Dumontheil, et al., 2010; Symeonidou et al., 2016; van den Bos et al., 2016), with children and adolescents typically making more errors than adults on perspective taking tasks (Dumontheil, et al., 2010; Symeonidou et al., 2016). It has been suggested that inhibitory control may be contributing to these differences (Symeonidou et al., 2016; Crone & Fuligni, 2020). For example, in one study, performance on an inhibitory task (measured by a simple No-Go task) explained some additional variance over and above age, on the performance on the Director task (Symeonidou et al., 2016). Interestingly, performance on the more complex, go/no-go, version of the task was unrelated to performance on the Director task, perhaps as it increased demands on working memory. Similarly, Lin et al., 2010 found that participants with poorer working memory capacity, performed less well on the Director task, relative to individuals with greater working memory capacity.

1.4. Risk-taking in adolescence

Health risk behaviours, such as binge drinking and illicit substance use, cluster during the adolescent years (DuRant et al., 1999; van Nieuwenhuijzen et al., 2009). Previous work has shown that belonging to a peer group that engages in smoking or drinking increases an individual's likelihood of smoking by 5.4 times and drinking by 1.9 times (Loke & Mak, 2013). Adolescents are more likely to engage in health risk behaviours such as excessive alcohol consumption, experimentation with illicit substances and smoking when with their peers, compared to when alone (Reniers et al., 2017). Data from across three US government surveys have shown that the risk of car accidents is greater for young drivers when they have a passenger in the car (Chen et al., 2000).

Developmental scientists have proposed several theories as to why risk-taking behaviours increase during this period of life, and in particular, why they occur more frequently in the presence of peers (Ciranka & van den Bos, 2019). Several theories focus on the heightened degree of sensation seeking, reward value and peer influence (Steinberg, 2008). First, I will elaborate on a number of the most prominent models of adolescent risk taking, before focusing on the impact that the peer environment has on decisions to engage in risk behaviours during adolescence.

1.4.1. Dual systems models

As previously discussed in **1.2.2**, reward sensitivity models, such as the dual systems model, attribute increased risk-taking during adolescence to divergent patterns of developing motivational and cognitive control systems (Steinberg, 2010). The dual systems account of adolescent risk behaviour posits that increased risk-taking during adolescence results from faster maturing reward systems, implicated in sensation seeking, and the slower maturation of prefrontal regions implicated in self-regulation (Shulman et al., 2016). Evidence for the dual systems model comes from neuroimaging findings that adolescents show increased subcortical (e.g. ventral striatum) activity to socially beneficial contexts (e.g. risk-taking in the presence of peers), during a period of development when pre-frontal regions implicated in cognitive control are still developing. For example, one study that investigated the degree to which adolescents

(13-16 years old), young adults (17-24 years old) and adults (25-40 years old) took risks when alone or in their presence of their peers, involved a computerised driving task – the stop light task. The stop-light task requires participants to drive a virtual car along a track to earn points. Participants are presented with a decision at each intersection when the traffic light is red – they can either 'jump' the light (go; risky) or wait for the light to turn green (stop; safe). If they go at the red light, they may be hit by an oncoming car and loose a large portion of time and points, or they may get away and progress further along the track in a timely fashion which is rewarded by a higher pay out of points. If they choose to wait at the light, they will lose only a small portion of time. In this task, adolescents and young adults were significantly more likely to take driving risks when in the presence of friends, compared to when alone (Gardner & Steinberg, 2005). When this task was carried out in an MRI scanner, adolescents showed greater activity in reward-related brain regions, such as the ventral striatum and orbital frontal cortex, when being watched by their friends compared to when playing alone. This was not the case for adult participants (Chein et al., 2011). This suggests that, during adolescence, the presence of peers increases the reward value of certain risky decisions, especially when these are favoured by the peer group. However, drawing clear conclusions regarding the reward value of such stimuli from fMRI data alone is problematic given the problem of reverse inference, in which the presence of neural activation is used to infer the engagement of certain mental processes, which is not possible or valid (Poldrack, 2006).

Behavioural findings demonstrate that context is an important factor in predicting the degree to which self-regulatory processes are enacted during adolescence. In 'cold' contexts, characterised by less arousing situations, adult-like self-regulation appears present at around age 15 (Casey et al., 2016). However, in 'hot' contexts, such as when with friends, characterised by high demand or emotional arousal, adult-like self-regulation may not be met until the early twenties, on average (Shulman et al., 2016; Veroude et al., 2013).

In one study conducted across 11 different countries, over 5,000 individuals aged between 10 and 30 years of age completed self-report and task-based measures of self-

regulation and sensation seeking. Sensation seeking was assessed through self-report, the Iowa Gambling task (a card task designed to simulate real-life decision making) and the stoplight game (a simulated driving task in which participants can take risks to earn potential monetary rewards). Self-regulation was assessed using the self-report, the Stroop task (a measure of response inhibition) and the Tower of London task (a planning task). Although this was a behavioural study, these findings lend support to the dual-systems hypothesis showing that sensation seeking followed an inverted U-shaped trajectory, peaking at age 19 and declining into the twenties. Self-regulation, on the other hand, steadily increased from early to late adolescence, plateauing around the ages of 23 to 26 (see **Figure 1.4**; Steinberg et al., 2018). Whilst these trends were observed across the majority of countries studied, a few exceptions were found. For example, in Jordan, sensation-seeking increased linearly with age, suggesting that cultural context may impact, self-report and performance on these tasks used to assess sensation-seeking.

Focusing on the role of sensation seeking in predicting risk-taking behaviours, previous research has documented a positive association between sensation seeking, substance use and sexual risk-taking (Byck et al., 2015; Quinn & Harden, 2013; Zhang et al., 2016). Research investigating the relationship between sensation seeking and peer influence has also shown, in a large sample of adolescents, that peer pressure to engage in marijuana and cigarette use had a greater effect on high sensation-seekers (Slater, 2003). Subsequent research has also found that the frequency with which individuals (college students) associated with alcohol-using peers influenced the relationship between sensation seeking and alcohol consumption (Yanovitzky, 2006). Taken together, this suggests that social context has the potential to moderate the relationship between sensation seeking and engagement in health risk behaviours.

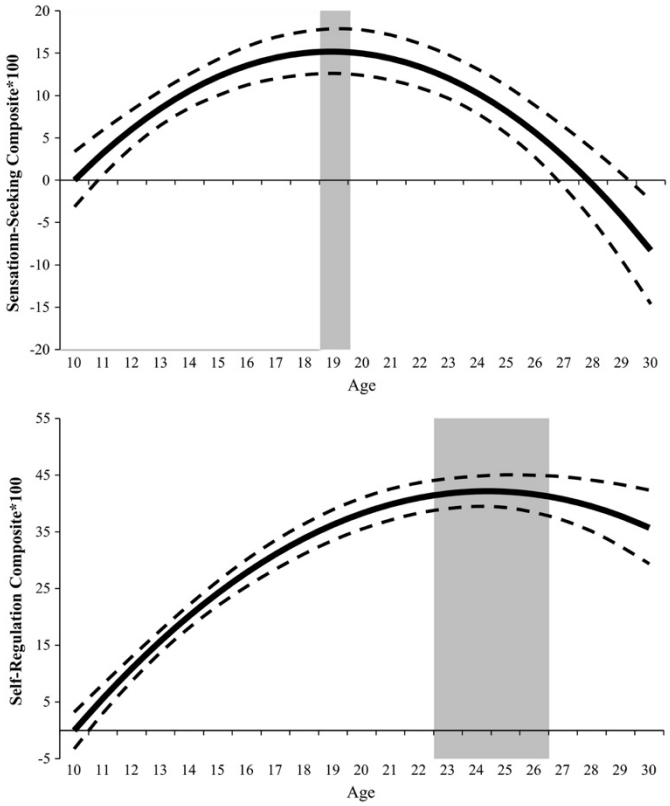

Figure 1.4. Age-related changes in sensation seeking and self-regulation across 11 countries (China, Colombia, Cyprus, India, Italy, Jordan, Kenya, the Philippines, Sweden, Thailand and the United States). Age differences in scores on sensation seeking (top) and self-regulation (bottom) in the whole sample. Grey shading denotes a plateau/peak, defined as years of age for which the instantaneous rate of change (i.e. the estimated slope of the age curve) did not differ significantly from zero. Dashed lines indicate 95% confidence bands. Reprinted from Steinberg et al 2018.

A number of neuroscientific findings in the last decade are, however, inconsistent with the dual systems model (Crone & Dahl, 2012; Pfeifer & Allen, 2012). For example, as discussed above in **1.2.3**, one study found that at an individual level there was wide variation in the timing of development between subcortical regions (involved in motivational processes) and prefrontal regions (involved in cognitive control), with a number of individuals showing no evidence of a mismatch at all (Mills, et al., 2014). This is inconsistent with the dual systems model, which is founded on the premise that reward regions develop earlier than the PFC. Further, the extent to which this mismatch was present was unrelated to participants' retrospectively self-reported engagement in risky behaviour during adolescence (Mills et al., 2014). In contrast, in recent years, the imbalance model (Casey et al., 2008) has moved away from the dichotomy inherent in

the dual systems model, and towards a more nuanced understanding, which accounts for variation in self-control across both content (e.g. emotions or actions) and context (e.g. in the presence of peers or parents) (Casey, Galván, & Somerville, 2016).

1.4.2. Challenges to the dual systems model

It has been proposed that adolescent risk-taking can be adaptive and can require cognitive control, which is counter to existing dual systems models (Do et al., 2020). This model, the expected-value-of-control (EVC) model, suggests that, in situations where risk behaviours are not habitual (e.g., when engaging in a risk behaviour for the first time), it is likely that individuals employ a degree of cognitive control to counter their habitual response (to avoid the risk behaviour), particularly in contexts where risk engagement may be valued through social approval (Do et al., 2020). Therefore, it is possible that risk-taking behaviour may result from enhanced levels of cognitive control, if engaging in the risk behaviour requires more cognitive control than not engaging in the risk behaviour (Do et al., 2020). This is in opposition to the dual systems model, which suggests that risk-taking is characteristic of poor cognitive control. Important to the EVC model is the valuation process, which determines the degree to which cognitive control is enacted. The value of a behaviour may be brought about by both top-down (e.g. the use of memory to determine what is valued) and bottom-up (e.g. estimating certain choices over others) processes.

In situations where risks are unknown, adolescents demonstrate increased risk-taking behaviour compared to adults, whereas when risks are known, risk-taking declines monotonically from childhood to adulthood (Tymula et al., 2012). This increased exploration of unknown environments during adolescence is thought to facilitate the acquisition of new knowledge and learning about the consequences of enacting different behaviours (Crone & Dahl, 2012). Adolescents may, therefore, be more likely to engage in risky behaviour if they have less prior knowledge of the consequences and the EVC model provides a framework with which prior knowledge can be factored into computations that might determine adolescent decision processes. This suggests that

some risk-taking during adolescence may be adaptive, serving to sample the environment for information relevant to future decisions.

Like the EVC model, the Lifespan Wisdom Model challenges the notion of a universal imbalance between the development of brain systems underpinning motivation and cognitive control, and delineates adaptive and maladaptive risk-taking during adolescence (Romer, Reyna, & Satterthwaite, 2017). This model argues that most risk-taking during adolescence is adaptive, allowing the individual to gain experience through exploration of the environment, particularly during ambiguous risk contexts (Romer, Reyna, & Satterthwaite, 2017). In one study that used a patch foraging paradigm (in which participants can choose between exploiting a novel resource that has a fresh distribution of rewards, or a known resource in that gradually yields rewards), adolescents, relative to adults, demonstrated greater exploration when presented with a novel environment. This behaviour led to adolescents becoming more optimal foragers, in that they employed a more optimal learning strategy than adults (Lloyd et al., 2020). Findings such as this suggest that greater exploration of novel environments during adolescence may be beneficial and can lead to positive outcomes. Indeed, the Lifespan Wisdom Model is consistent with these findings and findings from other studies showing that individual differences in sensation seeking are related to adaptive risk behaviours such as engaging in scholastic competitions and sporting events (Hansen & Breivik, 2001).

When risk-taking behaviours are perceived to have high social value, engagement in these behaviours may be more likely in order to facilitate one's social goals (Blakemore & Mills, 2014; Crone & Dahl, 2012). Individuals' goals vary, however, and much like the EVC model, value-based choice explanations of adolescent decision-making have also been proposed to account for individual differences in what adolescents themselves value (Pfeifer & Berkman, 2018). This value-based choice account proposes that a single system integrates diverse value-laden inputs (which could include social motives) to inform choices (Pfeifer & Berkman, 2018). Given that, during adolescence, developing a positive personal and social identity is a key goal, it is likely that self-related and social cues are given significant value in the decision-making process (Pfeifer & Berkman,

2018). This perspective assumes that peer norms and peer group values will be a significant driver in guiding decisions made by adolescents. One way we can see the effects of peer group norms on adolescent decision-making is through studies that have looked at the effects of peer influence.

1.4.3. Peer influence on risk taking

During adolescence, individuals undergo a period of substantial social-reorientation where they begin to spend more time with their peers (Lam et al., 2014; Nelson et al., 2016) and establish their position within a widening, and often unstable, social network of friends (Hartl et al., 2015). Adaptively navigating one's social environment during adolescence in order to attain social status and good quality of friendships has been shown to have particular benefits for one's future social, psychological and physical health (Almquist, 2009; van Harmelen et al., 2017). One mechanism via which individuals may attain a beneficial position within a social group is through normative social influence, which is conforming to others in order to be accepted or liked. There is evidence that feeling non-prototypical, or dissimilar to one's peers, creates adherence to group norms (Noel et al., 1995), particularly in individuals who have a significant motivation for group acceptance (Steinel et al., 2010). Therefore, it is possible that, for adolescents, this feeling may be particularly marked and thus peer influence becomes heightened in order to motivate group belonging and peer acceptance.

A study investigated the role of social influence on risk perception in a large sample of individuals ranging from 8-59 years. Participants were provided with a set of risky, everyday scenarios and were asked to rate the riskiness of each scenario before being shown an average rating purportedly from groups of teenagers or adults, before being and asked to rate again. Whilst all age groups were influenced by the ratings of other people, younger adolescents (12-14 years) (see **Figure 1.5**) were the only age group who were more influenced by the ratings of teenagers than the ratings of adults (Knoll et al., 2015 these findings were replicated in a second large study (Knoll et al., 2017).

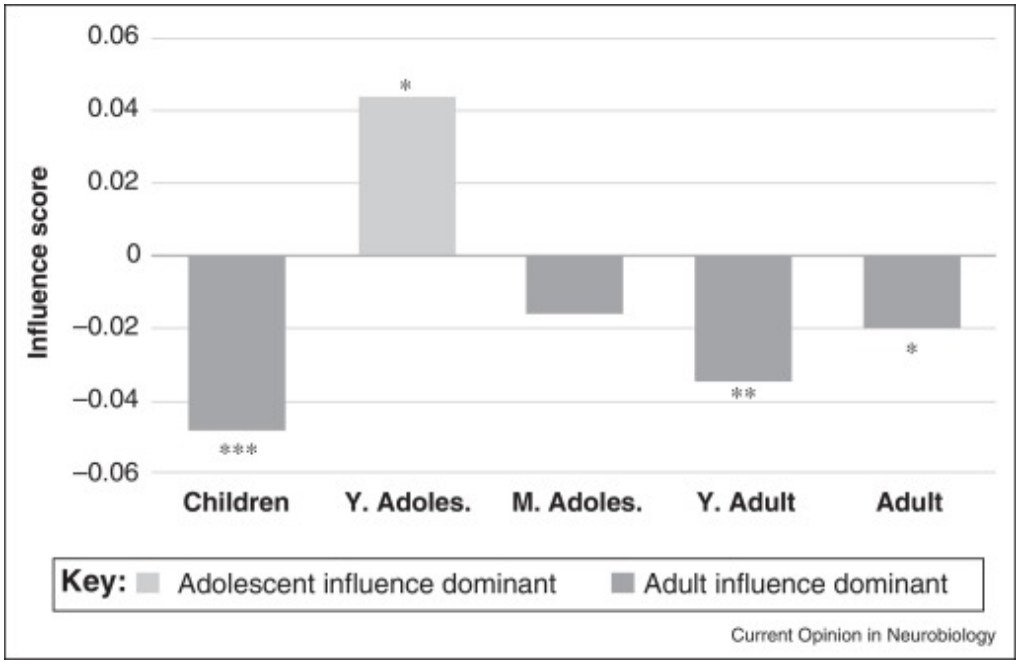

Figure 1.5. Effect of social influence on risk ratings for different age groups. Bars appearing above the zero line represent age groups that were more influenced by the ratings of adolescents than by the ratings of adults. Bars appearing below the zero line show the opposite, with those age groups being more influenced by the ratings of adults than by the ratings of adolescents. Light bars represent a dominant influence from adolescents and dark bars a dominant influence from adults. Data from Knoll et al., 2015, figure reprinted from Foulkes & Blakemore, 2016.

As described above, data from car accidents have shown that the risk of having a car accident is greater for young drivers when they have a passenger in the car (Chen et al., 2000), and lab experiments have also shown that the presence of one's peers has the ability to selectively increase risk-taking behaviour in adolescents versus adults (Gardner & Steinberg, 2005; Chein et al., 2011). One task frequently used to assess risk-taking tendencies in a laboratory setting is the Balloon Analogue Risk Task (BART). The BART requires participants to inflate a virtual balloon, with each pump translating to a monetary reward. However, with each pump the chance that the balloon will explode (and all money is lost) increases. The propensity to take risks, measured by the number of pumps made, is correlated with a number of real-world risk behaviours such as smoking and substance use (Lejuez et al., 2003, 2007). In a social adaptation of the BART, information about peer choices impacted the number of risks older adolescents (18-25 years) took on the BART. The number of pumps participants made was influenced by the

perceived choices of others, such that when other participants were perceived to be making high and low risky choices, individuals took more or fewer risks, respectively (Tomova & Pessoa, 2018). These findings corroborate other evidence suggesting that, when observing peers making safe, risk averse and prosocial decisions, adolescents are likely to follow suit (Braams et al., 2019; Ciranka & van den Bos, 2019; Foulkes et al., 2018; van Hoorn et al., 2016).

Another variation of the BART task, the Social Analogue Risk Task (SART), has been used to study risk-taking tendencies in response to social feedback (McCormick et al., 2018). Participants (aged 8-17 years of age) knock on a door in order to gain points; with each knock, the resident's facial expression becomes angrier. If their facial expression becomes too angry, the door slams shut and participants lose their points. Behavioural findings revealed that older adolescents took more optimal risks, by cashing in before experiencing a door slam, thus gaining more points. During this task, older adolescents also showed reduced tracking of negative feedback in regions of the brain implicated in social processing, including the TPJ and pSTS. These results imply that adolescents are capable of suppressing negative social cues when these cues interfere with the goals of the task (in this case, to win points; McCormick et al., 2018).

One fMRI study investigated the effects of social exclusion on subsequent risky decision making in adolescence. Individuals were asked to play a risky driving task (the stop light task), after being socially excluded. The findings revealed that adolescents with greater self-reported susceptibility to peer influence took significantly more risks after being socially excluded, compared to individuals with high resistance to peer influence. Further, adolescents with low resistance to peer influence, showed greater activity in social brain regions, such as the right temporoparietal junction, during risky decisions (Peake et al., 2013). These findings suggest that individual variation in resistance to peer influence moderates risk-taking within a social context.

1.4.4. Prosocial peer influence

While adolescents are particularly susceptible to peer influence in risky contexts, experimental research has begun to explore the positive influence peers can have on prosocial decisions (Telzer, van Hoorn, et al., 2018). Adolescents are more likely to volunteer in the community if they observe peers doing so (Choukas-Bradley et al., 2015), and adolescents are more likely than adults to be influenced by others toward (hypothetical) prosocial behaviours (Foulkes et al., 2018). As with risk-taking behaviour, high-status peers (Choukas-Bradley, et al., 2015) and very close friends tend to be more influential (Padilla-Walker et al., 2015). In incentivized charitable donation tasks and public goods games, adolescents who observed peers being generous were more likely to be generous themselves (Padilla-Walker, Fraser & Bean, 2015) and exhibited higher activity in social brain regions, such as the dmPFC, TPJ, precuneus, and superior temporal sulcus, during prosocial decision making (Hoorn et al., 2016). In a study of older adolescents (mean age of 20 years), participants recruited brain regions involved in self-control and mentalising when making decisions to donate money to family members. Greater functional coupling between self-control and mentalizing regions and the ventral striatum was observed in participants who reported stronger familial obligation (Telzer et al., 2013). This suggests that prosocial behaviour may be reliant on the development of brain regions involved in mentalizing and self-control, in addition to reward-related regions.

Recent studies have investigated prosocial risk-taking, defined as making risky decisions with the intention of helping others—for example, standing up to someone who is bullying a friend (Do et al., 2017; Duell & Steinberg, 2019). Findings show that, unlike potentially harmful risk-taking behaviours such as reckless driving and illicit drug taking, prosocial risk-taking is not associated with impulsivity or risk-taking in experimental tasks and is instead associated with a number of positive outcomes including greater school engagement (Duell & Steinberg, 2019). Whilst these findings suggest that prosocial risk-taking may be beneficial for adolescents, future research is needed to establish if there exists a causal relationship between prosocial risk-taking and positive social outcomes among adolescents.

1.4.5. Social reward processing

It has been proposed that one reason we observe heightened peer influence effects in adolescence is that the reward value associated with social interaction and gaining social approval is amplified during this period of development (Foulkes & Blakemore, 2016). However, research investigating age differences in social reward processing has revealed mixed results (Foulkes & Blakemore, 2016). For example, in one study of participants aged 8-25 years, no association was found between age and likability ratings given to peers who presented participants with positive social feedback (Demurie et al., 2012). In contrast, in another study, adolescents (13-17 years) demonstrated a reduced ability to suppress approach behaviours when presented with appetitive cues (happy faces) versus neutral cues (calm faces) on a go/no-go task, compared with children (6-12 years) and adults (18-29 years) (Somerville et al., 2010). Similarly, performance on an N-back working memory task was reduced for adolescents (12-14 years old) compared to adults (18-29 years old) when distracted by smiling faces, but not for angry or neutral faces (Cromheeke & Mueller, 2016). This suggests that adolescence may represent a period of hypersensitivity to social cues. However, incentive delay tasks exploring the rewarding value of socially rewarding stimuli versus non-social rewarding stimuli have found no difference in adolescents' preference for social (faces) versus non-social (money) stimuli (Ewing et al., 2013) or for images of people versus cartoons (Silva et al., 2015). This finding was mirrored in a social motivation study in which participants were required to exert varying levels of effort (via key presses) in order to watch either a social or non-social movie. On this task, young adolescents (aged 9-12) did not show a difference in the amount of effort they exerted to reveal the social or non-social stimuli (Dubey et al., 2017).

Evidence presented in **1.4.1**. also demonstrates that when risk-taking in the presence of peers, adolescents, relative to adults, exhibit heightened activity in reward-related brain regions, including the ventral striatum and the orbitofrontal cortex (Chein et al., 2011). In addition, during the go/no-go task (Somerville et al., 2011) mentioned in the previous paragraph, adolescent participants showed higher activation in the ventral striatum when presented with happy faces versus calm faces. That said, subsequent work has also found that activity in the orbitofrontal cortex and MPFC is heightened in

adolescents (13-17), relative to children (6-12) and adults (18+), when presented with fearful, versus neutral, faces (Dreyfuss et al., 2014). Further, in another longitudinal neuroimaging study, activity in the ventral striatum and VMPFC increased between aged 10 and 13, when participants viewed both happy and sad faces (Pfeifer et al., 2011). Together, these findings suggest that adolescence may be a period of sensitivity to both positive and negative social stimuli, not just socially rewarding stimuli (Foulkes & Blakemore, 2016).

1.4.6. Peer-led interventions

The evidence that peers have the capacity to influence decisions towards positive and negative outcomes has the potential to inform interventions aimed at improving health and well-being during adolescence. However, interventions and campaigns aimed at influencing adolescent behaviour are often unsuccessful (Yeager et al., 2018). Many of these interventions are based on the theory that increasing adolescents' knowledge and awareness of certain health risks will result in positive changes to behaviour. However, as Yaeger and colleagues argue, these traditional interventions, which are predominantly adult-led, are often not particularly successful. One meta-analysis of bullying interventions found that prevention efforts were often successful below the 7th grade (under 13 years), but not beyond 8th grade (over 13 years) (Yeager et al., 2015). Interventions aimed at adolescents are most likely to result in behaviour change when they afford adolescents respect and autonomy, and account for what they value (Yeager, et al., 2018).

Indeed, studies that target social norms through peer-led interventions have shown positive outcomes across a number of domains such as bullying (Paluck et al., 2016) and smoking (Campbell et al., 2008). In one study, 56 middle schools in the USA were randomly allocated to either a peer-led anti-bullying programme or practise as usual. In the peer-led intervention schools, social network analysis was employed to identify students with a large number of positive social connections among their peers (socially referent students). The schools in which the anti-bulling programmes were led by the students saw a 25% reduction in conflict over the space of a year, compared with the

control schools (See **Figure 1.6;** Paluck et al., 2016). The effect was strongest in schools with a higher proportion of socially referent (well-liked) students leading the campaigns.

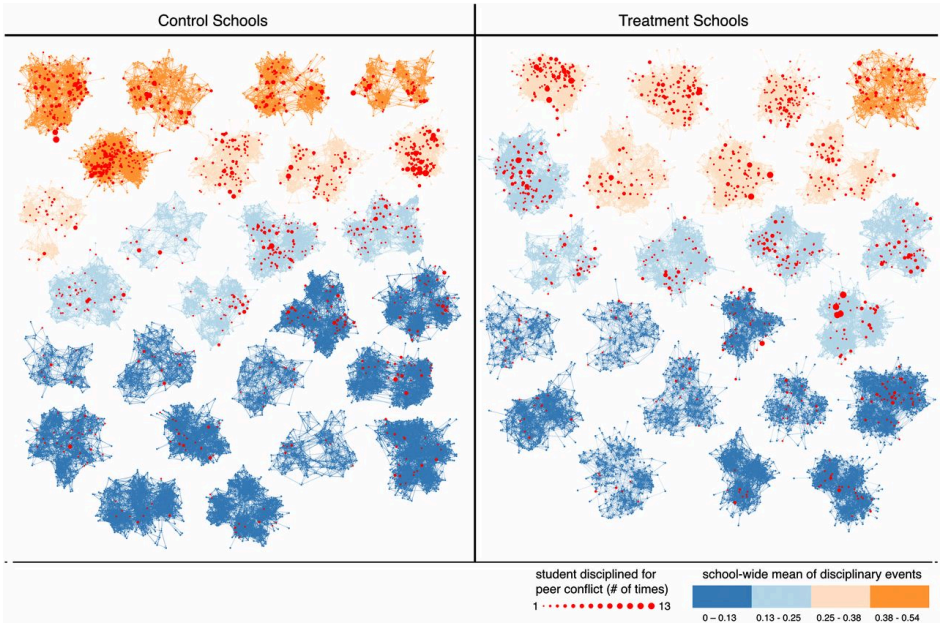

Figure 1.6. Effects of a school-based peer-led anti-victimisation intervention. The distribution of disciplinary events in control (no change to normal school practice) and treatment schools (who received the peer-led intervention). The average number of times each student was disciplined for peer conflict is shown from dark blue (little conflict) to dark orange (high conflict). There is a higher concentration of dark orange events (high conflict) in the control schools. Red nodes are representative of students disciplined for conflict and are scaled to the number of times they were disciplined across the school year. Reprinted from Paluck et al., 2016.

1.5. Social rejection and evaluation

Adolescence might be a period of particular susceptibility to peer influence due to sensitivity to the negative effects of social rejection. Several experimental studies have shown that healthy adolescents, in comparison to healthy adults, are particularly sensitive to the negative consequences of social rejection. For example, following experimentally-induced social exclusion elicited by a paradigm called Cyberball – in which participants are either included or excluded by other alleged players in a computerised ball tossing game – young adolescents (age range 11-13) and mid-adolescents (age range 14-15), reported more of a decrease in mood compared with

adults (22-47), and an increase in anxiety for young adolescents relative to adults, following the exclusion condition (Sebastian et al., 2010).

Cyberball has been adapted for fMRI and previous results have shown that adults demonstrate increased dorsal anterior cingulate cortex (ACC) and anterior insula activity, related to social pain processing, and also ventral lateral PFC activity, which is thought to downregulate negative affect (Eisenberger, 2003). In the first fMRI study using Cyberball among adolescents, 13-year-olds showed increased insula activity when excluded, relative to being included (Masten et al., 2009). Whilst there was no effect of dorsal ACC or VLPFC activity between inclusion and exclusion trials, ventral ACC activity at age 13, during social exclusion, predicted depressive symptoms one year later (Masten et al., 2011). In another study, which compared responses to Cyberball between female adolescents (14-17 years) with adults (24-39 years), all participants showed increased ventral ACC, VMFC and OFC activity during exclusion versus inclusion. However, VLPFC activity was significantly lower among adolescents, relative to adults (Sebastian et al., 2010).

Other studies that elicited social rejection or negative social evaluation in different ways to Cyberball, have shown similar findings. For example, one study, which utilised a social judgment task in which participants have to predict which unfamiliar peers will like them, found increased activity among 8- to 25-year-olds, in ventral ACC and VLPFC when they received negative social feedback (Gunther Moor et al., 2010). In a study including 17-18 year olds, time spent with friends during high school predicted activity in the anterior insula during the exclusion condition in Cyberball two years later: increased time spent with friends was related to reduced insula activation during exclusion (Masten et al., 2012).

More recent work, however, has challenged the idea that the dorsal ACC and anterior insula are uniquely sensitive to social rejection and in turn exclusively indicate experiences of social pain. In one study, using a novel social feedback paradigm, activation in the dorsal ACC and anterior insula was shown to track information relevant to both inclusion and exclusion among 17-21-year olds (Dalgleish et al., 2017). In this

study, individuals engaged in a multi-round, multi-player social-feedback task (where participants made a video of themselves that would be rated, and in turn they would rate the videos made by the other participants). Participants were led to believe they were playing with others at the same time, in a hyper-scanning setting – they were in fact playing against confederates and only the participant was scanned. Following each round, participants received feedback and were either provided with positive, neutral or negative feedback. The findings here, that dorsal ACC and anterior insula are activated in response to signals of inclusion and exclusion, are counter to some of the traditional results elicited from Cyberball studies showing that inclusion does not activate the dorsal ACC or anterior insula. However, the inclusion condition in Cyberball could be interpreted as merely the absence of rejection. Whereas in the social feedback task used by Dalgleish et al (2017) inclusion was more 'active' (where individuals were given positive feedback), thus better representing an inclusion experience. In another study conducted with adolescents (aged 15-19), the dorsal ACC and the anterior insula demonstrated greater activity when participants received feedback (both positive and negative) from others about one's self versus about other people (Perini et al., 2018). This suggests that these regions are sensitive to self-relevant information, rather than exclusively involved in the processing signals indicative of social rejection.

In addition to reporting greater decreases in mood relative to adults, following social rejection adolescents also demonstrate heightened neural and neuro-endocrinological responses to social evaluation. During laboratory studies, in which participants are placed under social stress, adolescents, relative to children and adults, release greater levels of cortisol (Gunnar et al., 2009; Stroud et al., 2009). This physiological response to social evaluation is mirrored by findings that day-to-day adolescents feel greater levels of self-conscious emotions (Westenberg et al., 2004). In a study that measured responses to participants being told that someone is observing them, adolescents, relative to children and adults, reported greater embarrassment and showed higher physiological arousal as measured by galvanic skin response. In addition, compared with adults, adolescents showed increased activity in the mPFC and increased connectivity between the striatum and the mPFC, regions involved in promoting motivated social behaviour (Somerville, 2013).

1.5.1. Mentalising, social rejection and the peer environment

Adolescents who perform less well on mentalising tasks that involve inferring mental states from vignettes and film clips depicting social situations are more likely to report higher levels of loneliness and peer rejection, independent of age and socioeconomic status, compared with adolescents who show better mentalising performance (Devine & Hughes, 2013). This suggests that individual differences in mentalising are correlated with social experiences in adolescence, though longitudinal studies are needed to confirm the direction of causality.

Neuroimaging studies have reported increased activity in the mPFC, precuneus and TPJ (areas within the mentalising network) in response to peer rejection (Beyer et al., 2014; Meyer et al., 2013; Powers et al., 2013; Puetz et al., 2014). Social network studies, in which individuals' peer relationships are mapped, have begun to relate individuals' social network positions to their brain function during tasks involving social information. In one such study involving adolescent boys (16-17 years old), participants with higher brokerage – the ability to connect with otherwise disconnected others – exhibited greater activity in mentalising regions when presented with divergent feedback from peers on a task that required participants to provide recommendations for computer games (O'Donnell et al., 2017). These findings suggest the mentalising network is more strongly recruited in situations where individuals are required to integrate contrasting information. In addition, there is evidence that following social exclusion, activity in brain systems involved in processing social exclusion and mentalising predict increased risk-taking in the presence of a peer one week later (Falk et al., 2014). The authors suggested that adolescents who show this heightened response in the face of social rejection may be more likely to change their behaviour in the presence of peers in order to avoid further exclusion and to promote affiliation with peers.

Studies have also shown increased functional connectivity between social brain regions involved in mentalising during experimentally-induced social exclusion, relative to social inclusion, in adolescents (Schmälzle et al., 2017). Stronger connectivity within the mentalising network during exclusion was found among participants with less dense real world social networks (Schmälzle et al., 2017). This suggests that adolescents may over-

recruit mentalising resources to a greater degree following social exclusion, or stressful social situations, and that this is moderated by individuals' social networks. Mentalising may therefore be important in successfully adapting to stressful social interactions. In turn, there is evidence of a reciprocal relationship between poor mentalising abilities and mood disorders, such that impairments in mentalising may be both a cause and an effect of internalising disorders (Fischer-Kern & Tmej, 2019; Li et al., 2015; Luyten et al., 2020; Nolte et al., 2011). In one study of adolescents with depression, reduced mentalising was associated with the severity of depression (Belvederi Murri et al., 2016). The stress-reward-mentalising model accounts for these findings by suggesting that child and adolescent depression emerges from the interaction between stress-regulatory, reward and mentalising systems (Luyten & Fonagy, 2018).

1.5.2. Is adolescence a sensitive period for the negative effects of social rejection?

Sensitive periods can be thought of as specific developmental stages whereby experiences shape a particular phenotype to a degree of greater magnitude than during other developmental stages (Fawcett & Frankenhuis, 2015). Sensitive periods in humans exist for a number of processes including visual and auditory perception (Takesian & Hensch, 2013), stress responses (Lupien et al., 2009) and certain features of cultural learning (Cheung et al., 2011). Development and evolution can be thought of as nested processes, whereby development has the ability to construct phenotypes, resulting in certain developmental mechanisms becoming prominent in future generations (Frankenhuis et al., 2013). Therefore, natural selection may favour periods of developmental plasticity, whereby the individual can flexibly adjust to environmental cues, rather than exclusively selecting fixed or stable traits (Frankenhuis et al., 2013; West-Eberhard, 2005). When environmental conditions are stable it is therefore expected that plasticity will decline, gradually, as the environment is reliably sampled. The implications of this are that we should find the greatest developmental plasticity when the environmental conditions are most variable or unpredictable. This is certainly true during childhood, but periods of significant transition, such as adolescence, also exhibit marked environmental uncertainly (Fawcett & Frankenheuis, 2015).

Adolescence has been proposed to be a sensitive period for a number of processes, including memory, drug use and the effects of stress on mental health (Fuhrmann et al., 2015). In particular, the effects of social stress during adolescence, may disproportionally impact mental health trajectories of young people, rendering it a sensitive period (Andersen & Teicher, 2008). For example, social stress attributed to migration and bullying during adolescence has been shown to impact mental and physical health later in life (Sirin et al., 2013). As described in the previous section, adolescents demonstrate hypersensitivity to the negative effects of experimentally-induced social rejection and this is observed both in self-report measures and in underlying neural circuitry. In addition, adolescents are also hypersensitive to social evaluative concerns, relative to children and adults **(see 1.5)**. Moreover, the work reviewed in **1.5.1** demonstrates that the social networks to which young people belong impacts the way they, and their brains, respond to social rejection. These findings suggest that adolescence may be a sensitive period for the negative effects of social rejection, when the long-term effects of being excluded are greater during this period of development.

Given the limited ability to manipulate environmental conditions in humans, we often have to infer the existence of sensitive periods from longitudinal studies. These studies, which track the same individuals over time, have established a link between peer victimisation, or being bullied, during childhood and adolescence, and poor mental health outcomes. The effects of peer victimisation during childhood and adolescence are persistent and have been associated with a number of poorer life outcomes, relative to individuals who have not experienced victimisation. For example, in one large longitudinal study (the Avon Longitudinal Study; ALSPAC), adolescents who reported being frequently victimised by peers at age 13 had more than a twofold increase in their odds of developing depression at age 18 (Bowes et al., 2015). Similar findings have also been observed for anxiety, with chronically victimised adolescents (by the age of 13) at substantially higher risk of developing an anxiety disorder by the age of 18, compared to non-victimised adolescents (Stapinski et al., 2014). In one large birth cohort study (the UK's National Child Development Study), rates of bullying during childhood (age 7) and in early adolescence (age 11) were assessed and found to be related to psychological

distress at age 50, with higher rates of bullying being associated with greater incidence of depression and anxiety (Takizawa et al., 2014). Numerous other birth cohort studies have found similar effects. Among other large cohort studies similar results have been found linking child and adolescent peer victimisation with increased suicide attempts (Brunstein Klomek et al., 2009; Wolke et al., 2013).

The long-term effects of peer victimisation are not only associated with poorer mental health outcomes but also to adverse outcomes among a number of other domains include physical health and crime and socio-economics (Arseneault, 2018). For example, increased rates of obesity and inflammation (Baldwin et al., 2016; Copeland et al., 2014; Takizawa et al., 2014), unemployment (Takizawa et al., 2014) and the inability to maintain friendships (Wolke et al., 2013) have all been related to victimisation experiences in childhood and adolescence. There is also evidence from epidemiological studies that an individual's social status amongst their peers during adolescence predicts future mental and physical health outcomes in adulthood. For example, data from the Stockholm Birth Cohort Study, which comprised 15,117 individuals, has shown that lower peer status at ages 12-13 years, was associated with increased risk of mental and behavioural disorders (e.g. alcohol abuse and suicide) as well life-style related diseases (e.g. ischaemic heart disease and diabetes) in adulthood. Importantly, these findings were not explained by childhood social class (Almquist, 2009). Given that these findings are correlational, they should not be interpreted as establishing a direct causal link between childhood social status and adverse (mental) health outcomes. However, avoiding social rejection and reducing social risk (social risk-taking being defined as any decision or action that might lead to peer exclusion, a reduction in one's place in the social hierarchy, embarrassment or loss of face) likely represent an important social goal for adolescents (Blakemore, 2018).

1.6. Avoiding social risk in adolescence

A social risk can be defined as any action that might lead to a loss of face, a reduction in one's position in the social hierarchy or social exclusion (Blakemore, 2018). Therefore, what constitutes a social risk behaviour depends on the context and situation. An

example of a social risk behaviour could be expressing an opinion that one's peers do not hold or refusing to engage in a health or legal risk, such as taking illicit substances, when one's friends are. During adolescence, individuals are exposed to widening social networks, which are often unstable and present many social risks (Blakemore, 2018; Burnett Heyes et al., 2015). It has been suggested that adolescents may be more likely to give greater weight to the social risks, involved in complex social decisions, in comparison to the consequences of any health or legal risks involved, such as causing harm to oneself and being caught (Blakemore & Mills, 2014; see **Figure 1.7**).

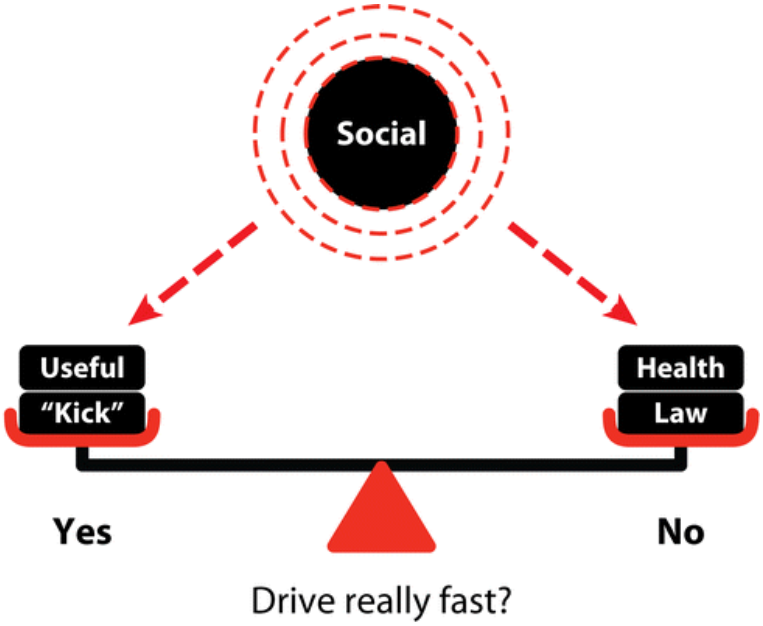

Figure 1.7. Social influence on risk behaviour. Illustration of some of the factors that influence certain risky decisions. In a scenario in which the individual is making a choice whether or not to drive very fast, multiple factors might weigh in, such as the potential outcome of injury (health), being arrested (law), arriving somewhere in less time (useful), and getting a subjective feeling of pleasure from the experience ("kick"). Above this "seesaw" is another potential factor that could weigh on either side of the decision process, which is made up of social factors (e.g., family, teachers, peers). The potential of peer acceptance/rejection could weigh on either side of the seesaw depending on the peers, and the weight of the factor (indicated by dashed lines) could vary on the basis of the individual and the developmental stage. Reprinted from Blakemore & Mills (2014).

From a social risk perspective, any view that is in direct conflict with behaviours or actions that are valued by one's peer group could increase that individual's social risk.

Therefore, allowing one's behaviour to be influenced by their peers might serve to reduce the discrepancies between the individual and their peer group, and thus reduce their social risk. The extent to which individuals are socially risk averse or resistant to peer influence will vary. A number of factors may contribute to this individual variation such as prior experience of, and sensitivity to, social exclusion and social disadvantage (e.g. belonging to a minority group).

Individuals with a history of chronic victimisation may be more sensitive to indicators that predict social risk. According to the social augmentation hypothesis, peer exclusion may lead adolescents to become more sensitive to social rewards, and in turn more susceptible to peer influence (Dishion et al., 2008; Dishion & Tipsord, 2011). Further, there is evidence that individual variation in neural sensitivity to social exclusion predicts susceptibility to peer influence. As discussed in **1.5.1**, adolescents aged 16-17, who showed higher activity in the ACC and anterior insula following social exclusion (elicited by the Cyberball task), demonstrated more risky behaviour in a subsequent driving simulator task when a peer was present (Falk et al., 2014). This suggests that adolescents who are more sensitive to the experience of being excluded are more susceptible to peer influence. This may function to reduce their social risk by engaging in behaviours perceived to carry social value within their peer group.

There is evidence that inhibitory control, a cognitive process implicated in resistance to peer influence (Peake et al., 2013) shows a different developmental trajectory in adolescents who have grown up in poverty, compared to those who have not (Deater-Deckard et al., 2019). Advanced pubertal development was associated with decreased inhibitory control among adolescents from low-income families, but not those from higher income families (Deater-Deckard et al., 2019). This suggests that systemic social factors may indirectly influence adolescents' tendency to resist peer influence, through affecting the development of inhibitory control – although it remains difficult to infer causality. Moreover, belonging to a minority group, such as identifying as Lesbian, Gay, Bisexual, Transgender, Queer (LGBTQ+), is also a likely risk factor for increased social risk. Members of minority groups are known to be at a higher risk of minority stress, in which stigmatized minority groups experience chronically high levels of stress. Findings

from one large UK Cohort study have found that 14-year olds who identify as a sexual minority are more likely to endorse low mood relative to their heterosexual counterparts (Amos et al., 2020). Research has also shown that structural stigma interacts with rejection sensitivity to predict health risk behaviours (e.g. tobacco and alcohol use) among young sexual minority men (Pachankis et al., 2014).

1.6.1. Social risk and adolescent depression

75% of all mental health problems begin before the age of 24 and incidence of depression in children remains low and rises sharply during adolescence (Kessler et al., 2007). Rates of depression are also more common in girls relative to boys and this difference continues into adulthood (Bone et al., 2020; McGuinness et al., 2012). During adolescence, young people may be at an increased risk for depression, in part, because of developmental changes in social cognition that are observed during this period of life (Allen & Badcock, 2003; Petersen et al., 1993; see **1.3**). These changes have important implications for adolescent development: adolescents are especially sensitive to the social environment with which they inhabit. Indeed, a central goal of developmental psychopathology is the isolation of environmental experiences – such as social rejection - which may confer risk for later mental health problems (Fearon, P., 2019).

According to the social risk hypothesis of depression, some depressed states may emerge as an adaptive, temporary mechanism to minimise the risks associated with social interactions when individuals perceive their value to others to be low and their burden on others to be high (Allen & Badcock, 2003). Allen and Badcock define social risks as 'risks to one's social circumstances, wellbeing and reputation' (Allen & Badcock, 2003). According to their social risk hypothesis, a loss of significant social relationships and experiencing situations that might lead to reduced social status represent signals that predict social exclusion or ostracism from valuable social contexts (Allen & Badcock, 2006). The hypothesis follows that these signals, such as social rejection or loss of social status, orient the individual towards socially risk-averse behaviour, which may lead to a state of depressed mood. It is likely therefore, that individuals who are especially sensitive to environmental cues that signal that their social burden is significantly

greater than their social value, would be more likely to experience depressed mood. Indeed, there is evidence that individual variation in rejection sensitivity is related to depressive symptomatology, with evidence of a reciprocal relationship between these two constructs (Platt et al., 2013).

Relative to adults and children, adolescents are especially sensitive to social evaluation and social rejection (see **1.5.2**), which may in part explain why adolescents are at an increased risk of developing mental health problems such as depression. Arguments that this social sensitivity is thought to have evolved as a way to increase social belonging are also supported by a number of theorists (Baumeister & Leary, 1995; Tooby & Cosmides, 1996). Adolescents may be particularly motivated to avoid social rejection, and establish themselves in a social group, as they transition into more independent roles. This sensitivity to the social environment may motivate adolescents towards socially risk-averse behaviours. For example, heightened peer influence effects during adolescence may facilitate this by increasing conformity to valued peer norms (Blakemore & Mills, 2014; Blakemore, 2018; see **1.5.3)**. Social exclusion presents a tangible threat to adolescent mental health and avoiding social risks, which could lead to social rejection, might be a sensible strategy for adolescents.

1.6.2. Empirical contribution within this thesis

In the following four chapters of this thesis, I report the results of a series of studies that investigated social development and social risk in adolescence. In **Chapter 2** I developed a novel self-report measure of concern for health and social risk behaviours in order to assess the age-related differences in concern for health and social risk. I further explored the extent to which concern for social risk is related to rejection sensitivity and depressive symptomatology among adolescents and adults. In **Chapter 3** I explored the degree to which adolescents' engagement in health risks and illegal behaviours was related to the perceived social benefit that engaging in these behaviours would bring, i.e. whether or not adolescents perceived engaging in these behaviours would lead to an increase in their likeability among others. I also investigated how this relationship is impacted by adolescents' experience of victimisation, by testing the social

augmentation hypothesis (described in **1.5.3**). I further explored the degree to which the perceived social benefit of engaging in health and legal risk behaviours moderated a commonly reported relationship between sensation seeking and risk taking. In **Chapter 4**, I used network analysis to explore the link between sexual minority status, depression, interpersonal-relationships, and health-risk behaviours among a large sample of adolescents. Lastly, in **Chapter 5** I designed an experiment to measure the extent to which adolescents versus adults show a preference for social versus non-social stimuli within an academic diligence task.

Chapter 2: Amplified concern for social risk in adolescence

The study presented in this chapter has been published as: **Andrews, J. L.,** Foulkes, L. E., Bone, J. K., & Blakemore, S. J. (2020). Amplified concern for social risk in adolescence: Development and validation of a new measure. ***Brain Sciences***, *10*(6), 397.

2.1. Introduction

Adolescence is a sensitive period of development, characterised by significant changes in both the biological and social environment. In particular, adolescence is a time of social reorientation, greater susceptibility to peer influence and heightened sensitivity to social rejection (see **1.4.3** and **1.5**). Adolescents are also stereotyped as risk takers, which is likely due to evidence that risk behaviours, such as binge drinking, risky driving and smoking, are heightened during this period of life (DuRant et al., 1999; van Nieuwenhuijzen et al., 2009).

This commonly held perspective, that adolescence is a period of heightened risk taking, conceals a more nuanced reality. Social context significantly affects adolescents' engagement in health risk behaviours. For example, in **1.4.3** I discussed how adolescents are more likely to engage in health risk behaviours, such as smoking and binge drinking in the presence of peers, compared to when alone (Reniers et al., 2017). I also discuss how evidence from car accidents shows that, for young drivers, the risk of engaging in a fatal car accident increases with the number of passengers in the car (Chen et al., 2000), which is reflected in the experimental literature (Gardner & Steinberg, 2005). However, not all adolescents take risks, and recent work has led to the suggestion that adolescence is in fact a time of increased sensitivity to risk, characterised by wide variation in risk seeking and risk averse behaviours (van Duijvenvoorde et al., 2015). Therefore, the extent to which individuals are risk seeking or risk averse depends on multiple factors, including the context of the risk behaviour and the type of risk being taken. Sensitivity to the social environment is further reflected in a study that investigated the role of social influence on risk perception in a large sample of individuals ranging from 8-59 years (Knoll et al., 2015, 2017; see **1.4.3**). As previously described, whilst all age groups were influenced by the ratings of other people, younger adolescents (12-14 years) were the only age group who were more influenced by the ratings of teenagers than the ratings of adults (Knoll et al., 2015, 2017).

The importance of the peer environment in influencing adolescent risky decision making is likely tied to the evidence that during adolescence individuals become increasingly sensitive to social evaluation and social rejection (Sebastian et al., 2010; Somerville,

2013; see **1.5.2**) . It has been proposed that, for some adolescents, the decision to take a health or legal risk (such as smoking) is pitted against a second type of risk: the social risk of being excluded or humiliated (Blakemore & Mills, 2014; Blakemore, 2018). This theory proposes that one possible reason that adolescents take health or legal risks is that, in the moment, the social risk is weighted more strongly than potential negative health or legal outcomes (Blakemore & Mills, 2014b). For example, a 14-year-old who is invited to smoke a cigarette by a popular group of friends might weigh the social risk of rejecting the cigarette, and possibly losing face, as greater than the health risks associated with smoking. It is likely that individuals with higher sensitivity to social rejection will be more concerned about the social risk involved in any given decision, possibly leading them to take more social risk averse decisions.

Additionally, high quality friendships and increased social status during adolescence are associated with positive psychological and physical health outcomes (Almquist, 2009; van Harmelen et al., 2017). Therefore, making decisions that increase one's social value through reducing exposure to social risk is an important task for adolescents (see **1.6** for a longer discussion). In addition, there is evidence that feeling dissimilar to one's peer creates adherence to group norms (Noel et al., 1995), particularly in individuals who have a significant motivation for group acceptance (Steinel et al., 2010). It is possible that, for adolescents, this feeling may be particularly marked given the importance that the peer environment has on mental health.

In **1.6.1** I introduced the social risk hypothesis of depressed mood and discuss how social risk may be linked to depressive symptoms. This might be particularly true during adolescence (Platt et al., 2013), when peer relationships become increasingly important to individuals (Brown & Larson, 2009). However, few studies have directly investigated whether adolescence is a period of heightened concern for social risk, and the extent to which concern for social risk predicts depressive symptomatology.

Current questionnaire measures of risk-taking behaviour do not uniformly include social risks as a risk-taking domain, and instead focus on the domains of health (e.g. taking illicit substances), financial (e.g. gambling) or legal (e.g. stealing) risk. One adult risk-

taking questionnaire, the Domain-Specific Risk-Taking Questionnaire (DOSPERT) includes a social risk subscale, but this includes items that are not applicable to adolescent populations. For example, the social risk items in this measure include 'Approaching your boss to ask for a raise' and 'Taking a job that you enjoy over one that is prestigious but less enjoyable' (Blais & Weber, 2006). Another issue with current questionnaire measures of risk taking is the conflation between health and social risk. Many health risks carry with them some degree of social risk, e.g. smoking may carry with it both health and social risk considerations. Further, it is unclear whether concerns about social risk are independent of concerns for other risk domains, such as health risk behaviours, so whether an individual's propensity to take risks is uniform across risk domains.

Given these issues, I developed and validated a measure of concern for health and social risks, which is suitable for both adolescents and adults. In this measure, I conceptualised social risk as any behaviour that marks individuals as being different from their peers – for example, openly endorsing music that friends do not like, or befriending an unpopular peer. I attempted to isolate the social risk items by including social risks that involve little or no obvious health risk. I conceptualised health risks as risks to one's physical wellbeing, such as crossing a street on a red light. I included health risk behaviours that have as little conflation with social risk as possible.

I had four primary hypotheses. I first hypothesised that concern for social risk would be distinct from health risk concerns. In order to establish this, I developed a measure using exploratory and confirmatory factor analysis (EFA; CFA) to assess whether health and social risk domains are distinct constructs. Second, and in order to validate the measure, I hypothesised that higher concern for social risk would be associated with greater sensitivity to rejection and lower mood. I hypothesised that this relationship would be stronger for adolescents compared with adults. Third, I hypothesised that greater concern for each risk domain would be positively related to risk perception and negatively related to engagement in that domain of risk. Finally, I hypothesised that concern for social risk would decrease with age from early adolescence to late adulthood, relative to concern for health risk.

2.2. Method

2.2.1. Participants

Sample 1 (Exploratory Factor Analysis: EFA; Adults). Participants (N=500) were recruited from two sources: the university participant pool (N=177) and Prolific, an online participant recruitment and data collection platform (N=323). Participants (295 females, 204 males, one did not disclose gender) were aged 18-60 years (mean = 32.2, SD = 10.72).

Sample 2 (Confirmatory Factor Analysis: CFA; Adults). Participants (N=415) were recruited via Prolific. Participants (284 females, 129 males, two did not disclose gender) were aged 18-77 years (mean = 36.53, SD = 13.10).

Sample 3 (Confirmatory Factor Analysis: CFA; Adolescents). Participants (N=484) were recruited from schools in the Greater London area, as part of ongoing research projects in our lab. Participants (333 females, 107 males, four did not disclose gender) were aged 11-17 years (mean = 13.54, SD = 1.91).

All participants were from the United Kingdom and all completed the questionnaires online. Ethical approval was obtained from the university ethics board (7199/001; 3453/001). Participants were paid at a rate of approximately £10 per hour for their time.

2.2.2. Questionnaire development: Health and Social Risk Questionnaire (HSRQ)

I developed a questionnaire measure in order to assess the degree to which adolescents and adults are concerned about engaging in health and social risk behaviours. Given that many social risks also incur health risks, items were developed with as little conflation between the two as possible. I developed a list of social risk items, e.g. *"spend time with someone your friends don't like"*, and health risk items, e.g. *"cross a main road when the crossing light is red*".

A panel of five researchers with expertise in adolescent social development reviewed an initial list of items and provided feedback on the content and suitability for individuals

aged 11 and above, with the aim of making sure each item was distinct from the opposing type of risk. Following this, a total list of 16 items was included in the scale validation: eight health and eight social (see **Table 2.1**).

In the version of the questionnaire given to participants, individuals were asked: "*For each statement please rate how worried you would feel doing this behaviour. (If you have never done it, imagine how you would feel).”* Answers were given on a sliding scale from, *“Not worried at all (0)”* to *“Very worried (100)”*. The questionnaire was administered online and the numbers (0-100) were visible along a slider (see **Appendix A1.1** for the final questionnaire).

2.2.3. Measures used for construct validation

All participants completed a number of additional measures in order to assess construct validity of the HSRQ. All participants included in the adult CFA completed each additional measure (N=415). However, due to time constraints imposed by testing sessions, a subset of the participants in the adolescent CFA completed the rejection sensitivity (C-RSQ; N=207) and depressed mood (MFQ; N=281) measures only.

Rejection sensitivity

Adults: Rejection Sensitivity RS-Adult Questionnaire (A-RSQ). The Adult Rejection Sensitivity Questionnaire is a validated measure of sensitivity to actual or perceived rejection (Berenson et al., 2009). Individuals were presented with nine scenarios such as “You approach a close friend to talk after doing or saying something that seriously upset him/her”, and are asked to rate their rejection concern and level of acceptance expectancy. Scores are computed by reversing the level of acceptance expectancy and multiplying this by the level of rejection concern. Scores across the nine items are then averaged to create a total rejection sensitivity score; higher scores indicate higher rejection sensitivity. I predicted that higher scores on the social subscale of the HSRQ would be positively associated with higher scores on the A-RSQ.

Adolescents: Children's Rejection Sensitivity Questionnaire (C-RSQ). Participants completed the Anxious Expectations subscale of the Children's Rejection Sensitivity Questionnaire which is a valid measure of rejection sensitivity in children (Downey et al., 1998). Participants were presented with six scenarios and were asked to report on a scale of 0-6 their expected likelihood of the outcome of the scenario and how nervous they would be given the content of the scenario. Their expected likelihood was multiplied by their nervous expectation for each scenario and then a mean score was derived across all items. Higher scores relate to greater rejection sensitivity. I predicted that higher scores on the social subscale of the HSRQ would be positively associated with higher scores on the C-RSQ.

Depression

Adults: Personal Health Questionnaire Depression Scale (PHQ-8). The PHQ-8 is a validated eight item measure of depression (Kroenke et al., 2009). Participants were asked how often over the past two weeks they have experienced eight different symptoms, such as "how often were you bothered by feeling down, depressed, or hopeless?" Participants were asked to report on a 4-point scale (0 = "Not at all" […] 3 = "Nearly every day"). I predicted that higher scores on the social subscale of the HSRQ would be positively associated with higher scores on the PHQ-8.

Adolescents: Mood and Feelings Questionnaire (MFQ) – Short Version. The MFQ (Messer et al., 1995) is a depression screening tool for individuals aged 6 to 17 years old. It is a validated measure of depression in children and young people (Daviss et al., 2006). Individuals were presented with 13 questions, such as "I felt miserable or unhappy" in the past two weeks. Responses were scored on a 3-point scale (0 = "not true", 1 = "somewhat true", 2 = "true"). I predicted that higher scores on the social subscale of the HSRQ would be positively associated with higher scores on the MFQ.

Social risk-taking

Adults: Domain-Specific Risk Taking (DOSPERT) Scale. Participants completed the health and social risk subscales of the 30 item DOSPERT scale, a validated risk taking

measure for adults (Blais & Weber, 2006). Individuals were asked to report on a 5-point scale their likelihood of engaging in each activity or behaviour such as "speaking your mind about an unpopular issue in a meeting at work" ("1= "Very unlikely" to 5= "Very likely") and their assessment of how risky each situation or behaviour was ("1= "Not at all risky" to 5= "Extremely risky"). I predicted that higher scores on the social subscale of the HSRQ would be negatively associated with the social risk engagement subscale of the DOPSERT and positively associated with the social risk perception subscale of the DOSPERT, with the same being true for the health risk subscales.

Adolescents. Note that adolescents did not complete a social risk-taking measure because the items from the DOSPERT are not appropriate for this age group (e.g. "Approaching your boss to ask for a raise") and there is no existing social risk-taking measure for adolescents.

2.2.4. Statistical analyses

All data was analysed primarily using the laavan (version 0.6-5), psych (version 1.9.12.3) and semTools (version 0.5-2) packages in R (version 3.62; R Core Team, 2013).

Exploratory and confirmatory factor analysis.

I first conducted an exploratory factor analysis (EFA) using oblique (oblimin) rotation on the initial 16 items relating to health and social risks (eight health, eight social) on a sample of 500 adults. We determined the suitability of our sample size and data for EFA based on the Kaiser-Meyer-Olkin (KMO) index (>0.70) and Bartlett's test (<0.05) (Munro, 2005). I determined the number of factors to retain based on examination of the scree plot, retention of factors with eigenvalues of 1 or greater and factors with at least three items. Items with factor loadings of <0.4 were removed. Following factor and item reduction based on the above criteria, I subjected the same data to a confirmatory factor analysis (CFA) to assess the strength of the proposed factor structure.

I then used CFA to assess the strength of this factor structure in two new samples: one adult group (aged 18-77; N=415) and one adolescent group (aged 11-17, N=485). In line with the recommendations outlined by Browne and Cudeck (1992), our primary

measure of model fit was Root Mean Squared Error of Approximation (RMSEA). An RMSEA of around <0.08 indicates reasonable fit (Browne & Cudeck, 1992). I also assessed the model fit with the Standardised Root Mean Square Residual (SRMR; <0.08 reasonable fit), Comparative Fit Index (CFI; >0.9 reasonable fit), and the Tucker-Lewis index (TLI; >0.9 reasonable fit). I computed measures of internal consistency using Cronbach's alpha and McDonalds omega. I further tested the fit of each two-factor CFA using AIC, by comparing a one factor solution (where all items are loaded onto one higher order risk factor) with the two-factor solution (health and social risk). A lower AIC represents a better fit to the data. I assessed test-retest reliability of our Health and Social Risk Questionnaire (HSRQ) by inviting 100 participants from the adult CFA sample to complete the HSRQ again 11-12 days after the first completion.

Validation and test-retest reliability

To assess convergent and divergent validity, I assessed the relationship between the new HSRQ, rejection sensitivity (Berenson et al., 2009; Downey et al., 1998) and depressed mood (Daviss et al., 2006; Kroenke et al., 2009) across both CFA samples using Pearson r correlations. I then compared the strength of the relationship between the adolescent and adult sample with a Z statistic. One additional risk taking questionnaire, the DOSPERT (Blais & Weber, 2006), was used to relate the HSRQ to risk perception and engagement health and social risks, in the adult sample only. In order to establish the test-retest reliability of the HSRQ, I invited 100 participants from the adult CFA sample to complete the questionnaire a second time 11-12 days after the first completion. I used Pearson r correlations to establish the relationship between these individuals' scores at time point 1 and 2.

Age differences in concern for health and social risk

Using all the data collected (N=1399), I computed a mean score of the validated health and social subscale. I determined the relationship between age and the HSRQ using multiple linear regression. I included age, gender and risk domain (health, social) in the model, as well as an age*risk domain interaction, to predict risk concern. I used AIC to

compare between linear, quadratic and cubic models, with a lower AIC representing a better fit.

2.3. Results

2.3.1. Sample 1: Exploratory Factor Analysis (EFA)

Analysis showed that the sample size (N= 500) was suitable for conducting factor analysis (KMO=0.88, Bartlett's test <.001). Factor loadings of each item are presented in **Table 2.1**. Three factors showed eigenvalues above our threshold of 1: 5.92, 2.53, 1.14 respectively. A fourth factor with an eigenvalue of 0.88 was removed. The third factor (eigenvalue 1.14) only consisted of two items and so was removed. This resulted in a two-factor, 11-item solution. The two factors contained items pertaining to health risks (5 items) and social risks (6 items). We tested the strength of this two-factor solution on the same sample with CFA. The two-factor solution fit the data well (RMSEA= 0.07 (0.06-0.08), SRMR= 0.05, CFI=0.95, TLI=0.93). See **Appendix A1.1** for the final questionnaire.

2.3.2. Sample 2: Confirmatory factor analysis (CFA; adult sample)

I conducted a CFA on a new sample of 415 adults. The sample size was deemed appropriate for testing a model comprising of 24 parameters (11 factor loadings, 11 error variances and 2 factor correlations). The model approximates to a 17:1 subject to parameter ratio, above the recommended 10:1 (Bentler & Chou, 1987). The two-factor structure adequately fit the data according to our primary fit index; RMSEA=0.08 (0.07-0.09). Other fit indices were good (SRMR=0.06) or fell just below the suggested cut off CFI=0.87, TLI=0.83. Factor loadings of each item (see **Table 2.2**) were medium to high (0.42-0.76) except for one item (loading of 0.28). Although this item loading was low, I decided to retain it in order to maintain consistency with the factor structure in the adolescent sample and given its good loading in the adult EFA and the adolescent CFA sample. There was a positive correlation between the health and social subscale of the HSRQ ($r(482)=.21$, $p=<.001$). Measures of internal consistency were good (see **Table 2.3**).

Risk item	Factor 1	Factor 2	Factor 3	Factor 4
1. Defend an unpopular opinion that you believe in.	.86			
2. Admit that you listen to a singer or band that none of your friends like.	.65			
3. Argue with a popular friend in front of a group of people.	.83			
4. Wear clothes that are really different to your friends' clothes.	.50			
7. Stand up for someone who is being mocked by your friends.	.76			
8. Spend time with someone your friends don't like.	.56			
9. Eat food that has passed its sell-by date.		.57		
10. Ride a bicycle without wearing a helmet.		.48		
13. Cross a main road when the crossing light is red.		.64		
15. Pick up broken glass with bare hands.		.78		
16. Drink tap water in a foreign country.		.56		
5. Miss a popular friend's party that lots of people are attending.			.93	
6. Choose to stay at home when your friends are going out.			.80	
11. Spend an afternoon in the sun without wearing sun cream.				.35
12. Eat unhealthy (high fat/sugar content) foods.				.66
14. Avoid doing regular exercise.				.78

Table 2.1. Item loadings from EFA

An additional CFA to assess a one-factor structure did not achieve good model fit (RMSEA=0.12 (0.11-0.13), SRMR=0.10, CFI=0.72, TLI=0.70), indicating that concern about risk-taking is not a unitary construct across risk domains, and is instead domain-specific (e.g. specific to health and social risks). The AIC of the two-factor model (42983.13) was lower than the AIC of the one-factor model (43126.50), suggesting the two-factor model provides a better fit.

	Adult (CFA)		Adolescent (CFA)	
Risk Item	Social	Health	Social	Health
1. Defend an unpopular opinion that you believe in.	.60		.77	
2. Admit that you listen to a singer or band that none of your friends like.	.70		.67	
3. Argue with a popular friend in front of a group of people.	.44		.79	
4. Wear clothes that are really different to your friends' clothes.	.63		.59	
7. Stand up for someone who is being mocked by your friends.	.76		.69	
8. Spend time with someone your friends don't like.	.64		.58	
9. Eat food that has passed its sell-by date.		.42		.54
10. Ride a bicycle without wearing a helmet.		.60		.70
13. Cross a main road when the crossing light is red.		.62		.77
15. Pick up broken glass with bare hands.		.53		.73
16. Drink tap water in a foreign country.		.28		.54

Table 2.2. Item loadings from CFA in both the adult and adolescent sample

	Social		Health	
	Cronbach's alpha	McDonalds ω	Cronbach's alpha	McDonalds ω
CFA (Adults)	0.79	0.80	0.62	0.63
CFA (Adolescents)	0.84	0.84	0.79	0.79

Table 2.3. Measures of internal consistency

Test-retest reliability

To measure the test-retest reliability of the HSRQ, 100 adult participants were invited to complete the questionnaire a second time 11-12 days later; 68 participants responded. Pearson correlation between the two time points indicated good test-retest reliability (social risk subscale: $r(66)=.62$, $p<.001$; health subscale: $r(66)=.74$, $p<.001$).

Validation

To assess convergent and divergent validity, participants also completed measures of rejection sensitivity (A-RSQ*)*, depressed mood (PHQ-8) and risk taking (DOSPERT).

Association with rejection sensitivity. The social risk subscale positively correlated with rejection sensitivity ($r(413)=.22$, $p<.001$) such that individuals who scored high on concern for social risk also scored high in rejection sensitivity (see **Figure 2.1**, panel B). The health risk subscale did not significantly correlate with rejection sensitivity ($r(413)=-.00$, $p=.99$).

Association with depressed mood. The social risk subscale positively correlated with depressed mood ($r(413)=.13$, $p<.009$) such that individuals who scored high on concern for social risk also scored high in depressed mood (see **Figure 2.1**, panel D). The health risk subscale did not significantly correlate with depressed mood ($r(413)=-.05$, $p=.27$).

Association with risk taking. The social risk subscale of the HSRQ negatively correlated with the likelihood of engaging in social risks subscale of the DOSPERT ($r(413)=-.32$, $p<.001$) and was positively correlated with the perception of social risks subscale of the DOSPERT ($r(413)=.29$, $p<.001$). In other words, individuals who scored high on concern for social risk on the HSRQ were less likely to engage in social risk behaviours and more likely to rate social risk behaviours as risky. The health risk subscale of the HSRQ was negatively correlated with the likelihood of engaging in health risks subscale of the DOSPERT ($r(413)=-.18$, $p<.001$) and was positively correlated with the perception of health risks subscale of the DOSPERT ($r(413)=-.29$, $p<.001$). Thus, individuals who scored high on concern for health risks were less likely to engage in health risk behaviours and more likely to rate health risk behaviours as risky.

2.3.3. Sample 3: Confirmatory factor analysis (CFA; adolescent sample)

I conducted a CFA on a new sample of 484 adolescents. The sample size was deemed appropriate for testing a model comprising of 24 parameters (11 factor loadings, 11

error variances and 2 factor correlations). The model approximates to a 20:1 subject to parameter ratio, above the recommended 10:1 (Bentler & Chou, 1987). The two-factor structure fit the data well (RMSEA=0.07 (0.06-0.08), SRMR=0.05, CFI=0.95, TLI=0.93). Factor loadings of each item were medium to high 0.54-0.79 (see Table 2). There was a positive correlation between the health and social subscale of the HSRQ (*r*(482)=.21, p=<.001). Measures of internal consistency were good (see **Table 2.3**).

An additional CFA to assess a one-factor structure did not achieve good model fit (RMSEA= 0.18 (0.17-0.19), SRMR= 0.16, CFI=0.60, TLI=0.50), indicating that concern about risk-taking domain-specific, as in the adult sample. The AIC of the two-factor model (49696.51) was lower than the AIC of the one-factor model (50280.89), suggesting the two-factor model provides a better fit.

Validation

To assess convergent and divergent validity, a subset of the adolescent participants completed measures of rejection sensitivity (C-RSQ; N=207) and depressed mood (MFQ; N=281).

Association with rejection sensitivity. The social risk subscale positively correlated with rejection sensitivity (*r*(205)=.52, p<.001) such that individuals who scored high on concern for social risk also scored high in rejection sensitivity (see **Figure 2.1**, panel A). The health risk subscale did not significantly correlate with rejection sensitivity (*r*(205)=-.01, p=0.83).

Association with depressed mood. The social risk subscale positively correlated with depressed mood (*r*(279)=.31, p<.001) such that individuals who scored high on concern for social risk also scored high in depressed mood (see **Figure 2.1**, panel C). The health risk subscale did not significantly correlate with depressed mood (*r*(279)=-.11, p=.06).

Age differences in strength of correlations

I compared the strength of the correlations between concern for social risk, rejection sensitivity and depression between the adolescent CFA and adult CFA sample. The strength of the correlations between concern for social risk and rejection sensitivity and depression was stronger for adolescents than for adults (rejection sensitivity: Z=4.12, p-<.001; depression: Z=2.45, p=.007).

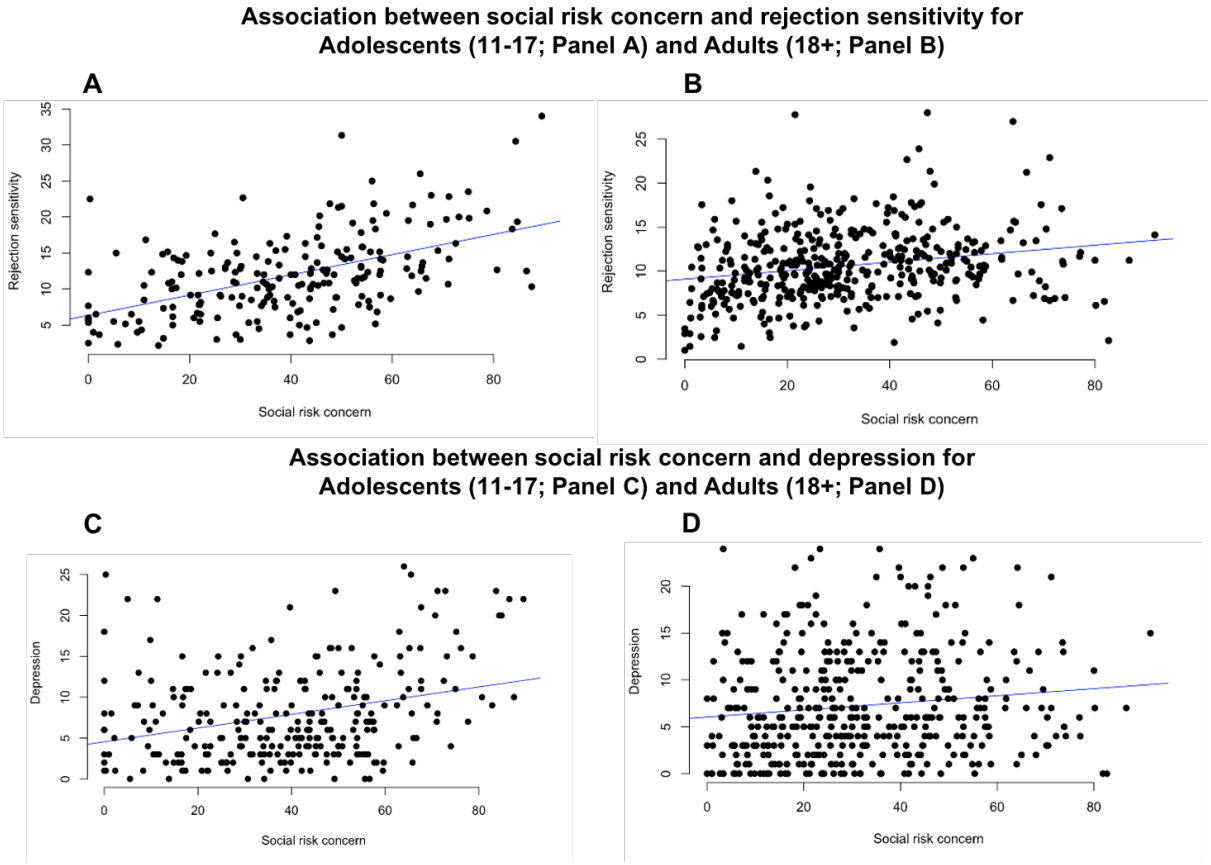

Figure 2.1. Relationship between social risk concern and rejection sensitivity for adolescents (r(205)=.52, p<.001; panel A) and adults (r(413)=.22, p<.001; panel B). Relationship between risk concern and depression for adolescents (r(279)=.31, p<.001; panel C) and adults (r(413)=.13, p<.009; panel D). The strength of the correlations between concern for social risk and rejection sensitivity and depression was stronger for adolescents than for adults (rejection sensitivity: Z=4.12, p-<.001; depression: Z=2.45, p=.007).

2.3.4. Age differences in concern for health and social risk

I conducted a multiple regression to assess the relationship between HSRQ and age, using data collected across all participants (N= 1399; aged 11-77). The outcome was risk concern (i.e. the mean score of the health and social subscales) and the predictor variables were age, gender, risk domain (health, social), and an age by risk domain interaction.

The overall regression model was significant (R^2=.14, F(3,2793)=113.2, *p*<.001; See **Table 2.4** for estimates). There was a significant main effect of age (β=-0.15; 95% CI: -0.23—0.07; *p*=<.001) and risk domain (β=-11.69; 95% CI:-15.18—8.19; *p*=<.001) and a significant interaction between age and risk domain (β=-0.16; 95% CI:-0.27-0.04; *p*=<.001). There was no main effect of gender (β=1.07 95% CI:-0.54-2.69; *p*=<0.19).

To explore the interaction between age and risk domain, I plotted the relationship (see **Figure 2.2**) and used simple slope analyses. The slope for both risks was significant (social: β=-.31, *p*<.001); health: β=-.15, *p*<.001). There was a significant difference between the gradient of these slopes (*t*(2794)=2.7, *p*=.008), driven by a steeper decline across age in concern for social risk compared to concern for health risk. This linear model (AIC: 25125.34) outperformed a quadratic model (AIC: 25142.67) and cubic model (AIC: 25156.83).

Predictor	β	SE	*t*	*p*
Intercept	49.43	1.85	26.69	<.001
Age	-0.15	0.04	-3.68	<.001
Risk domain (social risk)	-11.69	1.78	-6.55	<.001
Gender	1.07	0.82	1.31	0.19
Age*Risk domain (social risk)	-.016	0.06	-2.70	0.008

Table 2.4. Estimates from the model predicting risk concern

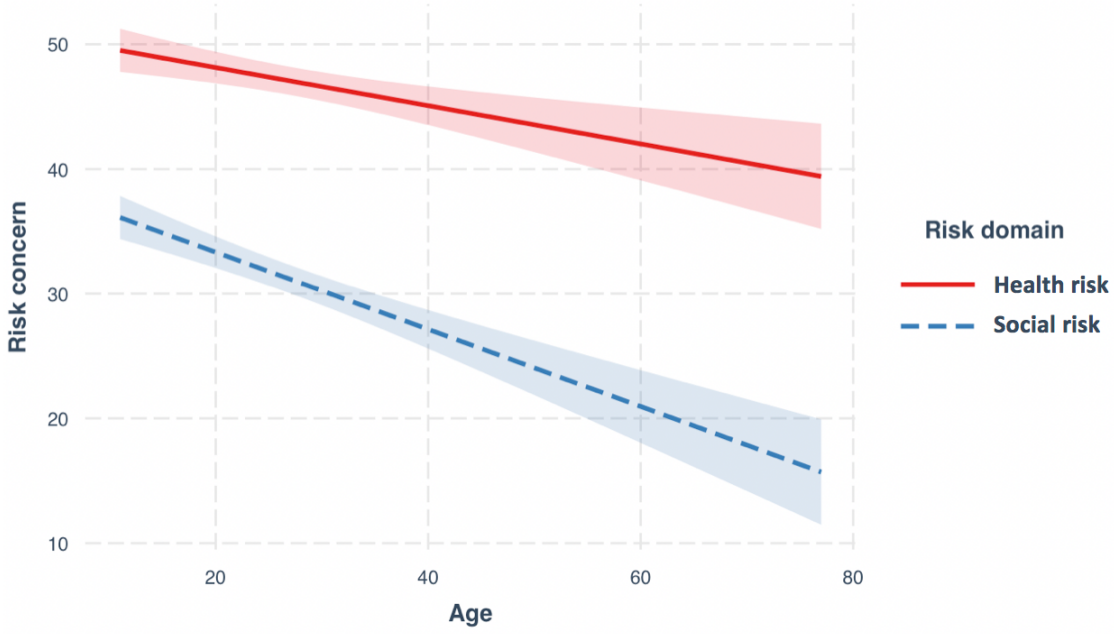

Figure 2.2. Relationship between age and concern for health risk (slope: β=-.15, *p*<.001) and social risk (slope: β=-.31, *p*<.001). There was a significant difference between the gradient of these slopes (*t*(2794)=2.7, *p*=.008), driven by a steeper decline across age in concern for social risk than for concern for health risk.

2.4. Discussion

In this study, I developed a questionnaire measure of social risk concern for use in adolescents and adults. The results showed that concerns related to engaging in social risks are distinct from concerns related to engaging in health risks. Overall, I found that people reported greater concern for health risks compared with social risks. I investigated age differences in concern for health and social risks and found that concern for both health and social risks decreased with age, from adolescence through adulthood. However, concern for social risks decreased to a greater extent than concern for health risks. This suggests that, relative to adults, adolescents are more concerned about social risks than health risks.

This heightened concern for social risks in adolescence has implications for understanding why adolescents engage in health and legal risks. One hypothesis is that adolescents are motivated to avoid what they consider to be a greater immediate risk, the social risk of being rejected or excluded by their peers (Blakemore, 2018). Avoiding social risks can be considered an important goal during adolescence, a period when

social status and friendships provide psychological and physical health benefits (Almquist, 2009; van Harmelen et al., 2017).

The association between our new measure, the Health and Social Risk Questionnaire (HSRQ), rejection sensitivity and depression indicate the potential relevance of social risk for understanding adolescent behaviour. Individuals who report greater concern for social risk were more likely to report greater sensitivity to rejection (Adolescents: C-RSQ; Adults: A-RSQ). Social rejection is an unpleasant feeling and therefore it makes sense that individuals with a heightened degree of sensitivity to the negative effects of social rejection would be more concerned with engaging in situations that could lead to, or indicate a possibility of, social rejection. Within the adult sample, individuals who scored high on concern for social risks were less likely to engage in socially risky behaviours and were more likely to rate social risk behaviours as risky. These finding indicates that higher concern for social risks is related to an increase in rejection sensitivity and an increase in socially risk-averse behaviour.

Concern for social risk was also related to depressive symptomatology (Adolescents: MFQ; Adults: PHQ-8), such that individuals with greater concern for social risk were more likely to report higher levels of depressive symptoms. This finding supports the predictions made by the social risk hypothesis of depression (Allen & Badcock, 2003). This hypothesis proposes that, when cues in the environment signal that one's social burden is significantly greater than their social value, depression manifests as an adaptive mechanism to remove the individual from social situations which might confer further risk of social rejection.

I further showed that concern for social risks is more strongly associated with rejection sensitivity and depression in adolescence (11-17 years), compared with adults (18+ years). This emphasises the increased importance that the social environment has on mental health in adolescence (Platt et al., 2013; Wang et al., 2017). During adolescence, individuals are particularly sensitive to social evaluative concerns (Somerville, 2013), and peer perceptions influence one's social and personal worth (O'Brien & Bierman, 1988). Here, I showed that the relationship between concern for social risks, social

rejection and depression is more strongly linked during adolescence, relative to adulthood.

These findings have a number of implications. At the theoretical level, the way in which risk behaviours have been traditionally conceptualised has focused heavily on the health, financial, legal and recreational domains. These results suggest that social risks should be incorporated into our understanding of risk-taking behaviour. For some individuals, taking a social risk, and placing themselves at risk of social rejection, is a real and 'risky' decision. At the practical level, interventions aimed at reducing health and legal risk behaviours should recognise the importance of concerns surrounding social risks. One promising approach is to focus on peer-led interventions, which work to influence social norms surrounding unhealthy or illegal behaviours (Andrews et al., 2020; see **1.4.4 and 6.3.1**). This approach encourages healthy behaviours by reducing the social risk of being ostracised by peers. Interventions using a peer-led approach have shown positive results for unhealthy behaviours such as bullying (Paluck et al., 2016) and smoking (Campbell et al., 2008).

2.4.1. Limitations

The HSRQ is a valid measure for individuals aged 11+. However, this measure has not been validated for children below the age 11 and very little is known about social risk in this younger age group. Future work should explore the extent to which the current items and factor structure are valid for use in children below this age. This sample was collected from the United Kingdom and therefore this measure should be cross-culturally validated for use in other socio-cultural environments. In addition, the HSRQ is based on self-report, and an important line of subsequent work is to relate responses on this questionnaire measure to a task-based assessment of social risk. Finally, the present study was not designed to investigate the degree to which individuals weigh up the health vs. social consequences of a given 'risky' decision. Therefore, an important outstanding question is the degree to which individual variation in concern for health and social risk impact involvement in 'risky' behaviours, especially when individuals are

presented with risks that often carry both social and health consequences, such as smoking or dangerous driving.

2.5. Conclusion

In the current study, I developed a self-report measure of social risk concern for use with adolescents and adults. I found that heightened concern for social risk was related to increased sensitivity to rejection and depression, with this relationship being stronger for adolescents compared to adults. This supports the body of evidence that adolescence is a period of heightened sensitivity to the social environment. In addition, both concern for health and social risk decreased with age, but the rate of decrease was steeper for social versus health risks, suggesting that adolescence is a period of amplified concern for social risk. Together, these findings highlight the importance of social risk in adolescent behaviour and suggest that interventions to reduce risk-taking behaviours in this age group should consider the role of social risk. Following on from this, in the next chapter I explore the extent to which individuals are motivated to engage in certain risk behaviours when they expect to be liked more, or less, by others.

Chapter 3: Social expectations and health risk behaviour during adolescence

The study presented in this chapter has been published as: **Andrews, J. L.,** Mills, K. L., Flournoy, J. C., Flannery, J. E., Mobasser, A., Ross, G., ... & Pfeifer, J. H. (2020). Expectations of Social Consequences Impact Anticipated Involvement in Health-Risk Behavior During Adolescence. ***Journal of Research on Adolescence***, *30*(4), 1008-1024.

3.1. Introduction

In the previous chapter I showed that concern for social risk declines with age, with adolescents reporting higher concern for engaging in behaviours that may act to differentiate them from others, relative to adults. In this chapter I turn to how social expectations may motivate adolescents to engage in health risk behaviours. Health risk behaviours such as binge drinking and illicit substance use, cluster during the adolescent years (DuRant et al., 1999; van Nieuwenhuijzen et al., 2009). This increase in health risk behaviours has fuelled the stereotype that adolescents generally take more risks than children or adults. However, recent studies have suggested that adolescence is a time of risk sensitivity (van Duijvenvoorde et al., 2015), rather than a time of universal increases in risk taking behaviour. Risk sensitivity is an individual difference characterised as the degree to which individuals are risk seeking or risk averse. In particular, it has been suggested that risk taking behaviours during adolescence are related to heightened social sensitivity, especially from peers (Blakemore & Mills, 2014b). This theory predicts that an adolescent's perception of the social outcome of engagement in a particular risky behaviour will in part determine their likelihood of engaging in that behaviour. In this study, I tested this prediction by building a model of adolescent risk taking that accounts for the perceived social consequences of engaging in a variety of risky behaviours.

Developmental scientists have proposed several theories as to why risk-taking behaviours increase during this period of life (Ciranka & van den Bos, 2019). Several theories focus on the heightened degree of sensation seeking, reward value and peer influence (see **1.4** for a discussion of these models). For example, reward sensitivity models, like the dual systems model, attribute increased risk taking during adolescence to divergent patterns of developing motivational and cognitive control systems (Steinberg, 2010). However, a number of neuroscientific findings in the last decade are inconsistent with the dual systems model (Crone & Dahl, 2012; Pfeifer & Allen, 2012; see **1.4.1 and 1.4.2**). More recently, models of adolescent risk taking such as the Lifespan Wisdom Model, have challenged these dual systems accounts. The Lifespan Wisdom model argues that the majority of adolescent risk taking is adaptive in which individuals

can learn from exploration of the environment, particularly during ambiguous risk contexts (which is characterised by sensation seeking). In general, however, when risks are known, risk taking declines monotonically from childhood to adulthood (Tymula et al., 2012). The Lifespan Wisdom Model also argues for the incorporation of broader risk contexts such as 'social conflicts', with parents or peers, to be included in models of risk taking (Romer, Reyna, & Satterthwaite, 2017).

In turn, models which focus on the role of sensation seeking in accounting for this rise in risk-taking behaviour between childhood and adulthood have also been widely discussed (Romer et al., 2017; Steinberg, 2008). One large cross-cultural study has shown that across a number of countries self-reported sensation seeking peaks during adolescence, at 19 years of age, before declining thereafter (Steinberg et al., 2018) and previous work has documented a positive association between sensation seeking, substance use and sexual risk taking (Byck et al., 2015; Quinn & Harden, 2013; Zhang et al., 2016). Work investigating the relationship between sensation seeking and peer influence has also shown, in a large sample of adolescents, that peer pressure to engage in marijuana and cigarette use had a greater effect on high sensation-seekers (Slater, 2003). Subsequent research has also found that the frequency with which individuals (college students) associated with alcohol-using peers influenced the relationship between sensation seeking and alcohol consumption (Yanovitzky, 2007). Taken together, this suggests that social context has the potential to moderate the relationship between sensation seeking and engagement in Health risk behaviours.

In situations where risk taking behaviours (e.g. health risk behaviours) are perceived to have a high social value, individuals may be more likely to engage in these behaviours in order to reach their social goals (Blakemore & Mills, 2014; Crone & Dahl, 2012). This social motivation account of adolescent risk behaviour is consistent with a value-based choice explanation of adolescent decision-making (Pfeifer & Berkman, 2018; Do, Sharp & Telzer, 2019; see **1.4.2**), which proposes that a single system integrates diverse value-laden inputs (which could include expectations of the social consequences/social motives) to inform choices.

3.1.1. Risk taking and the peer environment

As discussed in **Chapter 1.4** a wide body of work has shown that belonging to a peer group that engages in smoking or drinking increases an individual's likelihood of smoking by 5.4 times and drinking by 1.9 times (Loke & Mak, 2013). Adolescents are also more likely to engage in Health risk behaviours such as excessive alcohol consumption, experimentation with illicit substances and smoking when with their peers, compared to when alone (Reniers et al., 2017). Data from across three US government surveys have also shown that the risk of car accidents is greater for young drivers when they have a passenger in the car (Chen et al., 2000). Importantly, given that adaptively navigating one's social environment during adolescence, in order to attain social status and good quality of friendships, has been shown to have particular benefits for one's future social, psychological and physical health (Almquist, 2009; van Harmelen et al., 2017; see **1.5.2**). One mechanism via which individuals may attain a beneficial position within a social group is through normative social influence, which is conforming to others in order to be accepted or liked. It has been proposed that adolescence might be a period of susceptibility to peer influence due to hypersensitivity to social rejection (Sebastian et al., 2010).

Prior work has revealed an association between engagement in substance use and victimization during adolescence. For example, in a sample of 12-17-year-olds from South Africa, there was a significant association between substance use (e.g. tobacco, alcohol and marijuana) and prior victimization experiences (Morojele & Brook, 2006). Further, in a large study of over 400,000 adolescents from California, USA, aged between 12 and 17, found that individuals who experienced high rates of victimization were twice as likely to frequently use substances such as tobacco, alcohol and marijuana (Gilreath et al., 2014). The authors suggest that these results should be considered within the context of adolescence as a period crucial for developing peer relationships.

In the present study, I was interested in understanding how expectations of social consequences (expecting to be liked or disliked) impact decisions to engage in Health risk behaviours during adolescence. Therefore, I build upon predictions made by social motivation and value-based explanations of adolescent decision-making. These

accounts make the prediction that individuals who place a greater value on social approval, may be more likely to engage in certain Health risk behaviours if they expect this to lead to increased social status and likability. Therefore, engagement in health risk behaviours may be influenced by the perceived social consequences, which could include social risks. I propose that when making decisions, the expectations of the social consequences associated with each decision need to be better incorporated into models of risk taking behaviour and that individual variation in the degree to which these expectations relate to expected positive social outcomes is a likely predictor of an individual's involvement in health risk behaviours. Individuals who engage in Health risk behaviours, in order to avoid social risks, might be making decisions that minimize their overall risk when both are considered.

3.1.2. Current study

Previous work has shown that positive outcome expectancies (e.g. pleasure, winning money, feeling good about oneself) are positively associated with drug use whilst both positive and negative outcome expectancies are associated with heavy drinking (Katz et al., 2000). Yet, this does not appear to be the case across all health risk behaviours; the literature surrounding how outcome expectancies and motivations drive engagement in risky sex are mixed. For example, in one such study risky sex was not predicted by outcome expectancies in a sample of young adults (mean age 18) but rather by past experience (Katz et al., 2000). However, individual differences in appetitive self-focused motivations predicted engagement in risky sex in a sample of young adults (Cooper et al., 1998). In the present study, I examined how individual differences in expectations of the social consequences related to an individual's expectation of future involvement in a number of risky behaviours, during adolescence. I investigated the extent to which an individual's perceptions of the social benefit – that is, the extent to which they expect to be liked less or more by others as a result of their behavioural choices – is associated with expected engagement in a number of health risk behaviours including aggressive and illegal behaviour, substance use, risky sex and risky drinking.

I hypothesised that individuals who believe they will be liked more by engaging in a health risk behaviour will be more likely to expect to perform that behaviour, whilst individuals who believe that they will be liked less by engaging in said behaviour will be less likely to do so (hypothesis 1). I subsequently explored whether this hypothesis varies depending on the type of health risk, across four risk domains: aggressive and illegal behaviour; substance use; risky sex and risky drinking. Additionally, I anticipated that this relationship between perceived social benefit and engagement will be moderated by a number of characteristics. I predicted that individuals who report greater resistance to peer influence would show a diminished relationship between the perceived social benefit and engagement in risky behaviour (hypothesis 2), which would be consistent with previous findings (Peake et al., 2013). I further predicted that individuals who report greater fear of negative evaluation (hypothesis 3) and higher levels of peer victimisation (hypothesis 4) would show a stronger relationship between perceived social benefit and engagement in Health risk behaviours. Evidence in support of the social augmentation hypothesis (Dishion et al., 2008) suggests that victimisation experiences augment, or increase, the value of peer interactions. This leads to the hypothesis that individuals with a history of peer victimisation will be more sensitive to the social consequences associated with their involvement in Health risk behaviours. I further hypothesised that individuals with lower levels of self-esteem (hypothesis 5) would show a stronger relationship between perceived social benefit and engagement in Health risk behaviours. Previous evidence linking self-esteem to engagement in risk behaviours is varied. For example, one study found no relationship between self-confidence and risk taking (Bayat et al., 2019), whilst others show high self-esteem is related to increased risk-behaviour in a non-health context (Tian et al., 2020) yet when related to health risk behaviours, low self-esteem has been shown to contribute (Geckil & Dundar, 2011). Finally, I hypothesised that perceived social benefit would moderate the relationship between sensation seeking and engagement in risky behaviours, such that individuals who perceive the social benefit of risk taking to be high will show a stronger relationship between sensation seeking and engagement in Health risk behaviours (hypothesis 6).

3.2. Methods

3.2.1. Participants

One hundred and eighty-three participants between the ages of 11 and 19 years were recruited as part of the *Teen Decisions Study* (TDS; Research Component 1 of P50 DA035763) from the Eugene/Springfield, Oregon (USA) metropolitan area. The sample included in this project was drawn from three separate populations recruited for the TDS study. Of the 183 participants, 76 were recruited through contact with the Eugene Department of Human Services (DHS) (TDS 1), 97 were recruited in the local community (TDS 2), and 10 were recruited through their involvement with juvenile justice (TDS 3). The DHS-based sample participants were recruited because of their involvement with the Child Welfare System (e.g. in foster care) and were contacted through a DHS liaison. The community-based sample participants were recruited through distributed flyers, outreach events organized by the lab, online advertisement, tabling and word-of-mouth. The juvenile justice sample participants were recruited by re-contacting participants who had previously participated in another study conducted at the University of Oregon called the SHARP study (Research Component 2 of P50 DA035763). Caregivers of participants from TDS 2 and TDS 3, and caseworkers of participants from TDS 1, provided informed consent, and all adolescent participants provided informed assent, in accordance with the Oregon Institutional Review Board and the DHS review board.

For the purposes of this analysis and to maintain sample homogeneity I removed the small number of participants (N=10) who were recruited through the juvenile justice system. They were recruited during a period of time when we were experiencing difficulties recruiting through DHS, but are excluded here given that their experiences in the child welfare system were conceptually unique from other adolescents with a history of child welfare involvement (N=76). For completeness, I report in the **Appendix A2.2** the results of the same analyses conducted below when these 10 participants are included in the analyses. The results of these supplementary analyses are broadly similar to the main results presented here, despite only minor differences, primarily in the results of hypotheses 3 and 5. I only included participants who had complete data for

each variable of interest. This resulted in a total of 122 participants, between the ages of 11 and 17, of which 50 participants were from the DHS sample (TDS 1) and 72 were from the community sample (TDS 2). Across both samples the mean age of participants was 14 and there was an equal split of gender (61 females, 61 males). See **Table 3.1** for participant demographics split by sample.

Group	**TDS 1**	**TDS 2**
N	50	72
Age	Mean 14.0 (Range 11.7 – 17.9)	Mean 14.1 (Range 11.1 – 17.6)
Gender	Male=29, Female=21	Male=32, Female=40
IQ	Mean 98.8	Mean 108.0

Table 3.1. Participant demographic information

3.2.2. Study Design

Data for this analysis was collected at two sessions, with the second session occurring roughly three weeks after the first session. This study formed part of a larger project, which also involved an MRI scan at the second session. Therefore, in order to prevent participant fatigue given the number of assessments, data collection was spread across an initial and second session. The session in which each questionnaire was administered differed slightly between the DHS and community sample. This is outlined in **Appendix Table A2.1**. We report Cronbach's alpha scores, which assumes unidimensionality of constructs, for each measure and McDonald's Omega hierarchical (ωh), which does not assume unidimensionality, where possible.

3.2.3. Materials

Cognitive appraisal of risky events (CARE)

We used items from the expected involvement (EI) subscale of the Cognitive Appraisal of Risky Events (Fromme et al., 1997) to assess expected involvement in the following domains of risky behaviour; aggressive and illegal behaviours, substance use, risky sex and risky drinking. All items were rated on a 7-point scale: 1=not at all likely to

7=extremely likely to engage in the specific health risking behaviour over the next 6 months. Scores were computed for each risk domain by averaging responses from items corresponding to each of the four risk domains of interest within the CARE (see **Appendix A2.1** for the risk items included)**.** Aggressive and illegal behaviour (alpha 0.62; McDonald's ωh 0.57), substance use (alpha 0.55; McDonald's ωh 0.52), risky sex (alpha 0.72; McDonald's ωh 0.65) and risky drinking (alpha 0.73).

Social appraisal of risky events (SARE)

An addendum to the CARE was created in which for each item tapped in the CARE participants indicated how much people would like them if they (a) engaged in the behaviour (Social Benefit-Do), and if they (b) didn't engage in the behaviour (Social Benefit-Not). Items were rated on a 5-point scale: 1=a lot less, 2=less, 3=no difference, 4=more, 5=a lot more. Items posed in the negative (i.e., how much did people like them if they didn't engage in the behaviour) were reverse-scored, so that higher scores indicate higher perceived social benefit associated with engaging in risky behaviour. I computed an average score for each scale (Social-Benefit-Do/Not) by averaging the responses from items corresponding to each of the four risk domains of interest within the CARE. Social Benefit-Do scales: aggressive and illegal behaviour (alpha 0.82; McDonald's ωh 0.8), substance use (alpha 0.78), risky sex (alpha 0.75) and risky drinking (alpha 0.78); Social Benefit-Not scales: aggressive and illegal behaviour (alpha 0.93; McDonald's ωh 0.92), substance use (alpha 0.82), risky sex (alpha 0.84) and risky drinking (alpha 0.87).

Resistance to peer influence (RPI)

Resistance to Peer Influence (RPI). I scored each item on the 10-item RPI (Steinberg & Monahan, 2007) from 1 to 4 (reading left to right on the instrument) and reverse-scored items 2, 6, and 10. The mean score was calculated by summing the scores across the valid items and dividing them by the number of valid items. Alpha, 0.50; McDonald's ωh 0.54.

Fear of negative evaluation (BFNE-S)

The Brief Fear of Negative Evaluation (BFNE) is a 12-item questionnaire used to assess fear of negative evaluation. Each item is rated on a 5-point scale, ranging from 0 (not at all characteristic of me) to 4 (extremely characteristic of me). I calculated a mean score across the eight straightforwardly-worded items because they have been reported to be "more reliable and valid indicators" (Weeks et al., 2005). This 8-item version is called the BFNE-S (Carleton et al., 2006). Alpha, 0.94; McDonald's ωh 0.88.

Peer experiences questionnaire (RPEQ)

The Revised Peer Experiences Questionnaire (RPEQ) consists of 36 items that are scored on a 5-point scale: 1=never, 2=once or twice, 3=a few times, 4=about once a week, 5=a few times a week to assess bullying behaviour and experiences of victimization (Prinstein et al., 2001). For the current project I only used items that were worded such that the participant reports on being the victim, in order to get an indication of the participant's perceived sense of being victimized by peers. Average scores were computed from the items regarding individuals' overt and relational victimisation experiences and then combined in order to create a total victimisation score. Alpha 0.86; McDonald's ωh 0.64.

Self Esteem: Need threat scale (NTS)

Participants played Cyberball (Williams et al., 2000), a virtual ball tossing game, in which they are excluded from the game by two other players. Participants were led to believe they were playing against two other players; however, these players were programmed by the experimenter to exclude the participant. Participants were then asked the Need-Threat Scale (NTS) and asked to indicate how they felt during the Cyberball game. The NTS includes 12 items that are scored on a 5-point scale: 1=not at all, 3=moderately, 5=very much so. Only the Self-esteem subscale is included in the current analysis. The items included in the Self-esteem subscale are reverse-scored, so that higher scores correspond with experiencing greater threat to an individual's need for self-esteem. Alpha 0.60; McDonald's ωh 0.01.

Sensation seeking (BSSS)

The Brief Sensation Seeking Scale (BSSS) was adapted by Hoyle and colleagues from the Sensation Seeking Scale and tailored for adolescents (Hoyle et al., 2002). It consists of 8 pairs of statements, with one of the two statements associated with sensation seeking behaviour, and participants are asked to select the statement that best describes their preferences from of each pair. Sensation seeking scores are calculated by summing together the total number of sensation seeking statement selected from the 8 pairs. Alpha 0.68; McDonald's ωh 0.88.

3.2.4. Statistical Analyses

I employed a linear mixed effects modelling approach to our data with the lme4 package in R (R Core Team, 2014). I take a model comparison approach whereby the model with the lowest Akaike information criterion (AIC) value that was significantly different ($p<.05$), as determined by a likelihood ratio test (LRT), from the less complex model was chosen. p values for model comparisons therefore represent likelihood ratio testing. Where we are interested in the interaction between two or more variables, I use LRTs to compare the interaction model against a simpler model where the interaction term of interest is entered as a fixed effect ($p<.05$). Where omnibus tests and model parameters are reported, p values for F and t statistics are approximated with the Satterthwaite method, which approximates the degrees of freedom, given that the null distributions of parameter estimates and test statistics are unknown (Kuznetsova et al., 2017). All models were performed on the averaged scores derived from the subscales of each measure as detailed above, not at the item level. All models included age, gender, IQ and group (community: TDS2; child welfare services: TDS1) as fixed factors. Please see **Appendix Table A2.2** for a comparison of models including and excluding age, gender, IQ and group.

The first aim was to examine our hypothesis that there would be a relationship between expected involvement in risky behaviour and the perceived social benefit of engaging in, or not engaging in, these risky behaviours. Expected involvement was measured with the CARE and the perceived social benefit of engaging in (Social Benefit-Do), or not

engaging in (Social Benefit -Not) each of these behaviours was measured by the two questions asked in the SARE. In step 1, we found the best fitting model that predicts expected involvement using the SARE (see table 2 for models). In step 2, we were interested to see if an interaction between social benefit and risk domain, that is the type of risk behaviour (aggressive and illegal, substance use, risky sex or risky drinking), improved the model. We therefore compared our best fitting model from step 1 with a model incorporating the interaction with risk domain in step 2.

I tested hypotheses 2-5 (see **Table 3.2** for models), that this relationship would be moderated by a number of individual characteristics, such as resistance to peer influence, fear of negative evaluation, peer victimisation and fear of negative evaluation. I did this by comparing our best fitting model arising from the results of our first hypothesis, to a model that incorporated the individual difference of interest.

Our last hypothesis (6) investigated the relationship between sensation seeking and expected involvement in risky behaviours including the moderating effect of perceived social benefit on this relationship. I compared a model predicting expected involvement in risky behaviour with sensation seeking against our null model. I further compared a model incorporating an interaction between sensation seeking, social benefit, and risk domain with our simpler model.

Model Name	Fixed Effects	Random Effects	AIC	R^2 (marginal)
Hypothesis 1: Step one				
1 (null)	-	Subject ID	713.46	-
2	Age + Gender + IQ + Group	Subject ID	710.84	0.04
3	Age + Gender + IQ + Group + Social B-Do	Subject ID	682.98	0.11
4	Age + Gender + IQ + Group + Social B-Not	Subject ID	706.52	0.05
5	Age + Gender + IQ + Group + Social B-Do + Social B-Not	Subject ID	684.95	0.11
6	Age + Gender + IQ + Group + Social B-Do*Social B-Not	Subject ID	684.11	0.12
Hypothesis 1: Step two				
7	Age + Gender + IQ + Group + Social B-Do*Risk Domain	Subject ID	668.26	0.16
8	Age + Gender + IQ + Group + Social B-Do + Risk Domain	Subject ID	681.67	0.12
Hypothesis 2				
9	Age + Gender + IQ + Group + Social B-Do*Risk Domain*RPI	Subject ID	662.36	0.21
10	Age + Gender + IQ + Group + Social B-Do*Risk Domain + RPI	Subject ID	665.79	0.18
Hypothesis 3				
11	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Negative Evaluation	Subject ID	668.30	0.19
Hypothesis 4				
12	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Victimisation	Subject ID	657.83	0.21
13	Age + Gender + IQ + Group + Social B-Do*Risk Domain + Victimisation	Subject ID	665.22	0.17
Hypothesis 5				
14	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Self Esteem	Subject ID	671.10	0.18
Hypothesis 6				
15	Age + Gender + IQ + Group + Sensation seeking	Subject ID	699.90	0.08
16	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Sensation Seeking	Subject ID	648.02	0.23
17	Age + Gender + IQ + Group + Social B-Do + Risk Domain + Sensation Seeking	Subject ID	660.21	0.12

Table 3.2. Models predicting expected involvement in risky behaviours. Each model includes age, gender, IQ and group (TDS 1: child welfare sample and TDS2: community sample) as fixed effects. Social B-Do refers to the SARE scale measuring the perceived social benefit of engaging in the risk behaviour. Social B-Not refers to the SARE scale measuring the perceived social benefit of not engaging in the risk behaviour.

3.3. Results

3.3.1. Hypothesis 1: Social benefit of risk taking

In step 1, model 3, which included age, gender, IQ, group and Social benefit-do, best fitted the data. Across all models of interest, model 3 had the best model fit based on our AIC criteria. Model 3 provided a better fit to all simpler models; the null ($X^2(5)=40.48$, $p=<.001$) and a model (model 2) including just age, gender and IQ ($X^2(1)=29.85$, $p=<.001$). Model 3 provided a better fit (lower AIC) to more complex models (model 5 and model 6) in which Social benefit-do and social benefit-not were entered together either as main effects or as an interaction with each other, respectively. There was a significant correlation between the two subscales of the SARE: Social benefit-do and Social benefit-not (r=.51, $p<.001$).

In step 2, I added risk domain (substance use, aggressive & illegal behaviour, risky drinking, and risky sex) as an interaction term to our model. Model 7, which included age, gender, IQ, group and an interaction between social benefit and risk domain, explained more variance in expected involvement than model 3 ($X^2(6)=26.73$, $p=<.001$).

I tested the significance of this interaction by comparing model 7 to a model where Risk Domain was entered, but not as an interaction (model 8). Model 7 outperformed model 8 ($X^2(3)=19.41$, $p=<.001$), revealing the additional benefit of the interaction between perceived social benefit and risk domain in explaining expected involvement. Therefore, our best fitting model (model 7) included age, gender, IQ, group and an interaction between social benefit and risk domain.

Estimates for model 7 are found in **Table 3.3**. Omnibus tests on model 7, revealed a main effect of age ($F(1, 123.06)=6.15$, $p=.014$), social benefit ($F(1, 380.46)=19.62$, $p=<.001$), risk domain ($F(3, 350.60)=5.21$, $p=0.001$) and a interaction of social benefit and risk domain ($F(3, 356.92)=6.67$, $p=<.001$). To explore the interaction between perceived social benefit and risk domain I plotted the relationship for each risk domain (**Figure 3.1**) and used simple slope analyses. The perceived social benefit from engaging in aggressive and illegal behaviours ($\beta = 0.29$, $p<.001$), substance use ($\beta = 0.11$, $p=.03$) and risky

drinking (β = 0.30, p <.001) predicted expected involvement in these respective risk behaviours, however this was not the case for risky sex (β = -0.05, p =.52) (**Table 3.3**).

Figure 3.1: Relationship between perceived the social benefit and expected involvement in risk behaviour, broken down by risk domain.

3.3.2. Correlations between variables of interest

I computed a correlation plot depicting the relationship between each subsequent variable of interest (see **Figure 3.2**).

Fixed effects	**Estimate**	***SE***	***t***	***p***
Intercept	0.32	0.4	0.80	.42
Age	0.05	0.02	2.48	.02
Gender	-0.08	0.06	-1.20	.23
IQ	-0.0	0.0	-0.92	.36
Group	-0.02	0.07	-0.31	.75
Social B-Do	0.29	0.07	3.98	<.001
Substance use	0.20	0.17	1.23	.22
Risky drinking	-0.07	0.17	-0.42	.68
Risky sex	0.67	0.21	3.20	<.001
Social B-Do*Substance use	-0.18	0.08	-2.11	.04
Social B-Do*Risky drinking	0.01	0.08	0.15	.89
Social B-Do*Risky sex	-0.35	0.11	-3.18	<.001
Total Observations = 434				
Random effects	**Variance**		***S.D.***	
Participant (intercept)	0.058		0.24	
Simple slopes	**Estimate**	***SE***	***t***	***p***
Aggressive and illegal behaviours	0.29	0.07	4.02	<.001
Substance use	0.11	0.05	2.22	.03
Risky drinking	0.30	0.05	6.25	<.001
Risky sex	-0.05	0.08	-0.64	.52

Table 3.3. Estimates for model 7, which included age, gender, IQ, group and an interaction between social benefit and risk domain.

3.3.3. Hypothesis 2: Resistance to peer influence

A model including an interaction with resistance to peer influence (model 9) better fit the data compared to our simpler model (model 7) ($X^2(8)=21.90$, p =0.005). I further tested whether this model including the interaction with RPI explained more variance in expected involvement over a simpler model where RPI was entered, but not as an interaction (model 10). Model 9 provided a better model fit than model 10, revealing the additional benefit of the interaction between perceived social benefit, risk domain, and resistance to peer influence in explaining expected involvement. Therefore, model 9, which included the main effect of age, gender, IQ and group, as well as an interaction between social benefit, risk domain, and resistance to peer influence best explains the

data. Omnibus tests on model 9 revealed a main effect of age (F (1, 122.15)=11.17, p =.001) and social benefit (F (1, 364.33)=5.92, p =0.02). All other fixed effects did not meet significance (p >.05).

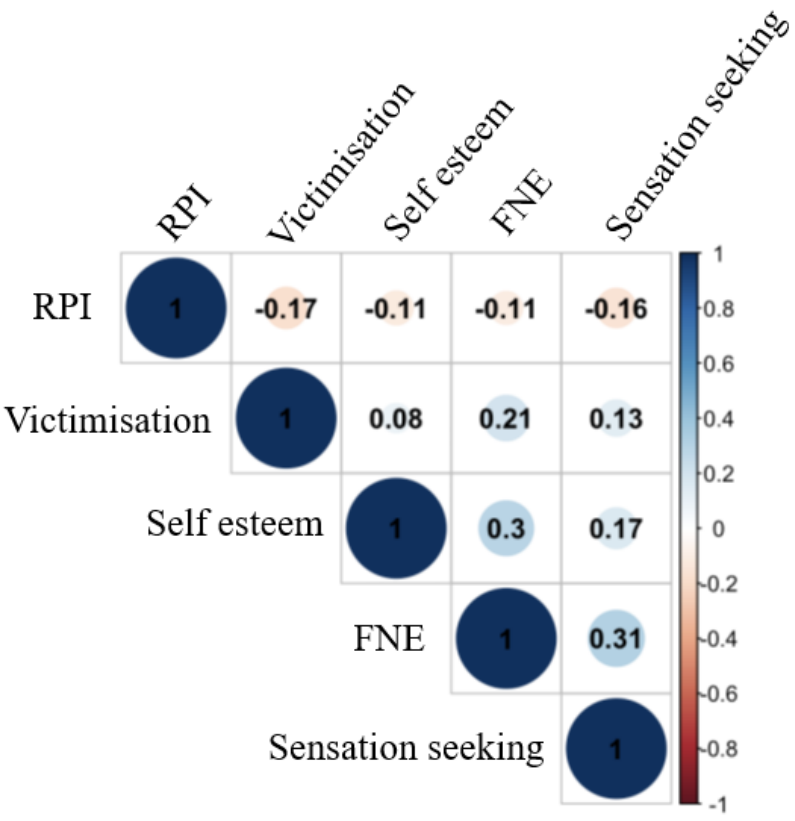

Figure 3.2. Correlation plot between all subsequent variables of interest (FNE = fear of negative evaluation, RPI = resistance to peer influence). Overlaid numbers indicate the Pearson correlation coefficient.

3.3.4. Hypothesis 3: Fear of negative evaluation

The more simple model (model 7), which included age, gender, IQ, group and an interaction between social benefit and risk domain, provided a better fit than a model including an interaction with fear of negative evaluation (model 11). Therefore, fear of negative evaluation did not interact with social benefit and risk domain in association with expected involvement in risk behaviours.

3.3.5. Hypothesis 4: Peer victimisation

A model including an interaction with victimisation (model 12) outperformed our simpler model (model 7) ($X^2(8)=26.43$ p =<.001). I further tested whether this model including the interaction with victimisation explained more variance in expected involvement over a simpler model where victimisation was entered, but not as an interaction (model 13). Model 12 provided a better fit to our data than model 13 ($X^2(7)=21.40$ p =.003), revealing the additional advantage of the interaction between social benefit, risk domain and victimisation in explaining expected involvement. Omnibus tests on model 12 revealed main effects of age (F (1, 122.85)=7.12, p =.008) and victimisation (F (1, 370.85)=4.715, p =.031), and a significant interaction between social benefit and victimisation (F (1, 421.80)=8.60, p =.004). All other fixed effects did not meet significance (p >.05). To explore the interaction between social benefit and victimisation I plotted the relationship (see **Figure 3.3**) and used simple slope analyses. When victimisation was high (+1 SD) individuals showed a strong relationship between social benefit and expected involvement (β = 0.39, p <.001), however, when victimisation was low (-1 SD) the slope was not significant (β = 0.06, p =.55). Estimates for model 12 are shown in **Table 3.4**.

3.3.6. Hypothesis 5: Self esteem

The more simple model (model 7), which included age, gender, IQ, group and an interaction between social benefit and risk domain, provided a better fit to a model including an interaction with self-esteem (model 14). Therefore, self-esteem did not interact with social benefit and risk domain in association with expected involvement in risk behaviours.

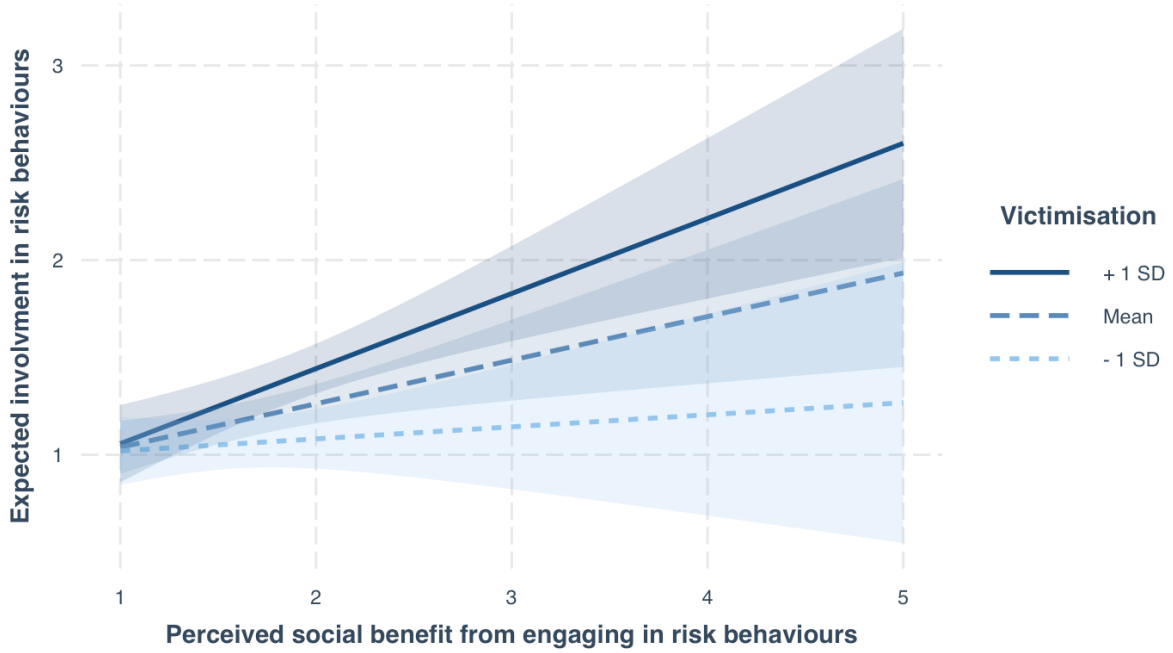

Figure 3.3. The moderating effect of victimisation on the relationship between social benefit and expected involvement in risk behaviours.

Fixed effects	**Estimate**	***SE***	***t***	***p***
Intercept	0.92	0.56	1.63	.10
Age	0.05	0.02	2.67	<.01
Gender	-0.06	0.06	-1.04	.30
IQ	-0.00	0.00	-1.24	.22
Group	0.01	0.07	0.14	.89
Social B-Do	-0.33	0.25	-1.31	.19
Substance use	-0.41	0.55	-0.75	.46
Risky drinking	-0.16	0.56	-0.30	.78
Risky sex	1.53	0.83	1.85	.07
Victimisation	-0.14	0.12	-1.17	.24
Social B-Do*Substance use	0.37	0.30	1.23	.21
Social B-Do*Risky drinking	0.23	0.30	0.78	.44
Social B-Do*Risky sex	-0.37	0.50	-0.80	.42
Social B-Do*Victimisation	0.16	0.07	2.41	.02
Substance use*Victimisation	0.16	0.15	1.01	.32
Risky drinking*Victimisation	0.00	0.16	0.02	.99
Risky sex*Victimisation	-0.30	0.25	-1.22	.22
Social B-Do*Substance use*Victimisation	-0.14	0.08	-1.75	.08
Social B-Do*Risky drinking*Victimisation	-0.05	0.08	-0.58	.56
Social B-Do*Risky sex*Victimisation	0.04	0.14	0.30	.77
Total Observations = 434				
Random effects	**Variance**		***S.D.***	
Participant (intercept)	0.05		0.22	
Simple slopes	**Estimate**	***SE***	***t***	***p***
Victimisation (-1 SD)	0.06	0.11	0.59	.55
Victimisation (Mean)	0.22	0.07	3.07	<.001
Victimisation (+1 SD)	0.39	0.09	4.16	<.001

Table 3.4. Estimates for model 12, which included age, gender, IQ, group and an interaction between social benefit, risk domain and victimisation.

3.3.7. Hypothesis 6: Sensation seeking

I built a model that predicted expected involvement in risky behaviours with sensation seeking (model 15). Model 15 provided a better fit than model 2 (which just included age, gender, IQ and group) ($X^2(2)=12.94$ p =<.001). I then added an interaction with perceived social benefit and risk domain to the model (model 16), which improved upon model 15 ($X^2(14)=79.90$, p =<.001). I tested the significance of including this three-way

interaction by comparing model 16 to a simpler model (model 17). Model 16 outperformed model 17 ($X^2(7)=26.19$, p =<.001), revealing the additional benefit of the interaction between sensation seeking, perceived social benefit, and risk domain in explaining expected involvement. Therefore, our best fitting model (model 16) included the main effect of age, gender, IQ and group, as well as an interaction between sensation seeking, perceived social benefit, and risk domain (see **Table 3.5** for the estimates of model 16). Omnibus tests on model 16, revealed a main effect of age (F (1, 118.85)=4.51, p =.04), a two way interaction of sensation seeking and risk domain (F (3, 359.0)=5.55, p =<.001) and a three way interaction of sensation seeking, social benefit, and risk domain (F (3, 364.31=6.20, p =<.001) (**Figure 3.4**). Simple slope analyses revealed that when individuals perceived the social benefit of engaging in aggressive and illegal behaviours to be high (+1 SD) they show a strong relationship between sensation seeking and expected involvement (b = 1.01, p =.01), however when they perceive the social benefit to be low there is no significant relationship (b = -0.2, p =.94). This same pattern was observed for risky drinking. When individuals perceived the social benefit of engaging in risky drinking to be high (+1 SD) they showed a strong relationship between sensation seeking and expected involvement (β = 0.82, p =<.001), however when they perceived the social benefit to be low (- 1 SD) there was no significant relationship (β = -0.23, p =.41). Simple slopes for drug use were not significant (p >.05). Finally, when the perceived social benefit of risky sex was low (-1 SD) there was a strong relationship between sensation seeking and expected involvement (β = 1.02, p =<.001), however when they perceived the social benefit to be low (- 1 SD) there was no significant relationship (β = -0.13, p =.71).

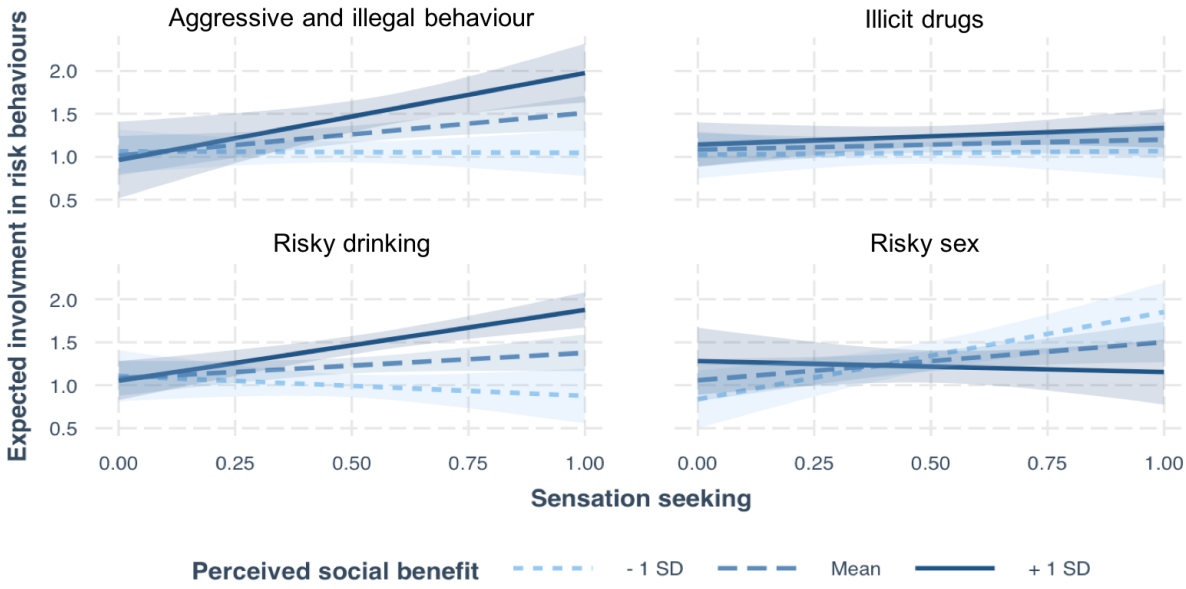

Figure 3.4. The moderating effect of social benefit on the relationship between sensation seeking and expected involvement in risk behaviours.

Fixed effects	**Estimate**	***SE***	***t***	***p***
Intercept	0.80	0.47	1.71	.09
Age	0.04	0.02	2.10	.04
Gender	-0.10	0.06	-1.63	.11
IQ	-0.00	0.00	-0.65	.52
Group	-0.04	0.07	-0.60	.57
Sensation seeking	-0.71	0.50	-1.43	.15
Social Benefit-Do	-0.07	0.17	-0.40	.69
Substance use	-0.20	0.36	-0.55	.58
Risky drinking	-0.00	0.36	0.01	.99
Risky sex	-0.59	0.41	-1.43	.15
Sensation seeking*Social B-Do	0.62	0.28	2.24	.03
Sensation seeking*Substance use	0.67	0.66	1.01	.31
Sensation seeking*Risky drinking	-0.21	0.64	-0.33	.74
Sensation seeking*Risky sex	2.49	0.73	3.40	<.001
Social B-Do*Substance use	0.13	0.19	0.71	.48
Social B-Do*Risky drinking	0.03	0.19	0.18	.86
Social B-Do*Risky sex	0.33	0.23	1.46	.15
Sensation seeking* Social B-Do*Substance use	-0.54	0.33	-1.60	.11
Sensation seeking* Social B-Do*Risky drinking	0.01	0.32	0.02	.99
Sensation seeking* Social B-Do*Risky sex	-1.30	0.39	-3.34	<.001
Total Observations = 434				
Random effects	**Variance**		***S.D.***	
Participant (intercept)	0.057		0.24	
Simple slopes	**Estimate**	***SE***	***t***	***p***
Aggressive and illegal behaviours				
Social B-Do (-1 SD)	-0.2	0.24	-0.07	.94
Social B-Do (Mean)	0.5	0.19	2.56	.01
Social B-Do (+1 SD)	1.01	0.34	2.82	.01
Substance use				
Social B-Do (-1 SD)	0.04	0.27	0.16	.87
Social B-Do (Mean)	0.12	0,18	0.65	.52
Social B-Do (+1 SD)	0.19	0.22	0.88	.38
Risky drinking				
Social B-Do (-1 SD)	-0.23	0.28	-0.82	.41
Social B-Do (Mean)	0.30	0.19	1.56	.12
Social B-Do (+1 SD)	0.82	0.19	4.30	<.001
Risky sex				
Social B-Do (-1 SD)	1.02	0.30	3.37	<.001
Social B-Do (Mean)	0.44	0.21	2.08	.04
Social B-Do (+1 SD)	-0.13	0.34	-0.37	.71

Table 3.5. Estimates for model 16, which included the main effect of age, gender, IQ and group, as well as an interaction between sensation seeking, perceived social benefit, and risk domain.

3.4. Discussion

In this study, I investigated the relationship between individual variation in expectations of social consequences and expected involvement in health risk behaviours in a sample of adolescents. I show that the perceived social benefit of engagement explains variance in an individual's expectations of engagement in aggressive and illegal behaviours, substance use and risky drinking, but not risky sex, during adolescence. More specifically, I found that individuals who perceived the social benefit of engaging in these risky behaviours to be high (increased likability) were more likely to expect to engage in said behaviour, whilst individuals who perceived the social benefit to be low (reduced likeability) were less likely to do so. This finding supports the theory that adolescents incorporate the social consequences when considering their likely engagement in a number of health risk behaviours. This data supports the view that individual differences in risk sensitivity, in particular sensitivity to social consequences, varies across adolescents – with some individuals placing greater weight on the social consequences than others. Across all models, we found that group membership (belonging to either the community or foster care sample) did not influence the findings. This suggests that the finding that the relationship between expected social benefit and anticipated involvement in health risk behaviours in adolescence might apply across individuals with diverse backgrounds, however, this should be followed up in future studies using samples with other forms of diversity including greater racial and ethnic diversity.

These findings build on previous work showing that knowledge of others' decisions impacts decisions to take risks. In one study using a monetary risk-taking task (the Balloon Analogue Risk Task, in which individuals pump up a virtual balloon for money and with each pump the risk of it popping increases), individuals took more or less risky choices when presented with the knowledge that others had made high or low risky choices, respectively (Tomova & Pessoa, 2018). In another study that investigated the effects of social norms on simulated risky driving performance, adolescents (16-18 years) made more risky decisions when watched by risk-accepting vs. risk-averse age-matched peers (Simons-Morton et al., 2014). These studies give weight to the social motivation model of risk taking, whereby individuals are motivated to conform to the

social norms displayed by their peers. Our study adds to this literature by showing that it is not just adherence to social norms that drives risky behaviour during adolescence, but the associated expected social outcomes, specifically if you anticipate being liked more or less as a consequence.

During adolescence, one's social and personal worth becomes increasingly dependent on peer relationships (O'Brien & Bierman, 1988). Therefore, engaging in behaviours that may lead to increased likeability, may lead to positive psychological outcomes such as an increase in individuals perceived social and personal worth. I observed that adolescents' expectations of engagement in health risk behaviours are, in part, explained by how much they think others will like them for engaging (or dislike them for not engaging). Interestingly, I found this relationship to be true for all risk domains investigated except risky sexual behaviours. This finding is consistent with prior work showing that both positive and negative outcome expectancies did not predict engagement in risky sexual behaviour (Katz et al., 2000). One possible explanation for this observation is that whilst sex is of course a social behaviour, it is unlikely to occur in the presence of one's peer group, in comparison to the other risky behaviours investigated, and therefore carries with it a different set of social evaluative concerns. In addition, societal expectations of what is 'deviant' and what is not may be a contributing factor with regards to these findings. It is a possible that risky sex is perceived as less deviant than the other health risk behaviours presented by the CARE, which might relate to our observed finding that social consequences do not relate to expected engagement in risky sex.

I subsequently found that individuals with a higher degree of peer victimization showed a stronger relationship between the perceived social benefit of, and expected involvement in, health risk behaviours. In previous studies, chronic peer victimization and experimentally induced social exclusion have both been related to increased risk taking behaviour on laboratory tasks (Peake et al., 2013; Telzer, Miernicki, et al., 2018). There is also evidence that feeling non-prototypical, or dissimilar to one's peers, augments adherence to group norms (Noel et al., 1995), particularly in individuals who have a significant motivation for group acceptance (Steinel et al., 2010). The findings

presented here suggest that victimized individuals expect to make more socially risk-averse decisions, which may include placing greater weight on the social rather than the health consequences associated with a given decision, perhaps as a mechanism to attain likeability and peer acceptance. According to the social augmentation hypothesis (Dishion et al., 2008), victimization amplifies the role of deviant values in friendship formation. In support of this there is evidence that individuals who have experienced peer rejection are likely to form friendships with other rejected peers, who support deviant behaviours (Dishion et al., 1991). This theory suggests that chronic victimization augments the value of peer interaction. Whilst the question here did not specifically ask about peers, the present findings support this idea that victimization increases social evaluative concern, leading to a greater weight being given to the social risk involved in a decision.

Although these findings suggest that the social consequences of health risk behaviours play an important contribution to one's expected involvement in a number of health risk behaviours, one prevailing view is that health risk behaviours during adolescence are in part explainable by a heightened degree of sensation seeking observed during this period of development. I showed that the relationship between sensation seeking and expected involvement in health risk behaviours is moderated by the perceived social benefit. With respect to aggressive and illegal behaviours, as well as risky drinking, individuals who perceive the social benefit of engaging in these behaviours (and/or social risks of not engaging) to be high, show an increased positive relationship between sensation seeking and engagement in the risky behaviour. I found no such moderating effect for substance use, and an opposite effect for risky sexual behaviour. When individuals believe they will be liked less by engaging in risky sex, their expected involvement in risky sex is better explained by sensation seeking than when they believe they will be liked more. Collectively, these findings demonstrate that, engagement in risky behaviours is explained by an interaction between sensation seeking and concerns over the social consequences associated with expected involvement in health risk behaviours.

3.4.1. Limitations and Future Directions

Future work should build upon the findings reported here, to incorporate social expectations into measures of actual engagement in risk taking behaviour and experimental risk-taking tasks. The present study was unable to dissociate the effects of peer vs. parent contributions to expectations of social consequences. In the present study, individuals were asked how much 'people' would like them, rather than specifically peers or parents, therefore conflating these different sources of influence. There is a growing literature showing that, as well as peers, parents continue to be an important source of influence in adolescents' decision processes (Qu et al., 2015; van Hoorn et al., 2018). Therefore, future work is needed in order to delineate the contribution of peers and parents in contributing to expectations of social consequences. In the present study I took a model comparison approach, finding that a model including the perceived social benefit of engaging in health risk behaviours outperformed similar models including the perceived social benefit of not engaging in health risk behaviours. This may in part be due to shared variance, explaining anticipated involvement in health risk behaviours, in our measures. That said, an interesting line of future work could be to further explore the qualitative differences between these measures.

In addition, the present study is unable to contribute to an understanding of how these social expectations impact expected involvement in health risk behaviours across the lifespan. Therefore, in order to understand developmental trends, future work should consider assessing the impact of social expectations on risky decision making across age. Additionally, our measure of the benefits associated with engagement in health risk behaviours are strictly social in nature, therefore we cannot infer beyond this to the contribution that more broader benefits e.g. financial gain, might have on engagement in these behaviours.

Whilst the data presented here was self-report, these findings have significant implications for public health interventions, specifically supporting the suggestion that interventions aimed at reducing risky health behaviours such as binge drinking and substance misuse in young people should focus on changing social norms around risk

behaviour (Blakemore, 2018). However, interventions should be cautious of the possible iatrogenic effects of grouping deviant peers together (Gifford-Smith et al., 2005). Rather, focusing on interventions that utilise a bottom-up, or peer-led, approach may have the most positive outcomes. This is evidenced by previous interventions that have utilised this approach reporting promising results for behaviours such as bullying (Paluck et al., 2016) and smoking (Campbell et al., 2008). More broadly, peers represent a potentially underused source of social change in current public health interventions; merely targeting the health consequences associated with a given risky decision ignores the broader social context that adolescents incorporate into their decisions regarding their engagement in (health) risk behaviours.

3.5. Conclusion

The findings from the present study demonstrate the importance of incorporating perceptions of social consequences into models of health risk behaviour. Individual differences in the perception of the social consequences associated with a number of health risk behaviours predicted adolescents expected involvement in these behaviours. This was true for aggressive and illegal behaviours, substance use and risky drinking, but not risky sex. In addition, I found that this relationship is augmented in individuals with a history of victimisation and that expectations of social consequences moderates the relationship between sensation seeking and expected involvement across a number of health risk behaviours. This study provides an important contribution to the understanding of adolescent risk behaviour.

Crucially, this study leads us to consider whether individuals, who are particularly sensitive to social consequences and also engage in health risk behaviours, may in fact not be engaging in risky behaviour *per se* but rather minimising their overall risk exposure when aggregating across social and health risks. When incorporating an understanding of an individual's expectations of the social consequences involved in these behaviours, adolescents may therefore be acting to attain social acceptance, and avoid negative social outcomes.

One group who are especially at risk of engaging in health risk behaviours are sexual minority adolescents. Sexual minority adolescents are also at greater risk of experiencing interpersonal difficulties, such as peer victimisation, and mental health problems, such as depression. These variables have complex interrelationships and in the next chapter I explore how belonging to a sexual minority relates to negative outcomes across these three broad domains of interest: depression, interpersonal relationships and health risk behaviour.

Chapter 4: The centrality of sexuality: Mapping mental health in adolescence

4.1. Introduction

Adolescence is a time of heightened risk for the onset of mental health problems, with approximately 75% of all adult mental health problems first appearing before the age of 24 and 50% before the age of 14 (Kesler et al., 2007). Adolescents who identify as a sexual minority (for example, identifying as gay, lesbian and bisexual) are at greater risk of developing depression relative to their heterosexual peers (Lucassen et al., 2017; Luk et al., 2018). Sexual minority adolescents are also at greater risk of a number of other adverse health and social outcomes, including peer victimisation and health risk-taking behaviours, such as smoking and drinking (Amos et al., 2020; P. Li et al., 2017). Here, I build on existing evidence by exploring how growing up as a sexual minority connects adverse mental health, interpersonal difficulties and health-risk outcomes. Understanding whether and how sexual minority status is associated with these outcomes is important because, in high income countries, depression, anxiety and substance use make up the leading causes of disability among young people (Erskine et al., 2015).

4.1.1. Mental health and the social environment

It has been proposed that the increased vulnerability to developing depression in adolescence, in part, due to heightened sensitivity to the social environment during this period of life (Andrews et al., 2021; Badcock et al., 2017; Blakemore & Mills, 2014). Adolescents report a greater decrease in mood following experimentally induced social exclusion, in comparison to adults (Sebastian et al., 2010). This is consistent with a growing body of research that suggests that adolescence is a sensitive period to social stress - situations that may threaten one's social relationships and belonging (Fuhrmann et al., 2015). For example, the effects of social stress attributed to migration and bullying during adolescence are persistent, and have been shown to impact mental and physical health later in life (Sirin et al., 2013; Takizawa et al., 2014).

Adolescents who report being frequently victimised by peers at age 13 have over a twofold increase in the likelihood of developing depression at age 18 (Bowes et al., 2015). Similarly, chronically victimised young adolescents (by the age of 13) have a

higher risk of developing an anxiety disorder by the age of 18, compared to non-victimised peers (Stapinski et al., 2014). These effects can be long lasting. In one birth cohort study (National Child Development Study, UK) rates of bullying during childhood (age 7) and early adolescence (age 11) predicted psychological distress at age 50, with higher rates of bullying being associated with greater incidence of depression and anxiety (Takizawa et al., 2014). Numerous other birth cohort studies have found similar links between child and adolescent peer victimisation and subsequent increased suicide attempts, even after controlling for baseline conduct problems and depression (Brunstein Klomek et al., 2009; Wolke et al., 2013)

Social status amongst peers during adolescence also predicts future mental and physical health outcomes in adulthood. Data from the Stockholm Birth Cohort Study, which comprises of 15,117 individuals, shows that the lower the peer status at 12-13 years, the greater the risk of mental and behavioural disorders (e.g. alcohol abuse and suicide) as well life-style related diseases (e.g. ischaemic heart disease and diabetes). Importantly, these findings were not explained by childhood social class (Almquist, 2009). Parent-child relationships also play an important role in both the aetiology and recovery of adolescent depression. For example, positive support from parents is a protective factor against depression among adolescents (Gariépy et al., 2016).

Adolescent depression rarely occurs in isolation but instead has reciprocal relationships with health risk behaviours such as alcohol abuse and smoking (Heger et al., 2014; Marmorstein, 2009). In addition, victimisation can amplify the extent to which adolescents incorporate social expectations (e.g. their desire to be liked by others) when making decisions to engage in health risk behaviours such as substance use and risky drinking (Andrews, Mills, et al., 2020).

4.1.2. The impact of sexual minority status

One known risk factor for depression, peer victimisation and substance use during adolescence is belonging to a marginalised group, such as identifying as a sexual minority. In addition to a greater likelihood of experiencing depression, sexual minority

adolescents are also more likely to report lower life satisfaction, lower self-esteem, poorer sleep quality and higher rates of victimisation and increased rates of smoking and illicit drug use compared with their heterosexual counterparts (Amos et al., 2020; Li et al., 2017; Lucassen et al., 2017; Luk et al., 2018). It has been widely hypothesised that sexual minority adolescents are at increased risk of developing depression because of minority stress, which is sustained through the experience of stigma and homophobic-related victimisation (Bariola et al., 2016; Meyer, 2003).

Sexual minority youth are often faced with the worry of family acceptance following disclosure of their sexual orientation (Katz-Wise et al., 2016). One study from 1998 found that sexual minority youth from the USA were more likely to experience verbal and physical abuse by family members following disclosure of their orientation (D'Augelli et al., 1998). Individuals who fear rejection from family and peers are more likely to report higher levels of depression, compared with those who do not (D'augelli, 2002). However, sexual minority adolescents whose parents support them are more likely to report increased levels of self-esteem and reduced levels of depression, compared to those who do not have family support (Ryan et al., 2010).

One barrier to understanding the experience of sexual minority adolescents is that young people who are not entirely heterosexual may not identify as a sexual minority (Mikulsky, 2005; Russell, 2003), or individuals may not have 'come out' to themselves or others at the point of questioning (Savin-Williams, 2001). Establishing the true percentage of this population is therefore a challenge, but it is estimated that sexual minority individuals make up approximately 2.3-12% of the overall population (Lucassen et al., 2017). Additionally, data since 2000 indicates that the average age of 'coming out' is approximately 14 (D'Augelli et al., 2010)19/07/2021 10:52:00, which is lower than the previous decade, when it was around 16 years (Rosario et al., 1996). The average estimated age of coming out at around 14 years of age coincides with a period of development during which peer influence and sensitivity to social rejection is heightened (Knoll et al., 2015; Sebastian et al., 2010). Therefore, peer relationships are also likely to be a predictor of positive outcomes for this group. This is evidenced from data showing that sexual minority youth who report retaining friends following

disclosure of their orientation also report higher levels of self-esteem and lower levels of depression, compared to those who lost friends due to disclosing their orientation (D'Augelli, 2003). Further, sexual minority youth who have other sexual minority friends are less likely to report depression and less likely to feel the negative effects of victimisation, compared to those who do not (Ueno, 2005).

4.1.3. The current study

Adolescence is a period of heightened sensitivity to the opinions of others, and the consequences of victimisation, bullying and exclusion can last a lifetime. Sexual minority status appears to confer a particular risk for these negative outcomes. What is currently unknown is whether these negative outcomes are directly associated with sexual minority status, or whether they are simply a downstream consequence of other negative outcomes. For example, are increased rates of substance use directly associated with sexual minority status? Or are they consequence of increased victimisation due to sexual minority status? This kind of information is vital for tailoring support for this community. To address this, I took a network analytic approach to explore the role that sexual minority status plays in connecting three broad domains of interest – depression, interpersonal relationships and health risk behaviours – in a large sample of adolescents. Previous work using this dataset (Millennium Cohort Study) has shown that endorsing same sex attraction in this age group is a significant predictor of a number of poor outcomes in each of these domains (Amos et al., 2020). However, these variables undoubtedly have complex interactions with each other, which makes network analysis an appealing method with which to explore co-dependences and potential mediating factors between variables (Borsboom & Cramer, 2013; Haslbeck & Waldorp, 2018). In addition, network analysis is an appealing method as it examines partial correlations between each node, or variable, in the network, whilst controlling for all other variables in the network. In order explore these questions, the current network model examined the extent to which sexual minority status (defined as self-reported same sex attraction) is associated with, and connected to, a number of variables that correspond to our three broad domains of interest: depression, interpersonal relationships and health risk behaviours. I predicted that some adverse

associations with minority status will be direct, and others will be downstream consequences of other more proximal associations. The network analysis allows us to distinguish these two types of relationship.

4.2. Methods

4.2.1. Sample

The Millennium Cohort Study (MCS) is a UK cohort study following children born between 2000 and 2002. 19,519 children were initially recruited. In the current study, I made use of data from the sixth sweep (January 2015-March 2016), when cohort members were 14 years old. The total sample size of cohort members followed up at this time point was 11,884. The MCS study received ethical approval from the National Research Ethics Service Committee London – Central (reference 12/LO/1786). Inclusion in the analysis was dependent on complete data across all variables included (Total N = 8017; Male = 4078; Female = 3939). Millennium Cohort Study Data is freely available to researchers via the UK Data service (SN: 8156).

4.2.2. Measures

Sexual minority status. Cohort members were asked to report if they had (a) ever been attracted to a female or (b) a male. Using this measure, I identified individuals who reported same sex attraction. This method of determining sexual minority status within this sample has previously been used by (Amos et al., 2020).

Depressive symptoms. Cohort members completed the Child Self-Report version of the Mood and Feelings Questionnaire (MFQ). This is a 13-item questionnaire that asks respondents to report how they have been feeling or acting in the past two weeks on a 3-point scale (0 = not true; 1 = sometimes; 2 = true). Higher scores represent greater endorsement of depressive symptoms. The maximum possible score is 26 and scores of 12 or higher may indicate the presence of depression.

Social support. Cohort members completed a three-item social support grid. Participants were asked to think about their current relationships with friends, family members, community members, and so on when answering the questions. For each item they were asked to indicate the extent to which each statement describes their current relationships with other people: (1) I have family and friends who help me feel safe, secure and happy; (2) There is someone I trust whom I would turn to for advice if I were having problems; and (3) There is no one I feel close to (this item was reversed scored). Answers were recorded on a 3-point scale (1 = very true; 2 = partially true; 3 = not true). Higher scores represent poorer social support.

Closeness with parents. Cohort members are asked how close they are with their (1) mother and (2) father, on a 4-point scale (1 not close at all – to - 4 extremely close). Items were reverse scored such that higher scores represent lower levels of closeness.

Victimisation. Cohort members answered questions pertaining to their experience of victimisation across three domains: (1) How often do your brothers or sisters hurt you or pick on you on purpose? (2) How often do other children hurt you or pick on you on purpose? (3) How often have other children sent you unwanted or nasty emails, texts, or messages or posted something nasty about you on a website? Answers were recorded on a 6-point scale (1 = most days, 2 = about once a week, 3 = about once a month, 4 = every few months, 5 = less often, 6 = never). Items were reverse scored such that higher scores represent greater levels of victimisation.

Conduct problems. This measure is a parent report subscale of the strength and difficulties questionnaire (SDQ). Parents are asked to score their child on 5 items relating to their conduct, such as ‘often fights with other children’ and ‘often lies or cheats’. Answers are given on a 3 point scale (0 = not true, 1 = somewhat true, 2 = certainly true).

Peer Problems. This measure is a parent report subscale of the SDQ. Parents are asked to score their child on 5 items relating to their relationship with peers, such as

'has at least one good friend' and 'generally liked by other children'. Answers are given on a 3-point scale (0 = not true, 1 = somewhat true, 2 = certainly true).

Smoking. Cohort members reported the extent of their smoking behaviour on a six-point scale, ranging from (1 = I have never smoked cigarettes, to 6 = I usually smoke more than six cigarettes a week).

Drinking. Cohort members were asked, 'how many times have you had an alcoholic drink in the last 4 weeks?', on a seven-point scale ranging from (1 = Never, to 7 = 40 or more times).

Drug use. Cohort members were asked two questions, (1) have you ever tried cannabis, or (2) any other illegal drug? Answers were scored as 0 = No, 1 = Yes, and aggregated to form a three-point scale (0= No to both questions, 1 = Yes to 1 of the two questions, 2 = Yes to both questions).

4.2.3. Statistical analysis

All data analyses were conducted in R (version 3.6.2). First, t-tests (Bonferroni corrected for multiple comparisons) were conducted to test for differences between sexual-minority and heterosexual adolescents on each variable.

A Mixed Graphical Model was estimated using the 'mgm' package (version 1.2-10; Haslbeck & Waldorp, 2020), which allows for network estimation when there is a mix of continuous and binary variables. A Least Absolute Shrinkage and Selection Operator (LASSO; Tibshirani, 1996) was used to regularise the network. The degree of regularisation is set by the EBIC hyperparameter (between 0 and 0.5). Setting the parameter at 0 errs on the side of discovery, whilst setting it to 0.5 provides a more conservative estimation – reducing spurious edges but increasing the probability of missing some true edges (Epskamp & Fried, 2018). Here we set our EBIC hyperparameter to 0.3, which takes a middle ground between exploration and parsimony when identifying edges in the network, and has been employed in recent studies of a similar

nature (e.g. Bird et al., 2021). The *qgraph* package (version 1.5.4) was used to visualise the network, and the Fruchterman-Reingold algorithm (Fruchterman & Reingold, 1991) was selected whereby the most highly connected nodes (corresponding to each variable) are placed more centrally in the network. Edges between symptom nodes represent the association between two nodes. Edge thickness and saturation is indicated by the strength of the associations. Green edges represent positive associations whilst red edges represent negative associations (Epskamp et al., 2012). The presence of node clusters within each network was explored using a spinglass algorithm computed using the *igraph* package (version 1.24). This algorithm identifies communities of nodes with a high proportion of edges within the community and few outside it.

We further estimated node predictability, which is determined by the degree to which each node is predicted by other nodes in the network that share a direct edge. The proportion of variance explained (r^2) was computed for continuous variables and correct classification (CC) was computed for binary variables (Haslbeck & Waldorp, 2020). We used the 'bootnet' package (version 1.3.0) in order to run a non-parametric bootstrap, in which 1000 permutations were specified, in order to determine the 95% CIs for each edge in the network. In order to compare edge weights, we used the bootstrap difference test (significance set at $p<.05$). We determined the shortest paths between sexual minority status and all other variables in the network using Dikstra's algorithm. The shortest path analysis determines the fastest route through the network between two nodes (the strength of each edge weight is accounted for)**.** This process highlights potential pathways that are mediated by additional nodes in the network.

We computed a number of centrality measures for each node in the network. These centrality measures indicate the relative importance of a node in maintaining the network composition and mediating associations between other variables in the network. Four centrality measures were computed: strength, expected influence, betweenness and closeness. Strength centrality refers to the sum of the strength of edges connected to any one node. Expected influence centrality is similar to strength centrality but does not take the absolute value of edges before summing, therefore

providing a measure of overall positive connectivity in networks with both positive and negative edges (Robinaugh et al., 2016). Betweenness centrality refers to the number of times any one node lies on the shortest path between two other nodes, and closeness centrality is the mean distance of a node from all other nodes in the network. The stability of these centrality measures was assessed using a bootstrapping method in which cases are removed from the dataset in increasing quantities and the centrality measure is recalculated at each point (Epskamp et al., 2018). We used the '*bootnet*' package for this and specified 1000 permutations.

4.3. Results

4.3.1. Differences in outcomes for sexual minority and heterosexual adolescents

A total of 490 cohort members reported same sex attraction and were included within the sexual minority group (Males = 116; Females = 374). The other 7527 cohort members included in this analysis did not report same sex attraction and were classified as heterosexual (Males = 3962; Females = 3565). T-test results revealed that sexual minority adolescents had significantly poorer outcomes in all variables assessed (Bonferroni corrected $p<.05$), except conduct problems (Bonferroni corrected for nine comparisons, $p>.05$). See **Table 4.1** for the results of each difference test conducted. Because of the asymmetric gender split, I repeated this analysis for each gender. Sexual minority and heterosexual females showed significant differences across all variables except conduct problems, whilst sexual minority and heterosexual males showed significant differences across all variables except conduct problems, drinking, drug use, smoking and social support (see **Figure 4.1** for a profile plot of mean standardised z scores for each group and **Appendix Table A3.1** and **Table A3.2** for the results of each difference test conducted for males and females, respectively).

Variable	Sexual minority (SM)		Heterosexual		Difference test	
	Mean	SD	Mean	SD	t-test	Adjusted *p*-value
Depression (DEP)	12.21	7.42	5.22	5.45	-20.48	<.00001
Conduct problems (CP)	1.50	1.71	1.30	1.52	-2.44	>.05
Peer problems (PP)	2.24	2.03	1.50	1.68	-7.89	<.00001
Social support (SS)	0.88	1.19	0.47	0.87	-7.57	<.00001
Victimisation (VIC)	7.98	3.53	6.14	2.97	-11.23	<.00001
Closeness to parents (PAR)	4.56	1.55	3.85	1.48	-9.71	<.00001
Smoking (SMO)	1.60	1.19	1.25	0.78	-6.11	<.00001
Drinking (DRI)	1.46	0.67	1.31	0.76	-4.15	<.00001
Drugs (DRU)	0.13	0.38	0.05	0.23	-4.80	<.00001

Table 4.1. Results from t-tests conducted on each variable of interest between sexual minority and heterosexual adolescents (Adjusted *p* value = Bonferroni corrected for multiple comparisons).

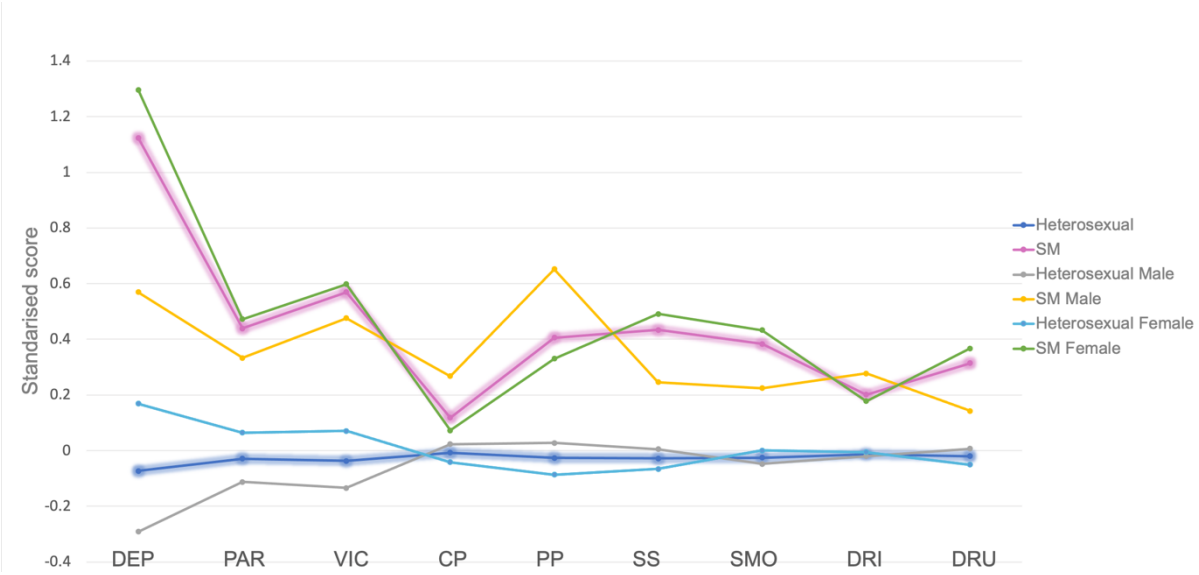

Figure 4.1. Profile plot of mean standardised z scores of each variable by group (SM = sexual minority status). The sexual minority (SM) and heterosexual groups are represented with bold lines, and sub-groups by the thin lines. DEP = Depression, MS = Minority Status, VIC = Victimisation, SS = Social support, PAR = Closeness to parents, PP = Peer problems, CP = Conduct problems, DRU = Drug use, SMO = Smoking, DRI = Drinking.

4.3.2. Network analysis

Network estimation and visualisation. The estimated network comprising of all 10 variables is shown in Figure 2. Four communities of variables were detected using the spinglass algorithm: (1) Sexual minority status, depression and victimisation; (2) social support and closeness to parents; (3) peer problems and conduct problems; (4) drinking, smoking and drug use (highlighted in **Figure 4.2**). Exploratory analyses showed that the structure of the edges in the network was the same for males and females. However, females showed greater connectivity within the network, relative to males (see **Appendix A3.1** for more details).

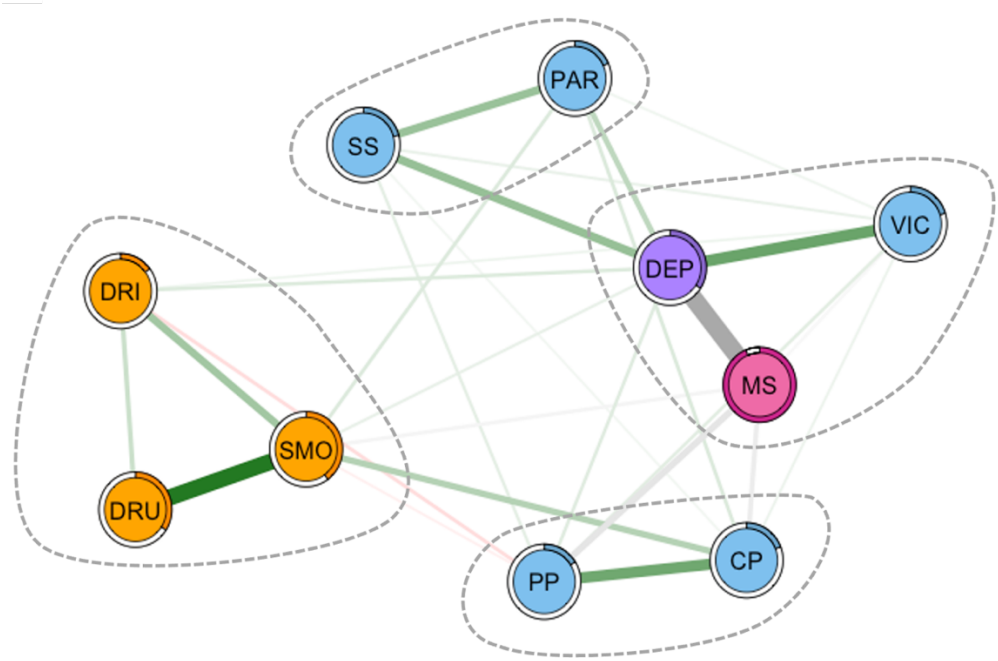

Figure 4.2. Network diagram. Yellow nodes represent substance use variables, blue represent interpersonal difficulties, purple corresponds to depression and pink corresponds to sexual minority status. Dashed lines represent the communities of nodes detected from the spinglass algorithm. DEP = Depression, MS = Minority Status, VIC = Victimisation, SS = Social support, PAR = Closeness to parents, PP = Peer problems, CP = Conduct problems, DRU = Drug use, SMO = Smoking, DRI = Drinking.

Node predictability. Sexual minority status had a correct classification score of 0.94. This suggests that approximately 94% of the time, individuals are correctly classified as either heterosexual or sexual minority given their scores on all variables that share a direct edge with sexual minority status. Depression had the highest r^2 value of all nodes in the network (r^2 = .34) and drinking had the lowest (r^2 = .14; see **Table 4.2** for the predictability values of all nodes).

Variable	R2	CC
Minority status (MS)	-	.939
Depression (DEP)	.343	-
Conduct problems (CP)	.192	-
Peer problems (PP)	.162	-
Social support (SS)	.209	-
Victimisation (VIC)	.204	-
Closeness to parents (PAR)	.185	-
Smoking (SMO)	.399	-
Drinking (DRI)	.149	-
Drugs (DRU)	.342	-

Table 4.2. Node predictability. This is determined by the degree to which each node (variable) is predicted by other nodes in the network that share a direct edge. The proportion of variance explained (r^2) was computed for continuous variables and correct classification (CC) was computed for binary variables.

Edge weight differences. Sexual minority status showed the largest unique relationship with depression (edge weight = 0.51, 95% CI = [0.51, 0.60]). In addition to depression, sexual minority status also shared direct edges with peer problems (edge weight = 0.18, 95% CI = 1.51, 0.06]), conduct problems (edge weight = -0.11, 95% CI = [-6.50, 0.07]), smoking (edge weight = 0.07, 95% CI = [4.62, 0.04]) and victimisation (edge weight = 0.05, 95% CI = [3.39, 0.04]). The edge between sexual minority status and depression was significantly larger than the edges between sexual minority status and all other variables (p<0.05). None of the other edges with sexual minority status were

significantly different in size (p>0.05; **see Table 4.3**). Bootstrapped 95% CIs are presented in **Appendix Figure A3.1**).

Shortest path analyses. The absence of direct edges between sexual minority status and drinking, drug use, closeness with parents and social support demonstrates indirect relationships between sexual minority status and these variables, occurring through other variables in the network (notably depression). The shortest path between sexual minority status and depression, peer problems and conduct problems showed that a direct route is the dominant pathway. The shortest path to smoking and drug use occurred via a mediated route through conduct problems and the shortest path to social support, closeness with parents and victimisation occurred via depression (see **Figure 4.3**). Given the importance of depression in the network, I further explored the extent to which sexual minority status lay on the shortest path between depression and all other variables in the network. The shortest paths between depression and peer problems, conduct problems, drug use and smoking all occurred via sexual minority status.

Centrality measures. Centrality scores were computed for each node in the network (see **Figure 4.4**). Depression had the highest strength and expected influence centrality, followed by smoking and sexual minority status. Depression had the highest betweenness centrality, followed by minority status and then smoking. Depression and sexual minority status shared the highest closeness centrality, followed by peer problems. For the bootstrapped stability analysis conducted on the centrality measures see **Appendix Figure A3.2**.

Node 1	Node 2	Lower CI	Upper CI	p<.05
Depression	Victimisation	-0.6333441	-0.4044245	TRUE
	Social support	-0.6479693	-0.4933341	TRUE
	Cloesness to parents	-0.6333441	-0.4174752	TRUE
	Smoking	-0.6215934	-0.4194751	TRUE
	Drinking	-0.6392697	-0.4911276	TRUE
	Drugs	-0.632366	-0.449948	TRUE
Conduct problems	Peer problems	0	0.3900229	FALSE
	Victimisation	0	0.26392121	FALSE
	Social support	0	0.18660249	FALSE
	Cloesness to parents	0	0.26300858	FALSE
	Smoking	0	0.27921171	FALSE
	Drinking	0	0.18917936	FALSE
	Drugs	0	0.24681788	FALSE
Peer problems	Victimisation	-0.2173928	0	FALSE
	Social support	-0.2520723	0	FALSE
	Cloesness to parents	-0.2205536	0	FALSE
	Smoking	-0.2088281	0.00800039	FALSE
	Drinking	-0.2367495	0	FALSE
	Drugs	-0.231532	0	FALSE
Victimisation	Social support	-0.1271399	0	FALSE
	Cloesness to parents	-0.101917	0.09695875	FALSE
	Smoking	-0.0923175	0.11324126	FALSE
	Drinking	-0.1162798	0	FALSE
	Drugs	-0.1053711	0.08145051	FALSE
Social support	Cloesness to parents	0	0.13785265	FALSE
	Smoking	0	0.14302571	FALSE
	Drinking	0	0.05855993	FALSE
	Drugs	0	0.1063283	FALSE
Closness to parents	Smoking	-0.0903553	0.11850642	FALSE
	Drinking	-0.1182697	0	FALSE
	Drugs	-0.104264	0.0959857	FALSE
Smoking	Drinking	-0.1306774	0	FALSE
	Drugs	-0.1256004	0.09354153	FALSE
Drinking	Drugs	0	0.10217411	FALSE

Table 4.3. Bootstrap edge difference test comparing the size of the edges connecting with minority status. In each case, the edge weight between sexual minority status and the variable included in the first column (Node 1), is compared with Node 1 and the variable included in the second column (Node 2). The lower and upper confidence intervals are reported in column 3 and 4, respectively. Column 5, reports the significance of the differences in these edge weights (TRUE = significant and FALSE = non-significant, at p<.05).

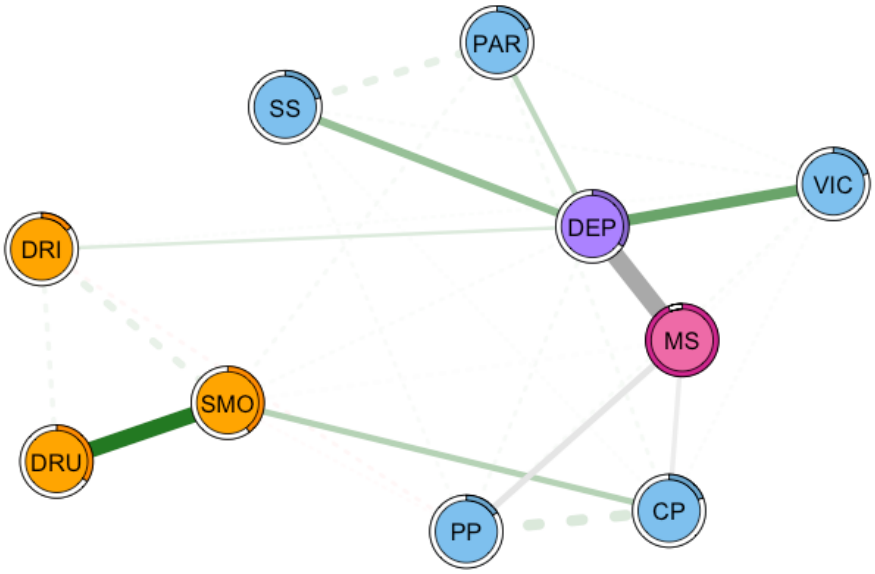

Figure 4.3. Shortest paths from sexual minority status. The shortest path between sexual minority status and depression, peer problems and conduct problems shows that a direct route is the dominant pathway. The shortest path to smoking and drug use occurred via a mediated route through conduct problems and the shortest path to social support, closeness with parents and victimisation occurred via depression. Key: DEP = Depression, MS = Minority Status, VIC = Victimisation, SS = Social support, PAR = Closeness to parents, PP = Peer problems, CP = Conduct problems, DRU = Drug use, SMO = Smoking, DRI = Drinking.

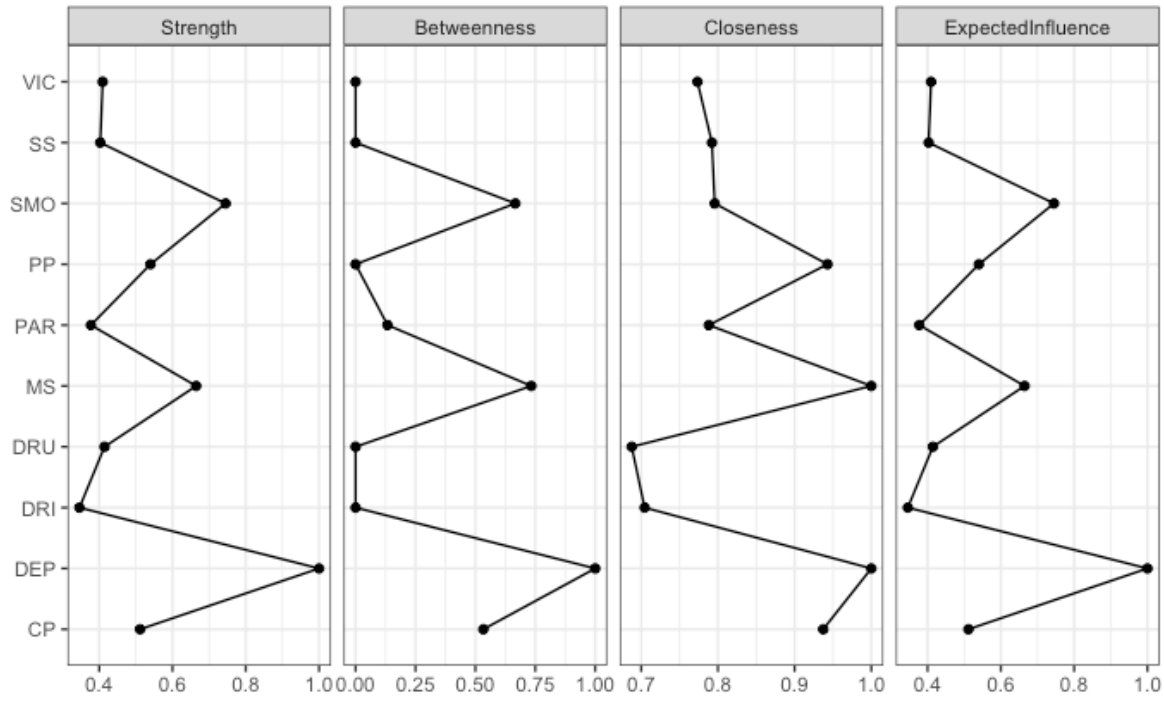

Figure 4.4. The relative centrality scores for strength, betweenness, closeness and expected influence are plotted for each node within each network. Symptom nodes are represented along the Y-axis and the relative centrality scores are represented on the X-axis, from 0-1 (standardised). DEP = Depression, MS = Minority Status, VIC = Victimisation, SS = Social support, PAR = Closeness to parents, PP = Peer problems, CP = Conduct problems, DRU = Drug use, SMO = Smoking, DRI = Drinking.

4.4. Discussion

I set out to explore the complex links between sexual minority status and depression, interpersonal difficulties and health risk behaviours in a large sample of adolescents. I first replicated a previously reported effect in this sample (Amos et al., 2020), showing that across nearly all variables included, adolescents reporting same sex attraction had poorer outcomes across every measure. I then extended these findings by employing network analysis. This revealed that sexual minority status sits at centre of a network of adverse outcomes, with both direct and indirect relationships with multiple negative associations.

Sexual minority adolescents are more likely to experience depression and victimisation at rates much mightier than their heterosexual counterparts (Amos et al., 2020; Li et al.,

2017; Lucassen et al., 2017; Luk et al., 2018). In the network model I found that sexual minority status formed a cluster with depression and victimisation. This shows that these variables were uniquely related to one another, when controlling for all other variables in the network. Indeed, the single largest predictor of depression was sexual minority status. It is also worth noting that, whilst our network model is undirected - relationships are assumed to be bidirectional - given the nature of the variables included here we can reasonably assume the direction of effect is from sexual minority status towards depression. This relationship was significantly stronger than the relationships between all other variables and sexual minority status. This is striking when we consider the other variables included in the network and how regularly they are associated with poor mental health.

It is possible that identifying as a sexual minority at age 14 might act to differentiate a young person from his or her peers, placing him or her at greater risk of ostracism during a period of life when peer rejection and victimisation are risk factors for depression (Bowes et al., 2015; Platt et al., 2013). Previous work has shown that adolescents with higher concern for social risks – behaviours which could lead to social rejection (e.g. appearing dissimilar to one's friends) - are more likely to report higher rejection sensitivity and depressive symptoms (see **Chapter 2**). This concern for social risk may be especially salient for sexual minority adolescents who are already at significant risk of experiencing minority stress in which stigma, prejudice and discrimination increases incidence of mental health problems (Bariola et al., 2016; Meyer, 2003).

These analyses provide further insight into why sexual minority adolescents show such wide-ranging poor outcomes. Whilst some of the relationships between sexual minority status and other variables in our network (e.g. depression, peer and conduct problems) were direct, several observed relationships were indirect. For example, victimisation, poor closeness with parents, poor social support and drinking behaviour are not directly associated with sexual minority status but are indirectly related via depression. That is, poor outcomes in these domains for sexual minority adolescents can be understood as downstream consequences of depression. There is an extensive literature showing that depression during adolescence is related to excessive drinking, poor family relationships

and poor social support (e.g. Alm et al., 2020; Pesola et al., 2015; Scardera et al., 2020). The fact that sexual minority, relative to heterosexual, adolescents report higher scores on each of these variables, may therefore be a consequence of the vast increase in incidence of depression among this group of young people.

Similarly, drug use and smoking were indirectly related to sexual minority status, representing downstream consequences of conduct problems. Whilst there was no difference in the total scores of conduct problems between sexual minority and heterosexual adolescents (when controlling for multiple comparisons), the shortest path analysis found that the most likely reason that sexual minority status relates to higher drug use and smoking is via an indirect association with conduct problems. Given that sexual minority adolescents are more likely to report increased rates of health risk behaviours compared with their heterosexual counterparts, it is possible that interventions aimed at improving peer relationships and conduct problems - which formed a cluster of related variables in the network - among sexual minority adolescents might have positive effects in reducing engagement in certain health-risk behaviours (Amos et al., 2020; Li et al., 2017).

4.4.1. Limitations

The results presented here should be considered within the context of a number of limitations. Firstly, the measure of sexual minority status is solely based on same sex attraction. The measures within the MCS data do not ask more nuanced questions about sexual attraction, or gender identity. Second, although some work has shown age 14 to be the average age at which an individual 'comes out' as non-heterosexual (D'Augelli et al., 2010), many have not come out to themselves, or others by this age. Third, the importance of the contribution of interpersonal relationships to depressive symptoms might also differ depending on whether this information is disclosed or not to family and peers, a question that cannot be addressed with this data set. Fourth, many measures of depression exist, and each measure differs in some way – by content and scale. One outstanding question is how well our results translate when depression, and indeed other variables included here, are assessed with different measurement tools. Finally, around the time of data collection, marriage equality legalisation was being debated in

the United Kingdom. Subsequent changes in public perceptions and stigma may alter the interrelationships within the network, weakening links between sexual minority status and adverse mental health outcomes.

4.4.2. Conclusion

Here, I show that identifying as a sexual minority is connected to a wide array of adverse outcomes in adolescence. In our network, I found a unique and strong relationship between sexual minority status and depression. Indeed, many of the poor outcomes associated with sexual minority status, are indirectly related. That is, they are downstream consequences of depression and peer/conduct problems. In particular, the relationship between sexual minority status and victimisation, poor closeness with parents, poor social support and drinking behaviour all occurred indirectly via depression. In addition, the link between sexual minority status and smoking and drug use occurred via conduct problems. Interventions aimed at reducing poor outcomes among sexual minority adolescence may be most effective if they target depression and poor peer/conduct problems.

In the next Chapter, I ask a broader question relevant to adolescent social development, relating to how adolescents, relative to adults, show a preference social vs. non-social information.

Chapter 5: Social preference in adolescence

The study presented in this chapter has been published as: **Andrews, J. L.,** Foulkes, L., Griffin, C., & Blakemore, S. J. (2019). The effect of social preference on academic diligence in adolescence. ***Royal Society open science***, *6*(9), 190165.

5.1. Introduction

One proposed reason that adolescents are particularly sensitive to social influence is that social stimuli have a higher reward value for adolescents compared to adults (Foulkes & Blakemore, 2016). In one study, children (6-12 years old), adolescents (13-17 years old) and adults (18-29 years old) performed a go/no-go task, with both appetitive (happy faces) and neutral (calm faces) cues (Somerville et al., 2010). Compared with children and adults, adolescents made more errors on no-go appetitive trials (but not on neutral trials). This suggests that, when presented with appetitive cues (happy faces) adolescents exhibit a reduced ability to suppress approach behaviours (Somerville et al., 2010). In another study, adolescents (12-14 years old) but not adults (18-29 years old) showed reduced performance on an N-Back working memory task when distracted by smiling faces (Cromheeke & Mueller, 2016). There is also some evidence that adolescents show hypersensitivity to social reward, as shown by heightened activation in reward related brain regions such as the ventral striatum (Pfeifer et al., 2011; Somerville et al., 2010). However, drawing clear conclusions regarding the reward value of such stimuli from fMRI data alone is problematic give the problem of reverse inference (Foulkes & Blakemore, 2016; Poldrack, 2006). In sum, several studies to date have shown hypersensitivity to positive social stimuli in adolescence, but whether this is due to heightened reward value of social stimuli remains unclear (also see **1.4.5**).

Other studies investigating age differences in social reward or social preference have revealed mixed results (Foulkes & Blakemore, 2016). For example, social/monetary incentive delay tasks have shown no significant preference for social over non-social stimuli in adolescents for money versus faces (Damiano et al., 2015) nor for images of real people versus cartoons (Silva et al., 2015). Furthermore, a preference for non-social versus social stimuli in adolescents has been shown in an approach-avoidance task for cars versus faces (Ewing et al., 2013) and in a visual exploration task in which gaze behaviour was measured across an array of pictures including faces and non-social items related to circumscribed interests (e.g. trains) (Sasson et al., 2008).

In a more recent study, 255 typically developing individuals aged between 4 and 20 years old were evaluated on a social motivation 'Choose a Movie' Task. During this task, participants are asked to choose between viewing social (of people) or non-social (of

everyday objects) movies, which are presented with varying levels of effort (key presses required). The typically developing adolescents in this study showed no clear stimuli preference (Dubey et al., 2017). However, this study did not include participants older than 20 years. Therefore, the current study was developed to explore whether adolescents, compared to adults, show a preference for social versus non-social stimuli.

In order to investigate this question, I used a paradigm designed to study academic diligence, the tendency to expend effort on academic tasks that are momentarily tedious but beneficial in the long term (Galla et al., 2014). Academic diligence can be thought of as a domain-specific component of self-control and exercising self-control in order to stay focused on an academic task, especially given the many distractions adolescents are faced with, is beneficial to future success (Tangney et al., 2004). Higher academic diligence is related to better academic performance, as well as to other outcomes including good mental health (456 males tracked from 14 to 47 years) (Vaillant & Vaillant, 1981). For example, parental reports of their child's diligence (e.g. "stays at a task until it's done") are correlated with their child's academic outcomes, including high school and college grade point average (GPA) (Oliver et al., 2007).

The most widely used experimental measure of academic diligence is the Academic Diligence Task (ADT) (Galla et al., 2014). The ADT was designed to simulate the types of decisions that students are often faced with when doing school work. In this task participants must allocate their time and effort to either a tedious but "good for you" maths task or a more enjoyable distractor task (such as the video game Tetris™ or watching music videos). In a large sample of adolescents (mean age 17.9 years, SD= 0.51), proportion of time spent on the maths predicted GPA, maths and reading scores, and college enrolment more robustly than demographics and IQ (Galla et al., 2014).

Young people are often faced with a choice between academic work and social activities, such as spending time on social media or with friends in both home and school environments. Thus, in the present study, we adapted the ADT in order to assess whether the opportunity to engage with social or non-social stimuli (photographs) would have a differential effect on academic diligence in adolescents and adults.

Participants were presented with basic maths questions and the option to switch out of the maths activity in order to look at a show-reel of photographs. In the social ADT the photographs depicted people, while in the non-social ADT the photographs depicted landscapes. For each version of the task, participants had the option to switch between the basic maths activity and looking at the show-reel of photographs as many times as they liked within a 10-min period. After each condition, participants also provided enjoyment ratings for the maths questions and the photographs.

I hypothesised that there would be a difference in the amount of time adolescents and adults spent looking at photographs in favour of doing maths on the ADT, such that adolescents would be more interested in looking at photographs in the social condition than in the non-social condition and this would not be the case for adults. I further hypothesised that compared with adults, adolescents would report enjoying the social stimuli more than the non-social stimuli. Lastly, I hypothesised that the time spent looking at the photographs in each condition would positively correlate with the picture enjoyment ratings, for both age groups.

5.2. Method

5.2.1. Participants

Ninety-one female participants, comprising 45 adolescents aged 11-17 (mean age: 15.4; SD: 1.81) and 46 adults aged 23-33 years old (mean age: 24.96; SD: 2.61), took part in the study. Sample homogeneity was increased by recruiting only female participants, removing variance that could be accounted for by sex differences in puberty onset (Herting et al., 2012). Participants were excluded from participating if they had any diagnosed developmental disorder, including dyslexia, dyscalculia or autism spectrum conditions. Participants were recruited from the Greater London area through advertisements in schools, social media and via the Psychology department subject pool. Participants completed the matrix reasoning subscale of the WASI (Wechsler Abbreviated Scale of Intelligence), and questionnaire measures for autistic traits, social reward and grit (See **Appendix A4.1** and **Table A4.1** for descriptive information and further discussion of these measures).

The study followed the Research Ethics Guidelines and was approved by the University Research Ethics Committee. Informed consent was obtained from adult participants and consent was obtained from the parent or guardian of participants under 18 years old. Following the completion of the study, participants were debriefed, given the opportunity to ask any questions and compensated £10 for their time. Testing was carried out individually in a quiet room at school or in the lab.

5.2.2. Adapted academic diligence task

I developed an adapted version of the Academic Diligence Task (ADT) (Galla et al., 2014). As in the original ADT, participants were presented with the option of either completing arithmetic multiple choice problems (e.g. 5+5=?; 2x3=?), which were described as 'basic,' or engaging with a distractor task. The arithmetic questions were kept simple so that maths ability would not confound diligence, and they were designed to be boring in order to represent the temptation to stop a purportedly beneficial but monotonous task in favour of a more interesting distractor task. Using basic arithmetic problems reduced the likelihood that individuals who would ordinarily enjoy completing maths problems would find the task engaging (Fuhrmann et al., 2019). This increases the likelihood that any variation in the time spent on the maths is due to diligence.

In the original ADT paradigm, the distractor task gives participants the option of playing games (such as Tetris^{TM}) or watching videos. Here, I adapted the ADT such that the distractor task comprised a show-reel of photographs (**Figure 5.1**). The photographs either depicted people (either alone or interacting; the social ADT), or landscapes (the non-social ADT). The photographs within each condition were presented in a random order, with each picture presented for 5 secs before automatically moving to the next photograph. A large selection of social and non-social pictures was collected from online stock picture websites and Google searches. All pictures were free for non-commercial reuse. For the purpose of piloting, the images were rated by six adults for positive valence, and then reduced down to 60 social and 60 non-social pictures. Each photograph was included in both colour and black and white; therefore, a total of 120 social pictures and 120 non-social pictures were included for possible viewing in each

condition. The social and the non-social ADT each lasted 10 mins. Participants completed both the social and non-social ADT, so the total task duration was 20 mins per participant. Condition order (social or non-social ADT first) was counterbalanced across participants.

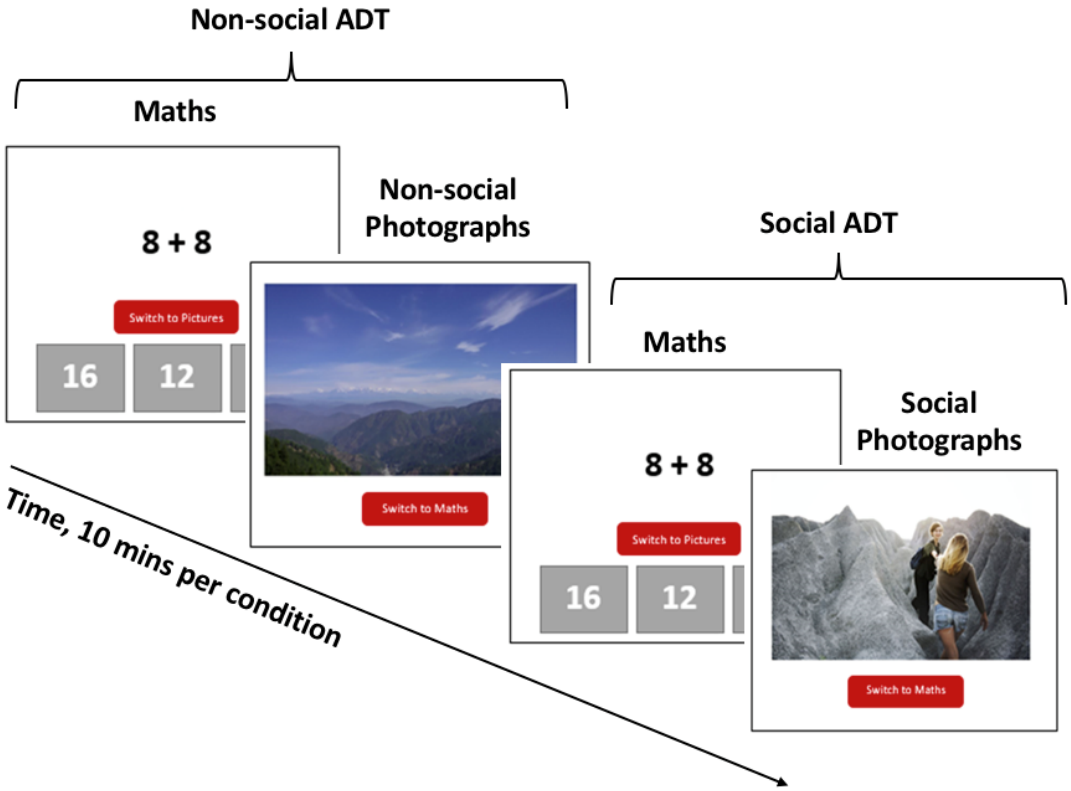

Figure 5.1. Task schematic of adapted ADT. Participants are presented with a non-social and a social version of the ADT (the order is counterbalanced across participants). Each condition lasts for 10 minutes and participants are given free choice to either complete simple mathematics questions or switch at look at non-social or social pictures, depending on the condition.

Participants were initially presented with an introduction screen that emphasised the benefits of practising simple maths problems: "Research has shown that completing simple maths questions such as these will help improve your problem-solving skills in the future". This statement was further emphasised by the experimenter. Participants were then told that at any moment they could switch from the maths and look at some

pictures of people (or landscapes). They were told that they could switch back and forth between the maths and pictures as many times as they liked within the 10-min block. Note that the task length was 10 minutes for all participants, regardless of the activity they chose. Before the task began, each participant was shown examples of the type of maths problems they would encounter, and the type of pictures they could view. The task always began with the maths questions. For each condition we were able to compute the percentage of time each individual spent doing the maths questions compared to looking at the photographs. Time looking at pictures was automatically recorded in milliseconds (ms) by the programme, and defined as the time between the button press to exit maths and look at pictures to the button press to exit the pictures and do maths.

After each version of the ADT, participants were asked to rate how enjoyable they found the maths and the show-reel of photographs, on a scale from 0 (not enjoyable) to 100 (extremely enjoyable), unless they spent 100% of their time on the maths, in which case they did not have to provide a rating for the photographs.

Once the participant had read the instructions the experimenter clarified any questions and left the participant to complete the ADT on their own in the testing room. The experimenter was not present in the room during the task in order to minimise any demand characteristics that may arise due to the participant believing that they should spend more time doing maths as the experimenter was watching.

5.2.3. Statistical analysis

Data were analysed using SPSS 24 (IBM Corp., Armonk, NY). In order to test the first hypothesis, a 2 (age group: adult, adolescent) x 2 (condition: social, non-social) mixed model repeated-measures ANOVA was performed to investigate the effect of age and task condition on diligence scores (i.e. time spent doing maths). To test the second hypothesis, I performed two further 2 (age group) x 2 (condition) mixed model repeated-measures ANOVAs on the enjoyment ratings, for the maths questions (see **Appendix A4.4** and **Figure A4.1** for the maths findings and **Appendix A4.2** for further analyses on

the number of switches participants made in each condition) and the photographs. Pairwise t tests were performed to interrogate simple effects, and were Bonferroni corrected for multiple comparisons. For each ANOVA, we then ran follow up ANCOVAs controlling for autistic traits, social reward and grit.

Pearson's r was used to test the third hypothesis. We investigated the correlation between the participants' picture rating scores and the time spent looking at the pictures, for each condition. We first performed two correlations, one for each condition, including all participants. We then split the analysis by age group, and compared the correlations between the two groups using Fishers Z.

5.3. Results

5.3.1. Percentage of time spent looking at photographs in the ADT

There was no main effect of age group (F(1,89)= 2.146, p= .146, η^2= .024) or condition (F(1,89)= 0.135, p= .714, η^2= .001) on the percentage of time spent looking at the photographs. However, there was a significant interaction between age group and condition (F(1,89)= 7.090, p= .009, η^2= .074) (**Figure 5.2**; see **Table 5.1** for descriptive statistics). This was driven by adolescents spending less time looking at the non-social photographs, compared with adults (t(89)= -2.867, p= .02). There was no significant difference in the time spent looking at the social photographs between adolescents and adults (t(89)= -.527, p= 1.00). Adolescents spent more time looking at the social photographs compared to the non-social photographs (t(44)= -2.197, p= .033), however this finding did not survive Bonferroni correction for multiple comparisons (correction for four post-hoc t tests; p=.132). There was no significant difference between the time spent looking at the social photographs compared to the non-social photographs for the adults (t(45)=1.586, p=.48). When controlling for AQ, there was a significant interaction between age group and condition (F(1,86)=6.187, p=.015, η^2=.067). Main effects of age and condition were non-significant (p>.05). Similarly, when controlling for social reward and grit there was also a significant interaction between age group and condition (p<.05) and all other main effects were non-significant (p>.05). The results did not change when the data was analysed continuously, controlling for autistic traits, social reward and grit.

See **Appendix A4.5 (Figure A4.2 and A4.3)** for distribution plots of the time spent looking at the social and non-social pictures for each age group.

	Adolescents		Adults	
	Social ADT	**Non-social ADT**	**Social ADT**	**Non-social ADT**
% time looking at photographs	*M*=24.4% *SE*=4.35 *N*=45	*M*=13.87% *SE*=2.86 *N*=45	*M*=21.43% *SE*=3.59 *N*=46	*M*=29.41% *SE*=4.57 *N*=46
Enjoyment ratings for photographs	*M*=45.89 *SE*=5.2 *N*=27	*M*=35.48 *SE*=5.08 *N*=27	*M*=41.11 *SE*=4.94 *N*=38	*M*=57.16 *SE*=4.52 *N*=38

Table 5.1. Descriptive statistics. Means and standard error for the time spent looking at the photographs and the self-reported enjoyment ratings for the photographs, in each condition of the ADT.

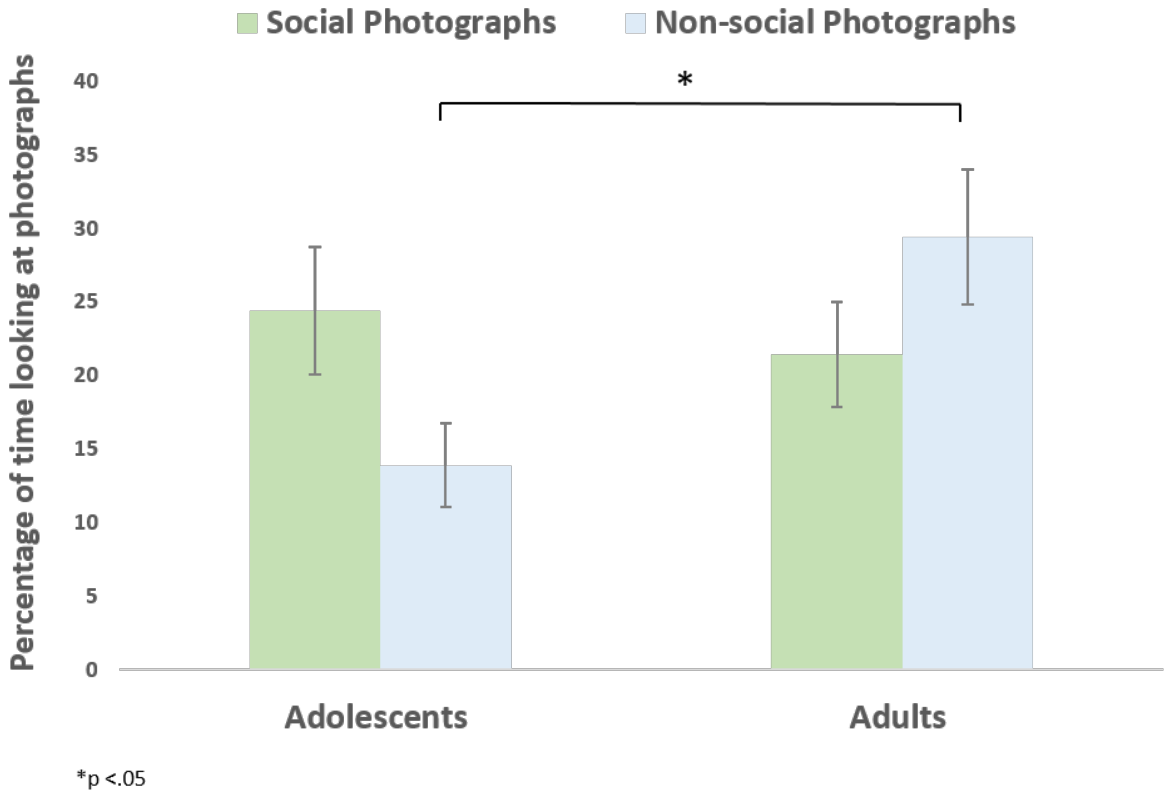

Figure 5.2. Mean percentage of time spent looking at the photographs in each condition, for adolescents and adults. Asterisks indicate Bonferroni corrected P values.

One adult participant answered no maths questions in either condition and another adult answered no maths questions in the non-social condition. Participants' accuracy (proportion of correct answers) on the maths task was very high for both the adolescents and adults in each condition. Within the social condition, accuracy on maths was 95.73% (S.D. 5.06) for adolescents and 97.78% (S.D. 4.77) for adults (t(88)= 1.98, p= .051). In the non-social condition, accuracy on maths was 96.79% (3.18) for adolescents and 98.25% (3.45) for adults (t(88)= 2.06, p= .04). The reaction time data showed that adolescents took longer to choose an answer to the maths questions compared to the adults, in both the social (*t*(88)= 5.99, *p*= .001) and non-social (*t*(87)= 4.66, *p*= .001) condition.

5.3.2. Photograph enjoyment ratings following the ADT

18 of the 45 adolescent participants and 8 of the 46 adult participants were not included in this analysis as they chose to spend all their time answering maths questions in either the social or non-social condition or both. There was no significant main effect of age group (*F*(1,63)=1.966, *p*=1.66, η^2=.030) or condition (*F*(1,63)=.564, *p*=.455, η^2=.009) on the picture enjoyment ratings. However, there was a significant interaction between age group and condition (*F(*1,63)=12.40, *p*=.001, η^2=.164). Pairwise comparisons showed that there was a significant difference between the enjoyment ratings for adults compared with adolescents for the non-social pictures, such that adults showed a greater preference for the non-social photographs (*t*(63)=-3.156, *p*=.008), but not for the social pictures (*t*(63)= 0.653, *p*= 1.00). Adolescents reported enjoying the social pictures significantly more than the non-social pictures (*t*(26)=2.705, *p*=.048), whilst adults reported enjoying the non-social pictures significantly more than the social pictures (*t*(37)=2.814, *p*=.032) (**Figure 5.3**; see **Appendix Table A4.1** for descriptive statistics). When controlling for AQ, there was a significant interaction between age group and condition (*F(*1,62)=10.04, *p*=.002, η^2=.137). Main effects of age and condition were non-significant (p>.05). Similarly, when controlling for social reward and grit there was also a significant interaction between age group and condition (p<.05) and all other main effects were non-significant (p>.05).

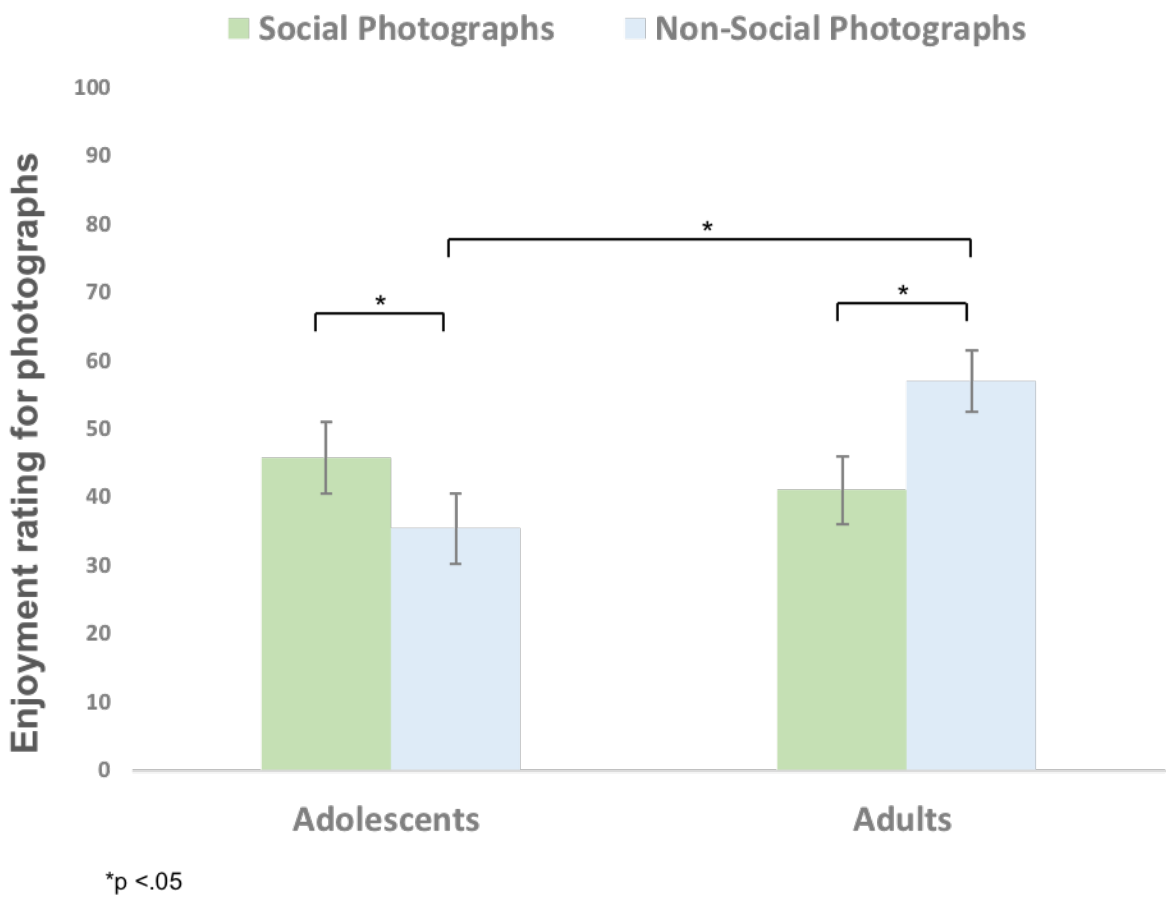

Figure 5.3. Mean enjoyment ratings for the photographs in each condition, for adolescents and adults. Asterisks indicate Bonferroni corrected P values.

5.3.3. Correlations

Across all participants, there was a significant positive correlation between the time spent looking at the social pictures and the enjoyment ratings provided for the social pictures ($r(73)=.274$, $p=.017$) (**Figure 5.4**). There was also a significant positive correlation between the time spent looking at the non-social pictures in the non-social ADT and the enjoyment ratings provided for the non-social pictures ($r(73)=.232$, $p=.045$) (**Figure 5.4**). When splitting the data by age group, within the non-social ADT, there was non-significant correlation between the time spent looking at the non-social pictures and the enjoyment ratings provided for the non-social pictures for adolescents ($r(30)=-.095$, $p=.606$). There was also a non-significant correlation for the adults ($r(41)=.286$, $p=.063$). There was a significant difference between these two correlations, with the adults showing a stronger correlation between enjoyment ratings for and time

spent looking at non-social photographs than the adolescents (Fisher's z=2.66, *p*=.008). Within the social ADT, there was a non-significant correlation between the time spent looking at the social pictures and the enjoyment ratings provided for the social pictures by the adolescents (*r*(33)=.253, *p*=.143). There was also a non-significant correlation for the adults (*r*(38)=.297, *p*=.063). There was no significant difference between these two correlations (Fisher's z=-.2, *p*=.84).

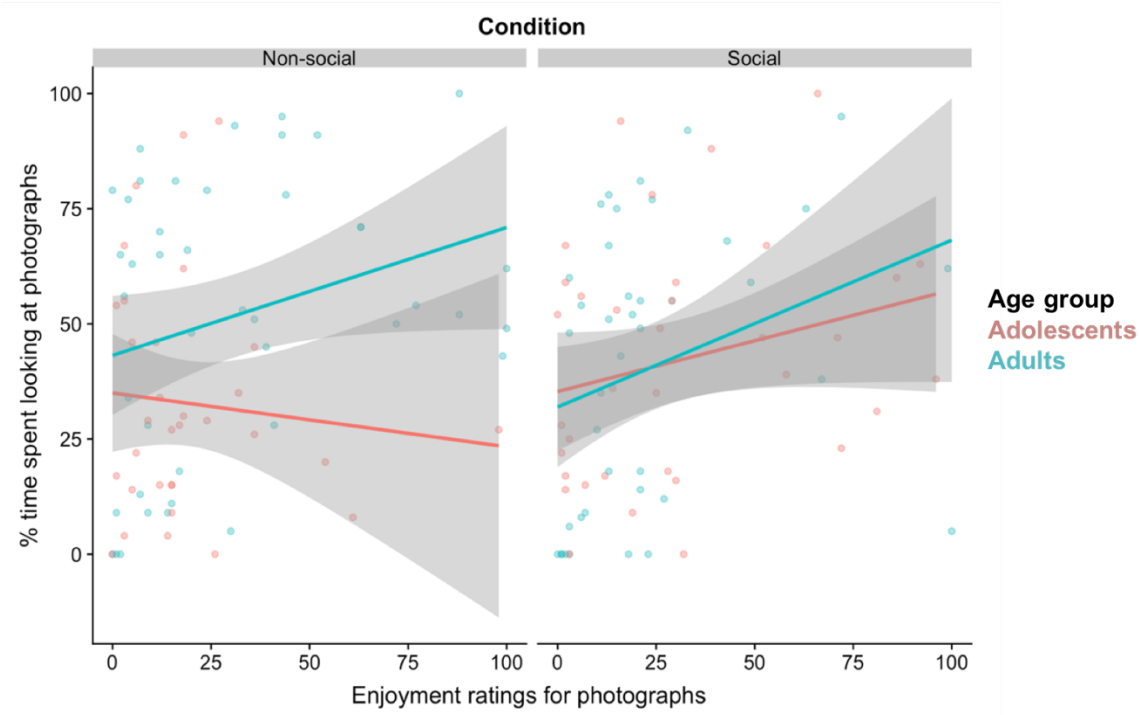

Figure 5.4. The relationship between the enjoyment ratings and time spent looking at the photographs, in the non- social ADT and the social ADT.

5.4. Discussion

The current study investigated the degree to which the presence of social versus non-social stimuli affects academic diligence in female adolescents and adults. In line with my second hypothesis, adolescents reported enjoying the social photographs significantly more than the non-social photographs, whilst the adults reported enjoying the non-social photographs significantly more than the social photographs. There was no significant difference in the time spent looking at the social photographs between

the adolescents and adults. However, adults spent significantly more time than adolescents looking at the non-social photographs, suggesting that adolescents were less motivated to look at the non-social stimuli in comparison to the adults. The correlation between self-reported enjoyment of the pictures and task performance was stronger for adults than for adolescents in non-social condition, suggesting that explicit enjoyment ratings are a stronger predictor of choice behaviour in adults than in adolescents.

The results showed that adolescents spent less time looking at the non-social photographs, compared to the adults, in the non-social ADT; in other words, adolescents were more diligent that adults in the non-social condition of the ADT. Thus, adolescents showed a reduced motivation to look at non-social stimuli compared with adults. While this is broadly in line with the first hypothesis, I found no difference between the time the two groups spent looking at the social photographs in the social ADT, which does not support the first hypothesis.

Consistent with my second hypothesis, adolescents reported enjoying the social photographs more than the non-social photographs, whilst the opposite was true for the adults, who reported enjoying the non-social photographs more than the social photographs. In addition, and in line with the ADT-preference data (photograph ratings), adolescents reported enjoying the non-social pictures less than did adults. In contrast, adolescents and adults did not differ in the degree to which they enjoyed looking at the social pictures. The photograph enjoyment ratings thus mirror the behavioural finding that adolescents spent less time looking at the non-social photographs than did adults, in the non-social ADT. These findings demonstrate that adolescents self-reported a preference for social over non-social stimuli, while adults explicitly reported a preference for the non-social over social stimuli. Taken together with the ADT-preference findings, these data suggest that between adolescence and adulthood, preference switches from social (people) to non-social (landscapes) stimuli.

For both the social and non-social ADT, there was no significant correlation between time spent looking at the pictures and reported enjoyment of the pictures for

adolescents, and only a trend for adults. Thus, in both groups, explicit enjoyment ratings were not a strong predictor of choice on the ADT. However, there was a significant difference between the correlations for the two age groups within the non-social ADT, which was driven by a stronger relationship between self-reported preference and choice behaviour in adults compared with adolescents. In non-social ADT, adults' choice behaviour more closely resembled their self-reported preferences, whilst the behaviour of adolescents was less related to their self-reported preferences. These results are consistent with previous findings that metacognitive and introspective abilities – the capacity to reflect on one's own thoughts or behaviours – continue to develop during adolescence (Weil et al., 2013). For example, in one study of 11-41-year-olds, the relationship between performance on a visual task and participants' confidence in their performance increased during adolescence, before plateauing into adulthood (Weil et al., 2013). These findings reveal a similar trend, whereby the self-reported preferences, reported after each version of the ADT, better reflected choice behaviour during the non-social ADT for adults, compared with adolescents.

Previous studies involving adolescent participants have also noted the absence of any significant relationships between self-reported 'liking' and behaviour. For example, in one previous study that investigated social motivation in adolescence, a social incentive delay task was carried out by a group of 8 to 16-year-olds, where social rewards were operationalised as smiling faces and verbal approval. Although the subjective value of the faces increased with the intensity of the faces' happiness, this intensity effect was not reflected in behaviour during a social incentive delay task (Demurie et al., 2012). Therefore, these results add to a broader literature that distinguishes self-reported liking from behaviour during adolescence, which we interpret within the context of developing introspective awareness during adolescence.

5.4.1. Limitations

There were a number of limitations of the current study. Only female participants were included in order to increase sample homogeneity, however this prevents any comparisons between genders. One limitation of the experimental design is that

participants who chose not to look at any pictures and spent all their time on the maths task, and vice versa, did not provide an enjoyment rating. This reduced the number of individuals included in the analyses of the enjoyment ratings. In future versions of the task, requiring all participants to trial the pictures and maths would provide a complete set of ratings. Given that 18 of the 45 adolescent participants and 8 of the 46 adult participants chose to spend all their time on the maths in at least one of the conditions, the strength of the stimuli (i.e. passively viewing photographs) may have been too weak to elicit a distraction effect for these individuals. Future studies of this nature should investigate the use of a social vs. non-social distraction task, such as engaging in a virtual game with other players (social) versus a single player game (non-social). Nevertheless, previous work using the original ADT paradigm in a sample of 40 adolescent girls aged 14-15 years found the average percentage time spent on the maths was 84% [22], comparable to the percentages observed in this study.

Another consideration is that the way in which this task conceptualises social preference differs to some degree to previous tasks aimed to elicit preference behaviour. Previous tasks such as those discussed in the introduction (Dubey et al., 2017.; Ewing et al., 2013; Silva et al., 2015) closely resemble a positive reinforcement paradigm, whereby individuals receive a positive reward following an action e.g. a button press. In this task, individuals' preference behaviour was assessed within a context of academic diligence, closely resembling a negative reinforcement paradigm, whereby individuals cease a 'boring' task in order to engage with something more appealing (the pictures). The pictures therefore act as a potential distractor, and as such I interpret this distraction effect as the extent to which individuals exhibit a preference towards the social vs. non-social stimuli.

5.5. Conclusion

The present study assessed the degree to which adolescents and adults show a preference for social versus non-social stimuli, within the context of an academic diligence task. I found an age-related effect on task performance, whereby adolescents chose to view the non-social stimuli significantly less than did the adults in the non-social

ADT, suggesting that adolescents are less motivated to seek out non-social stimuli than are adults. Adolescents reported enjoying the social stimuli more than the non-social stimuli, while the reverse was true for adults. Taken together, these results suggest that the value of non-social, relative to social, stimuli increases with age. Finally, adolescents' self-reported preferences showed a less strong significant relationship with behaviour in the non-social ADT, than did adults' self-reported preferences, which more closely related to their choice behaviour in the non-social ADT. These results support the notion that metacognitive and introspective abilities are still developing during adolescence.

Chapter 6: General discussion

Parts of this chapter have been published as:

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6.1. Summary of findings

The studies presented in this thesis contribute to a large body of findings from the developmental sciences suggesting adolescence to be a unique period of development, and in particular point to adolescence as a period of continued social development (Mills & Blakemore, 2016). In this discussion, I first summarise the findings from the studies presented in this thesis and discuss the general limitations of this work, before considering how the results from this thesis, and developmental science more broadly, can inform health policy and the law. Finally, I suggest future questions and directions.

Traditional models of risk-taking behaviour often focus on health risks (e.g. negative health risks such as binge drinking or drug taking), legal risks (e.g. stealing) or financial risks (e.g. gambling). However, models of risk behaviours have largely neglected another facet of risk, and risk-taking: social risk. As described in **1.6**, a social risk can be defined as any decision or action that could lead to an individual being excluded by their peers, such as appearing different to one's friends. Previous theoretical accounts of social risk (e.g. Mills & Blakemore, 2016; Blakemore, 2018; Allen & Badcock, 2003) have suggested that adolescents may be especially sensitive to social risks, and that this may in turn be a driver towards socially risk averse behaviours, such as an increased tendency to confirm to peer norms, with the ultimate aim to increase one's social value. In addition, Allen and Badcock's (2003) social risk hypothesis of depressed mood suggests that temporary states of depressed mood may have evolved to increase socially risk-averse behaviour when one's social value is low and their burden is high. This view is founded on evolutionary theory and suggests that some aspects of depression, such as social withdrawal, may provide temporary benefits to individuals at risk of rejection, by removing them from situations which could further damage their reputation.

Therefore, in the study described in **Chapter 2,** I developed and validated a measure of concern for health and social risk for use in individuals of 11 years and over (N=1399). I tested the relationship between concern for health and social risks with age and found that concerns for both health and social risk declined with age. This finding challenges a commonly held stereotype that adolescents are less worried about engaging in risk

behaviours, compared with adults. The rate of decline was steeper for social versus health risk behaviours, suggesting that adolescence is a period of heightened concern for social risk. In other words, adolescents reported greater concern than did adults about engaging in behaviours that run counter to the views or behaviours of their peers. This is consistent with previous work suggesting adolescence is a period of heightened sensitivity to social evaluation (Somerville, 2013).

Greater concern for social risk was also associated with increased sensitivity to rejection and greater depressed mood, and this association was stronger for adolescents compared with adults. This supports the proposal presented in **1.6** that during adolescence increased rates of depressed mood may be more likely given the increased sensitivity to social risk and desire to maintain one's social value and avoid social rejection. Perhaps as an extension to Allen and Badcock's social risk hypothesis, increased rates of depression observed during adolescence (Kessler, 2007) may in part reflect this heightened sensitivity to social risk and rejection (Sebastian et al., 2010). According to this hypothesis, low and transient states of depressed mood may be beneficial in times of heightened social risk. Therefore, it is possible that adolescents, who are especially sensitive to social risks and social rejection, are more likely to experience low mood, relative to adults.

Whilst these findings suggest that concern for social risks decline with age, from early adolescence through to late adulthood, the youngest participants in this study were 11 years of age. Therefore, we are unable to say whether this heightened concern for social risk seen during adolescence is also true for children below the age of 11. This increased sensitivity to social risk may be represented as a continuous sensitive period in which social risk concern declines from childhood into adulthood or may be adolescent specific. Future work should extend these results to younger populations, whilst making sure that the types of social risk presented are relevant to the age groups being studied.

These results from the study described in **Chapter 2** are consistent with a wider literature suggesting adolescence is a period of marked sensitivity to social evaluative concerns. In turn, decisions to engage in problematic risk behaviours such as health and

illegal risk behaviours are likely driven by social motives, which can include considerations of social risk (Blakemore & Mills, 2014). In **Chapter 3** I explored this further by making use of data collected as part of the Teen Decisions Study from the University of Oregon, USA. I examined how individual differences in expectations of social consequences relate to individuals' expected involvement in health risk behaviours. 122 adolescents (aged 11-17) reported their expected involvement in a number of risk behaviours and whether or not they expect to be liked more or less by engaging in the behaviour: the expected social benefit. Higher perceived social benefit was associated with higher anticipated involvement in a particular behaviour. In other words, adolescents who anticipated being liked more if they engaged in a risk behaviour were more likely to anticipate enacting that behaviour – this was true across all risk domains measured except risky sex. I speculate on reasons behind this in **3.4**.

The relationship between expected involvement and perceived social benefit was stronger for adolescents who reported a higher degree of peer victimisation, supporting the social augmentation hypothesis (Dishion et al., 2008). The social augmentation hypothesis proposes that experiencing chronic victimisation increases social reward sensitivity and increased the social value of peer interactions. As described in **1.6** young people with a history of victimisation may well be more sensitive to social risk and in turn more likely to engage in socially risk-averse behaviours. The findings presented here support this, demonstrating that the relationship between the expected social benefit of engaging in certain risk behaviours, and the anticipation of engaging in said behaviour is heightened for individuals who reported a higher degree of victimisation. This may function as a means to increase one's social value through giving increased importance to certain risk behaviours, despite the health and legal risks associated with them, that are thought to be valued by others. Later, in **6.3.1**, I discuss how the findings from **Chapter 2 and 3**, and prior work in this area, may have potential implications for public health interventions and the law.

Another factor that I proposed in **1.6** that might put individuals at higher social risk is belonging to a minority group. In **Chapter 4** I turned my attention to why it might be that sexual minority adolescents appear to have such poor outcomes across a number

of health and social domains. In particular, I was interested in understanding how sexual minority status impacts relationships between depression, interpersonal difficulties and health-risk behaviours. Using data from the UK's Millennium Cohort Study, I took a psychometric network approach to answering this question. I showed that for sexual minority adolescents, previously reported poor outcomes across drinking behaviour, poor social support, lack of closeness to parents and victimisation, may be downstream consequences of depression. The single largest association with sexual minority status in the network was with depression, reflecting a commonly found result that sexual minority adolescents are at a greater risk of experiencing depression relative to their heterosexual counterparts (Amos et al., 2020; Li et al., 2017; Lucassen et al., 2017; Luk et al., 2018). This is thought to be a product of minority stress (Bariola et al., 2016; Meyer, 2003); future work is needed to further explore the relationship between minority stress and depression in adolescent samples. In addition, the link between health-risk behaviours such as smoking and drug use and sexual minority status were found to be downstream consequences of conduct problems, which in turn clustered with peer problems. Collectively, these findings suggest that indirect interventions aimed at targeting poor interpersonal and health-risk behaviours may be effective if they directly target depressive symptoms and conduct/peer problems in this age group. In doing so, changing societal attitudes around minority groups, such as individuals identifying as a sexual minority are likely to be a significant driver of positive change.

One challenge that is likely when it comes to early intervention for sexual minority adolescence is identifying those in need. Although some evidence suggests that the average age of 'coming out' is 14, this still means that half of those individuals who will go on to identify as a sexual minority are yet to be open about their sexual orientation. This also raises the issue of whether the needs of individuals differ, depending on if they are 'out' or not. That said, the work I presented here identified two primary pathways that may perpetuate poor outcomes among those individuals at age 14 who identify as experiencing same sex attraction - via depression, and via conduct problems. There is some evidence that multifaceted psychosocial interventions for mental health using cognitive behavioural or attachment-based family therapy frameworks are effective in reducing depression and minority stress among sexual minority youth (Van Der Pol-

Harney & McAloon, 2019). However, it is worth noting here that these interventions are less likely to be needed if broader systemic social issues around sexual minority discrimination are addressed.

Given that adolescents spend a considerable amount of their time at school, interventions within school contexts aimed at reducing discrimination towards sexual minorities may also prove effective at reducing certain poor outcomes for this group of young people (Johns et al., 2019). For example, one such intervention conducted on over 21,000 Canadian school children aged 13-18, found that over the course of a year, the odds of sexual minority students experiencing discrimination, bullying and suicidal ideation reduced, following a school wide anti-sexual orientation discrimination campaign (Burk et al., 2018). Sexual minority adolescents who experience less discrimination are less likely to endorse depressive symptoms, which is likely to have positive knock-on effects across a number of other outcomes given the analysis presented in **Chapter 4**. It is promising that currently in the United Kingdom, all schools must discuss 'how stereotypes, in particular stereotypes based on…sexual orientation… can cause damage' (e.g. how they might normalise non-consensual behaviour or encourage prejudice). Whilst this a positive step in the right direction, targeted school based anti-sexual orientation discrimination campaigns are certainty still needed. These campaigns may be most effective when they are peer-led, as discussed **in Chapter 1.4.6**.

Finally, in **Chapter 5**, I presented evidence from an experiment I conducted to assess whether adolescents show a preference for social stimuli compared with non-social stimuli. I tested this within the context of academic diligence, that is, the ability to expend effort on tedious tasks that have long term benefits, by adapting the traditional version of the Academic Diligence Task (ADT). I created two variations of the ADT: a social ADT and non-social ADT. Individuals were required to freely split their time between an easy, boring arithmetic task and looking at a show-reel of photographs of people (in the social ADT) or landscapes (in the non-social ADT). Adolescents reported enjoying the social photographs significantly more than the non-social photographs, with the converse being true for adults. There was no significant difference in the time spent looking at the social photographs between the adolescents and adults. In addition,

adolescents did not spend significantly more time looking at the social versus non-social pictures, after controlling for multiple comparisons. This was not in line with my hypothesis but may have been due to a number of reasons including a conservative Bonferroni correction and sample size limitations. However, adults spent significantly more time than adolescents looking at the non-social photographs, suggesting that adolescents were less motivated to look at the non-social stimuli, relative to the adults. Further, the correlation between self-reported enjoyment of the pictures and choice behaviour in the ADT was stronger for adults than for adolescents in the non-social condition, revealing a greater discrepancy between self-reported enjoyment and ADT choice behaviour for adolescents. These findings add to a growling literature of mixed findings when it comes to social preference or social reward processing in adolescence (see **1.4.5** and **5.1**).

The practical implications of these results are somewhat difficult to infer given the mixed findings. However, given that the adolescent group showed a greater discrepancy between self-reported enjoyment and ADT choice behaviour, relative to the adult group, provides some support to previous findings that adolescents are still developing their metacognitive abilities as mentioned in **5.4**. This may have implications within educational contexts. During the teenage years, young people are often required to make long lasting decisions about their education, such as which subjects at school they wish to focus on. If their ability to reflect and accurately predict their own preferences is still developing this may be especially problematic when making some decisions that can have long lasting impacts on a person's future.

6.2. Methodological considerations and limitations

Taken together, the findings presented in this thesis suggest that adolescence is a period of social sensitivity. However, the work presented in this thesis should be interpreted within the context of a number of limiting factors. At the end of each empirical chapter, I raise a number of these limitations, and here I will build upon these by discussing some broad considerations and limitations.

Firstly, I present work that assessed age with the use of both continuous and categorical designs. For example, in **Chapter 2** I assessed the association between age and concern for health and social risks. Here I used a continuous approach assessing age from 11 to 79. However, when assessing the relationship between concern for social risk and rejection sensitivity and depression, I divided the sample into adolescents (under 18) and adults (18 and over), and then compared the strength of these correlations. This was because rejection sensitivity and depression were assessed with different scales and validated for different age groups. **Chapter 3 and 4** were conducted exclusively on adolescent samples, and comparisons with adults were not made. In **Chapter 3**, I controlled for age in all models where variation within adolescence may have impacted results. However, the lack of participants over the age of 17 in **Chapter 3** renders it impossible to discern whether or not the perceived social benefit of a decision remains an important predictor of risk-taking behaviour in adults, as well as adolescents. Relatedly, in **Chapter 4** all participants were aged 14, so developmental differences were not possible to explore, and I was unable to compare these findings with other age groups given the lack of consistent questions asked at each other time points in the MCS. However, in **Chapter 5** I split age into two categories; adolescents (aged 11-17) and adults (aged 23-33). It is important to point out that these cut-offs are somewhat arbitrarily formed and are not entirely consistent with the definition of adolescence as that made by Sawyer et al. (2018). This mixed approach, when assessing age, limits the ability to make direct comparisons across the studies presented.

The work presented in this thesis is cross-sectional in nature. This limits our ability to make inferences about within-individual developmental changes across time. For example, in **Chapter 2,** the finding that concern for social risk declines with age is inferred from data collected on different people across different ages. Therefore, we are unable to say anything about Individual trajectories of concern for health and social risk, and future work should seek to map longitudinal patterns of health and social risk. This same criticism also holds for the work presented in **Chapter 3,** in which we are unable to say anything about longitudinal changes in the extent to which perceived social benefit explains variation in expected involvement in certain risk behaviours.

The analyses conducted in **Chapter 4** made use of cross-sectional data from a large longitudinal study. However, at the time of analysis, subsequent waves of data had not yet been released, and indeed, comparison of networks across time requires the use of identical, or extremely similar, measures. In the subsequent wave of the Millennium Cohort Study, depression was not measured with the short-MFQ, but rather the 6 Kessler distress scale, making longitudinal analyses difficult and direct network comparisons difficult, if not impossible. Therefore, further longitudinal studies with a focus on sexual minority young people, in which consistent measures are taken, are needed to further probe the long-term trajectories of sexual minority adolescents.

Another limitation affecting the generalisability of the research presented in this thesis is the representativeness of the samples used. For example, in **Chapter 2**, to gain a large sample size, participants were recruited from several sources; in the case of under 18s this was from ongoing research projects in the lab and in schools, and over 18s were from ongoing research projects in the lab and through online recruitment. In **Chapter 3,** participants were recruited from two primary sources: the community and foster care settings. The participants in this study were also recruited from the USA, whilst participants included in **Chapters 2, 4 and 5** were from the UK. The data collected in this thesis is not nationally representative and also only provides a Westernised perspective, with participants recruited exclusively from the UK and USA. This limits cross-cultural comparison and therefore generalisations beyond the limited sample demographics of each respective study. Specific to **Chapter 2**, what is deemed a social risk will unquestionably vary with peer norms and these will vary based on location. The measure of concern for health and social risk I developed in **Chapter 2** should therefore be validated for use in other countries and may need adjustment to fit different cultural environments. For example, one question asks about concern for wearing clothes that are dissimilar to one's peers. In some countries, for example Islamic countries, this may not be a useful measure, given cultural and religious expectations on dress. Further, in **Chapter 5**, I only included female participants in order to increase sample homogeneity. This, of course, limits the ability to generalise these findings to males.

6.3. Applications to public-health and the law

6.3.1. Public-health implications: COVID-19

This thesis was written during the COVID-19 global pandemic and therefore presents an opportunity to discuss how developmental science, and the findings from this thesis can inform a specific public health problem of immediate concern. At the time of writing, governments worldwide have been implementing a number of measures to curtail the spread of the disease. These include closing sites of public recreation and education, such as schools and universities, and limiting face-to-face interactions through enforced 'social distancing'. This will, for the vast majority of the world's population, be an unprecedented experience in which the protection of the most vulnerable depends on strict adherence to the new measures. Whilst many people are adhering to guidelines, some are not. In particular, it is proving a challenge to convince some young people to refrain from physically meeting with friends and taking part in gatherings. For example, this was clearly demonstrated in reports of US students gathering in large groups during their Spring break (Noor, 2020).

As described in **Chapter 1,** adolescence is often associated with increased risk-taking, an increased need for social connection and peer acceptance, and a heightened sensitivity to peer influence. These factors mean that adherence to social distancing rules may be especially challenging for young people. Breaking social distancing rules is a risk-taking behaviour: it is a risk to one's own health and the health of others, and may carry legal or financial consequences. In the following sections I draw on evidence presented in **Chapters 1, 2 and 3** which demonstrates the effect of peer influence and social risk on adolescent risk behaviours, and how this peer influence could be harnessed in a positive way to encourage young people to follow social distancing measures.

Peer influence on adolescent behaviour. The presence of peers increases the likelihood that adolescents will take certain risks. For example, evidence from laboratory studies and real-world data show that, when driving, adolescents are more likely to have an accident when there is a passenger in the car, while adults are not (Chen et al., 2000; Gardner & Steinberg, 2005) (See **1.4**). Policy changes have been made to mitigate the

risk associated with young drivers carrying passengers. For example, in the Canadian state of British Columbia, drivers from the age of 17 are restricted to driving with only one passenger, unless they are carrying immediate family members or a full licence holder over the age of 25, for a minimum of two years. In the presence of peers, adolescents are also more likely to experiment with drugs, alcohol and cigarettes than when alone, and having friends who smoke or drink is one of the biggest predictors of adolescent engagement in these behaviours (Loke & Mak, 2013). This social influence is also seen online (Nesi et al., 2018). For example, adolescents (aged 14-17) are more likely to post sexual content online if their peers have done so. In fact, the speed and extent of peer influence is likely to be amplified online due to the wide reach and fast-acting nature of social media.

Adolescent social influence does not always have negative consequences. Young people are also less likely to engage in a risky behaviour if a friend discourages them from doing so (Maxwell, 2002). Adolescents are more socially influenced than adults to engage in (hypothetical) prosocial behaviours (Foulkes et al., 2018) and are more likely to volunteer in the community if they are told that their peers volunteer (Choukas-Bradley et al., 2015). Young people aged 12-16 years give more generously in an experimental public goods game when they observe peers being generous (Hoorn et al., 2016).

Adolescents are particularly susceptible to peer influence for several reasons. First, adolescents look to their peers to understand social norms. They align their behaviour over time with the norms of their group, or the group they want to belong to—a process known as peer socialisation (Henneberger et al., 2021). Second, adolescents may find it particularly rewarding to gain social status, a potential outcome of aligning with peers (Brechwald & Prinstein, 2011). Finally, adolescents tend to be hypersensitive to the negative effects of social exclusion (see **1.5**). They may conform to a group norm (which sometimes means taking a risk) in order to avoid this unpleasant social outcome: a view consistent with the evidence presented in **Chapters 2** and **3.**

Susceptibility to peer influence - both negative and positive - has important implications for the behaviour of adolescents in the current crisis. In the context of social distancing

measures, if an adolescent's friends break these rules and meet face-to-face, she may feel more inclined to do so herself. By breaking the rules, her friends have established a group norm, whereby meeting up is seen as acceptable. Fear of exclusion is also important: she may want to join because she misses her friends, but she may also feel a pressure to do so to reduce the social risk of being rejected (Blakemore, 2018). By the same token, in the current public health crisis, adolescents may also influence each other in a positive way. As discussed above, peers can also influence adolescents to behave more prosocially, and social norms can be changed (Paluck et al., 2016). This can be harnessed when communicating social distancing rules between young people.

Shifting social norms among adolescents. Many interventions aimed at changing behaviours among adolescents do not succeed. In **1.4.4** I discussed why this might be with the example of bullying interventions, which are primarily adult led and do not afford adolescents autonomy, nor do they speak to what is valued by young people. In the current pandemic, the campaigns to impose social distancing have been led by the government, and likely enforced by other adults (e.g. parents, teachers and police). One possible approach to enhance their effectiveness would be to provide adolescents with the autonomy to develop and deliver their own campaigns, with a focus on changing peer attitudes around the importance of social distancing. This process was successfully demonstrated by a study that utilised a peer-led approach to reduce rates of peer victimisation in schools. In this study, social network analysis was used to find highly connected, well-liked students (aged 11-15), some of which were randomly selected alongside other peers, to develop their own anti-bullying campaigns. Over the ensuing year there was a 25% reduction in victimisation rates in these schools compared with control schools. The effect was stronger when more well-liked students were randomly included to lead the campaigns (Paluck et al., 2016; see **Figure 1.6** in **1.4.4**). Similar successes have been observed for adolescent-led intervention programs aiming to reduce smoking, drugs and alcohol, compared with controls (MacArthur et al., 2016).

Given the current restrictions on face-to-face interactions, social media will likely be the most effective way to promote social distancing behaviours amongst adolescents.

Young people might post content online about how they are following the rules, for example, by sharing a photo or video of themselves at home. On platforms such as Instagram, they can add social distancing tags (phrases and images) to these posts. These will then be seen by their peers, who may add endorsements, such as comments and Likes, which increase the visibility of the post. As more adolescents see this content, social distancing can be established as a group norm amongst friends. This behaviour will then be modelled by those looking on, who may go on to post similar content themselves. One advantage of this approach is that it is adolescent-led and autonomous: the way in which young people manage social distancing, and their motivation for doing so, will stem naturally from the young people themselves.

Public health bodies should consider targeting, and even incentivising, influential individuals online, i.e. those who have the capacity to diffuse information amongst a large online social network. For example, it may be particularly useful to target social media 'influencers', individuals with a strong online presence and a large number of adolescent followers. If these individuals model positive social distancing behaviour and communicate the risk of COVID-19 through their platform, then adolescents may listen. An advantage of targeting social media influencers is that they exist across a number of domains of interest (such as different hobbies), and so are likely able to target large disparate groups of young people.

Although the coronavirus appears to pose a low risk to adolescents themselves, their willingness to follow social distancing guidelines is essential to reduce the risk for other people. Adolescent susceptibility to peer influence can be beneficial and should be harnessed by public health campaigns to increase social distancing. Adolescents themselves have a great capacity to influence each other in order to change norms and peer expectations towards public health goals. Especially important in creating change is the need to provide young people with the capacity to lead and enact their own ideas within their social networks. Asking adolescents to stay away from their friends at a key developmental period is a considerable challenge but can be achieved by taking advantage of adolescent social influence.

6.3.2. Legal implications

The age of responsibility in England varies across a number of domains. For example, the age someone can be held criminally responsible is 10, whilst the age at which an individual is legally allowed to drive a car is 17, and the age to vote, sit on a jury and purchase alcohol is 18. These laws are based on age grading – the use of chronological age as a marker of responsibility and competence. However, not all individuals develop equally and there is wide individual variation in brain, cognitive and behavioural development. In this section I briefly discuss how my findings, and developmental science more broadly, might be relevant to the debate around the age of criminal responsibility and joint enterprise convictions.

Around the world, the age at which an individual can be held criminally responsible for their actions varies considerably. For example, in England it is set at 10, whilst in most Scandinavian countries it is set at 15, and in Brazil it is 18. Although there is widespread variation in the age of criminal responsibility between countries, in the majority of cases it is set somewhere during the period of adolescence. In 2007 United Nations Committee on the Rights of the Child (UNCRH) published international recommendations that the minimum age of criminal responsibility (MACR) should be set no younger than 12 years of age. This recommendation has encouraged several countries to raise their MACR to at least 12. However, the MACR in England remains set at 10 years of age – the lowest in Europe. In reaching the recommendation of 12 years as the MACR laid out by the UNCRH, the committee highlight the importance of emotional, mental and intellectual maturity – evidenced by findings from developmental science that on average brain and behaviour continue to develop during childhood and adolescence (see **Chapter 1**).

Concerns have also been raised that an arbitrary cut-off age for criminal responsibility may not be justified given the wide individual variation observed in brain and cognitive development. However, solutions to this concern are far from clear without established norms for adolescent brain and cognitive development. A number of outstanding questions must first be answered. For example, the issue of what competencies would be included? And who would be qualified to administer such an assessment? At present, there remains no scientific, legal, or social consensus as to what these competencies

should be, and how they should be assessed. Given that there is currently no consensus as to how best to establish competence, age grading appears to be the most appropriate alternative (Zimring, 2005). Therefore, the need to establish a minimum age at which an individual can be held criminally responsible remains.

Throughout adolescence, perspective taking, emotion regulation, resistance to peer influence and metacognitive abilities all continue to mature (see **Chapters 1 and 5**). Given that these abilities are not yet fully developed, there remains an open question as to what extent adolescents should be afforded allowances under the law. In addition, adolescents may be especially driven to engage in behaviours which may lead to social approval, even if they are illegal (see **Chapter 3**) and this may be due to their desire to avoid social risks, especially given that adolescents report greater concern for social risks than adults (see **Chapter 2**). However, it remains extremely difficult to ascertain the extent to which adolescents should be afforded concessions by the law given findings such as these. Despite the scientific evidence being unable to identify a specific age at which criminal responsibility should be set, this should not deter policy makers from integrating what the evidence does suggest into their decisions to raise the MACR – that on average a 10-year-old is developmentally immature to a 12-year-old and so on.

In addition to debates surrounding the minimum age of criminal responsibility, in the United Kingdom, the law of secondary liability has also received significant criticism. The law of secondary liability, or sometimes referred to as joint enterprise, states that any individual who assists or encourages the perpetrator of a crime, will be held liable to the same degree as the perpetrator. Recently, a number of reports have highlighted the need for reform of this law, particularly given that sentences based on secondary liability are disproportionally applied to the Black, Asian and Minority Ethnic community. In addition, whilst there are no official published statistics on secondary liability convictions, over half of the 294 young prisoners surveyed by the Cambridge Institute of Criminology serving very long-life sentences were convicted through secondary liability, or joint enterprise (House of Commons Justice Committee, 2014).

From a social risk perspective, secondary liability, or joint enterprise, may also be disproportionally punitive towards young people. The evidence presented in **Chapter 2**, showing that the association between concern for social risks and rejection sensitivity is stronger among adolescents, relative to adults, suggests that adolescents may be especially driven to conform to the behaviour of their peers, in order to avoid appearing dissimilar and to increase group belonging. As discussed in **1.6** this aversion to social risk may be especially beneficial during adolescence, as adolescence might represent a sensitive period to the negative effects of social rejection. In turn, adolescents who engage in illegal behaviours in the presence of their peers may be doing so to reduce their social risk.

In Chapter 3, I showed that adolescents were more likely to anticipate engaging in aggressive and illegal behaviours, if they think this will lead to an increase in their likeability among others. In addition, I also show that the relationship between sensation seeking and expected involvement in aggressive and illegal behaviours is moderated by the degree to which individuals expect to be liked more or less by taking aggressive and illegal risks. The relationship between sensation seeking and expected involvement in aggressive and illegal behaviours is strong for individuals who also think they will be liked more. This means that social context can amplify the extent to which an individual's propensity to seek out rewarding and novel situations impacts decisions to engage in aggressive and illegal behaviour. Whilst this study did not make comparisons with adults, there is evidence that adolescents are more susceptible to social influence, relative to adults (Knoll et al., 2015, see **1.4.3**). Compared with adults, adolescents are also more likely to engage in risky, and illegal behaviours, such as breaking the speed limit when in the company of their peers, relative to when alone (see **1.4**). This may be one reason why there are higher rates of co-offending, versus solo-offending during adolescence. For example, in one study conducted in the United States on 937 male adolescents who had been convicted of serious offenses, 19% of participants reported engaging entirely in solo offending, 44% reported engaging in a mix of solo and co-offending and 37% reported just engaging in co-offending (Goldweber et al., 2011).

Given this information, secondary liability convictions may therefore be especially punitive towards adolescents, for whom reducing their social risk, during a developmental stage where peer acceptance is especially important for future health and wellbeing. Perhaps reform, or further discussion, is most crucial when secondary liability leads to a life sentence, for a crime such as murder.

6.4. Future directions

Throughout this thesis I have suggested a number of ways in which future work could, and should, build upon the findings presented here. However, here I will briefly discuss two ways in which the work presented could be extended.

6.4.1. Social risk and peer influence

One way the work presented in **Chapter 2** could be extended is by exploring the extent to which concern for social risk relates to behaviour. In particular, I had set up a study to explore the extent to which variation in concern for social risk relates to sensitivity to peer influence. However, due to the restrictions placed on in-person testing during the COVID-19 pandemic, this study was halted. I hypothesised that individuals who reported greater concern for social risk would be more influenced by peers, in an adapted version of the Knoll et al. study described in **1.4.3**. Individuals who are more concerned about engaging in behaviours which might lead to loss of face or social rejection may be more inclined to align themselves with the decisions of their peers in order to motivate group belonging. As previously discussed, peer influence in adolescence can be both prosocial and antisocial. An interesting question would be to explore the extent to which concerns for social risk influence both prosocial and antisocial influence in a similar way.

Another way this could be examined is to explore the degree to which one's changing social connections in their respective social network influences their engagement in certain risk-taking behaviours and how this is influenced by their concern for social risk. Using social network analysis, the relationship between individuals in a bounded network, such as a school, can be mapped. If this data is collected over time, alongside measures of risk-taking behaviour, modelling techniques, such as Stochastic Actor

Oriented Models (SAOMs), can be applied to explore the degree to which these behaviours can be seen to spread through the network, either as a function of selection (e.g. two individuals who smoke become friends) or influence (an individual takes up smoking as a product of being friends with someone who smokes). Indeed, existing studies using SAOMs of peer influence effects have shown that various traits and behaviours - such a positive and negative mood, smoking and marijuana use – indeed spread through influence across adolescent social networks (Burnett Heyes et al., 2015; Mills et al., 2019). In other words, spending time with individuals who engage in smoking or marijuana use, increases the likelihood that you will take up this behaviour, when controlling for baseline smoking or marijuana use. However, individual differences in susceptibility to influence effects are less well explored and one interesting future line of work could be to explore whether or not adolescents with high rejection sensitivity and concern for engaging in social risks are more susceptible to these peer influence effects.

6.4.2. Social preference

Building on the work presented in **Chapter 5**, future work should seek to build social preference tasks which more accurately simulate real-world behaviour. For example, the adapted academic diligence task presented here was low stakes, that is, there was little consequence for participants completing more of the maths. In turn, participants were unable to interact with the social and non-social stimuli. A better adaption of this task might incorporate a more interactive social and non-social task. For example, participants could be allowed to contrast the maths task with spending time on their social media applications such as Instagram or Facebook (for the social condition) or a game such as Tetris, used in the original ADT (for the non-social condition). This may improve the ecological validity of the task and better capture the types of social and non-social distractors which may influence people on a day-to-day basis.

6.5. Concluding remarks

This thesis investigated social risk and social development in adolescence. The findings presented have shown adolescence to be a period of heightened concern for social risk,

and a time when motivations to engage in certain risk behaviours are predicted by the perceived social benefit that engaging in these behaviours may lead to. In addition, this thesis has highlighted the significant relationship between sexual minority status and depression among adolescents, and has shown several poor outcomes among this group of young people to be downstream consequences of depression and conduct problems. This thesis has also shown that adolescence is a time of heightened self-reported preference for social, relative to non-social information, but that this does not reliably translate to behaviour. Finally, some of the empirical findings presented here, alongside previous work in the field, have been used to make public health recommendations, especially highlighting the power that peers have in guiding positive behaviour change.

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Appendices

A1. Appendix for Chapter 2

A1.1. Health and Social Risk Questionnaire (HSRQ)

Health and Social Risk Questionnaire (HSRQ)

For each statement please rate how worried you would feel doing this behaviour? (If you have never done it, imagine how you would feel). Not worried at all (0) – Very worried (100)*

1. Defend an unpopular opinion that you believe in. (S)
2. Admit that you listen to a singer or band that none of your friends like. (S)
3. Argue with a popular friend in front of a group of people. (S)
4. Wear clothes that are really different to your friends' clothes. (S)
5. Stand up for someone who is being mocked by your friends. (S)
6. Spend time with someone your friends don't like. (S)
7. Eat food that has passed its sell-by date. (H)
8. Ride a bicycle without wearing a helmet. (H)
9. Cross a main road when the crossing light is red. (H)
10. Pick up broken glass with bare hands. (H)
11. Drink tap water in a foreign country. (H)

Subscales: (S) = Social, (H) = Health.
Scoring: Compute an average score for each subscale by summing the responses of the social items and dividing them by six, and summing the responses of the health items and dividing them by five.

*Present as a sliding scale

A2. Appendix for Chapter 3

Measure	Acronym	TDS1		TDS2	
		Session 1	Session 2	Session 1	Session 2
Resistance to Peer Influence	RPI	x		x	
Cognitive Appraisal of Risky Events - Revised - Expected Involvement	CARE-EI	x			x
Social Appraisal of Risky Events	SARE	x		x	
Peer Experiences Questionnaire - Revised	PEQ - R		x		x
Brief Sensation Seeking Scale	BSSS		x		x
Need Threat Scale	NTS		x		x
Brief Fear of Negative Evaluation	BFNE		x		x
Wechsler's Abbreviated Scale for Intelligence	WASI		x		x

Table A2.1: Depiction of the timing of each assessment tool depending on the sample group

A2.1. Risk behaviours

Risk behaviours from the CARE included in analyses. For each of these behaviours individuals reported their expected involvement (CARE) and how much people would like them if they (a) engaged in the behaviour and (b) didn't engage in the behaviour (SARE).

Illicit drug use
Trying drugs other than alcohol or marijuana
Smoking Marijuana
Aggressive and illegal behaviours
Driving after drinking alcohol
Damaging/destroying public property
Hitting someone with a weapon or object
Slapping someone
Punching or hitting someone with fist
Risky sexual activities
Sex without protection against pregnancy
Sex without protection against STD's
Sex with someone I have just met or don't know well
Risky drinking
Drinking more than 5 alcoholic beverages
Playing drinking game

Comparison of models with and without control variables

Models predicting expected involvement in risky behaviours

Model Name	Fixed Effects	Random Effects	AIC	AIC of model without control variables	MLT
Hypothesis 1: Step one					
1 (null)	-	Subject ID	713.46	-	-
2	Age + Gender + IQ + Group	Subject ID	710.84	-	-
3	Age + Gender + IQ + Group + Social B-Do	Subject ID	682.98	682.49	>.05
4	Age + Gender + IQ + Group + Social B-Not	Subject ID	706.52	709.46	<.05*
5	Age + Gender + IQ + Group + Social B-Do + Social B-Not	Subject ID	684.95	684.32	>.05
6	Age + Gender + IQ + Group + Social B-Do*Social B-Not	Subject ID	684.11	683.89	>.05
Hypothesis 1: Step two					
7	Age + Gender + IQ + Group + Social B-Do*Risk Domain	Subject ID	668.26	668.41	>.05
8	Age + Gender + IQ + Group + Social B-Do + Risk Domain	Subject ID	681.67	681.41	>.05
Hypothesis 2					
9	Age + Gender + IQ + Group + Social B-Do*Risk Domain*RPI	Subject ID	662.36	665,26	<.05*
10	Age + Gender + IQ + Group + Social B-Do*Risk Domain + RPI	Subject ID	662.79	664.65	>.05
Hypothesis 3					
11	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Negative Evaluation	Subject ID	668.30	669.40	>.05
Hypothesis 4					
12	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Victimisation	Subject ID	657.83	658.89	>.05
13	Age + Gender + IQ + Group + Social B-Do*Risk Domain + Victimisation	Subject ID	665.22	666.60	>.05
Hypothesis 5					
14	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Self Esteem	Subject ID	671.10	672.05	>.05
Hypothesis 6					
15	Age + Gender + IQ + Group + Sensation seeking	Subject ID	699.90	702.32	<.05*
16	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Sensation Seeking	Subject ID	648.02	657.72	>.05
17	Age + Gender + IQ + Group + Social B-Do + Risk Domain + Sensation Seeking	Subject ID	660.21	661.43	>.05

Table A2.2: Models predicting expected involvement in risky behaviours; models including control variables (age, gender, IQ and group) are compared with models excluding these control variables. Social B-Do refers to the SARE scale measuring the perceived social benefit of engaging in the risk behaviour. Social B-Not refers to the SARE scale measuring the perceived social benefit of not engaging in the risk behaviour. MLT refers to maximum likelihood tests and the p values correspond to Chi Square values (* signifies significance where p<.05).

A2.2. Models on all data: including participants involved in the juvenile justice system

The following analyses are conducted on the complete sample, including the additional 10 participants with involvement in the juvenile justice system (see table S3 for demographics). Each model and its associated AIC and marginal R^2 values are reported in table S4.

Participant demographic information

Group	**TDS 1**	**TDS 2**	**TDS 3**
N	50	72	10
Age	Mean 14.0 (Range 11.7 – 17.9)	Mean 14.1 (Range 11.1 – 17.6)	Mean 16.36 (Range 14.45 – 17.80)
Gender	Male=29, Female=21	Male=32, Female=40	Male = 10, Female =0
IQ	Mean 98.8	Mean 108.0	Mean 106.2

Table A2.3: Participant demographic information

A2.3. Hypothesis 1: Social benefit of risk taking

In step one, model 3, which included age, gender, IQ, group and Social benefit-do, best fitted the data. Across all models of interest, model 3 had the best model fit based on our AIC criteria. Model 3 provided a better fit to all simpler models; the null ($X^2(5)=47.26$, p=<.001) and a model (model 2) including just age, gender and IQ ($X^2(1)=31.52$, p =<.001).

In step two, we added risk domain (substance use, aggressive & illegal behaviour, risky drinking, and risky sex) as an interaction term to our model. Model 7, which included age, gender, IQ, group and an interaction between social benefit and risk domain, explained more variance in expected involvement than model 3 ($X^2(6)=28.98$, p =<.001).

We tested the significance of this interaction by comparing model 7 to a model where Risk Domain was entered, but not as an interaction (model 8). Model 7 outperformed model 8 ($X^2(3)=19.77$, p =<.001), revealing the additional benefit of the interaction between perceived social benefit and risk domain in explaining expected involvement. Therefore, our best fitting

model (model 7), included age, gender, IQ, group and an interaction between social benefit and risk domain.

Estimates for model 7 are found in table S5. Omnibus tests on model 7, revealed a main effect of age (F(1, 134.02)=9.29, p =.003), social benefit (F (1, 372.43)=17.29, p =<.001), risk domain (F (3, 392.85)=5.21, p =0.002) and a interaction of social benefit and risk domain (F (3, 400.43)=6.75, p =<.001). To explore the interaction between perceived social benefit and risk domain we used simple slope analyses. The perceived social benefit from engaging in aggressive and illegal behaviours (β = 0.24, p <.001), substance use (β = 0.11, p =.05) and risky drinking (β = 0.35, p <.001) predicted expected involvement in these respective risk behaviours, however this was not the case for risky sex (β = -0.06, p =.54) (table 2).

Correlations between variables of interest

We computed a correlation plot depicting the relationship between each subsequent variable of interest (see Figure 2).

A2.4. Hypothesis 2: Resistance to peer influence

A model including an interaction with resistance to peer influence (model 9) better fit the data compared to our simpler model (model 7) (X^2(8)=19.99, p =0.01). We further tested whether this model including the interaction with RPI explained more variance in expected involvement over a simpler model where RPI was entered, but not as an interaction (model 10). Model 9 provided a better model fit than model 10, revealing the additional benefit of the interaction between perceived social benefit, risk domain, and resistance to peer influence in explaining expected involvement. Therefore, model 9 which included the main effect of age, gender, IQ and group, as well as an interaction between social benefit, risk domain, and resistance to peer influence best explains the data. Omnibus tests on model 9 revealed a main effect of age (F (1, 132.37)=15.70, p =.001) and social benefit (F (1, 368.55)=7.04, p =0.008) and a significant interaction between social benefit and RPI (F (1, 358.16)=4.37, p =0.03). We did not observe this significant interaction in our main analysis, in which the juvenile justice participants were excluded. All other fixed effects did not meet significance (p >.05).

A2.5. Hypothesis 3: Fear of negative evaluation

The model including an interaction with fear of negative evaluation (model 11) provided a better fit than the simpler model (model 7), which included age, gender, IQ, group and an interaction between social benefit and risk domain ($X^2(8)=27.41$, p =<0.001). Therefore, when in including the juvenile justice participants, we find that a model including an interaction with fear of negative evaluation better fits the data compared with our simpler model– this was not observed in our main analysis in which the juvenile justice participants were excluded. For completeness we then built an additional model (Model 11b) to compare model 11 with, in which fear of negative evaluation was included as a main effect. Model 11 (AIC: 838.26) outperformed our additional model (Model 11b; AIC: 842.28). Omnibus tests on model 11 revealed a main effect of age (F (1, 127.95)=6.62, p =0.01) and a significant interaction between social benefit, risk domain and fear of negative evaluation (F (3, 400.53)=7.04, p =0.01).

A2.6. Hypothesis 4: Peer victimisation

A model including an interaction with victimisation (model 12) outperformed our simpler model (model 7) ($X^2(8)=21.55$ p =0.005). We further tested whether this model including the interaction with victimisation explained more variance in expected involvement over a simpler model where victimisation was entered, but not as an interaction (model 13). Model 13 provided a better fit to our data than model 12 ($X^2(8)=15.99$ p =0.04). Therefore, when the juvenile justice participants are included we find the best fitting model to be a model in which victimisation is included as a main effect not an interaction with social benefit. Omnibus tests on model 13 revealed main effects of age (F (1, 132.34)=11.06, p =.001), social benefit (F (1, 366.63)=15.13, p =<0.001), risk domain (F (3, 395.63)=4.99, p =.002), victimisation (F (1, 138.76)=5.68, p =.02), and a significant interaction between social benefit and risk domain (F (3, 402.27)=6.54 p =<0.001). All other fixed effects did not meet significance (p >.05).

A2.7. Hypothesis 5: Self esteem

A model including an interaction with self-esteem (model 14) outperformed the simpler model (model 7), which included age, gender, IQ, group and an interaction between social benefit and risk domain ($X^2(8)=17.37$ p =0.03). For completeness we then built an additional model (Model 14b) to compare model 14 with, in which self-esteem was included as a main

effect. Model 14 outperformed our additional model (Model 14b; AIC: 849.28). Omnibus tests on model 14 revealed a main effect of age (F (1, 133.58)=9.7, p =0.002) and a significant interaction between social benefit and self-esteem (F (1, 329.35)=5.73, p =0.02). All other fixed effects did not meet significance (p >.05).

A2.8. Hypothesis 6: Sensation seeking

We built a model that predicted expected involvement in risky behaviours with sensation seeking (model 15). Model 15 provided a better fit than model 2 (which just included age, gender, IQ and group) (X^2(1)=12.72 p =<0.001). We then added an interaction with perceived social benefit and risk domain to the model (model 16), which improved upon model 15 (X^2(14)=83.57, p =<0.001). We tested the significance of including this three-way interaction by comparing model 16 to a simpler model, in which sensation seeking was added as a main effect not an interaction term (model 17). Model 16 outperformed model 17 (X^2(7)=26.66, p =<0.001), revealing the additional benefit of the interaction between sensation seeking, perceived social benefit, and risk domain in explaining expected involvement. Therefore, our best fitting model (model 16) included the main effect of age, gender, IQ and group, as well as an interaction between sensation seeking, perceived social benefit, and risk domain (see table S6 for the estimates of model 16). Omnibus tests on model 16, revealed a main effect of age (F (1, 130.22)=7.98, p =.04), a two way interaction of sensation seeking and risk domain (F (3, 404.38)=5.14, p =0.002) and a three way interaction of sensation seeking, social benefit, and risk domain (F (3, 410.61=5.86, p =<0.001). Simple slope analyses are reported in table S6.

Models predicting expected involvement in risky behaviours

Model Name	Fixed Effects	Random Effects	AIC	R^2 (marginal)
Hypothesis 1: Step one				
1 (null)	-	Subject ID	903.91	-
2	Age + Gender + IQ + Group	Subject ID	896.17	0.05
3	Age + Gender + IQ + Group + Social B-Do	Subject ID	866.65	0.11
4	Age + Gender + IQ + Group + Social B-Not	Subject ID	891.86	0.06
5	Age + Gender + IQ + Group + Social B-Do + Social B-Not	Subject ID	868.56	0.11
6	Age + Gender + IQ + Group + Social B-Do*Social B-Not	Subject ID	868.97	0.12
Hypothesis 1: Step two				
7	Age + Gender + IQ + Group + Social B-Do*Risk Domain	Subject ID	849.67	0.16
8	Age + Gender + IQ + Group + Social B-Do + Risk Domain	Subject ID	863.44	0.13
Hypothesis 2				
9	Age + Gender + IQ + Group + Social B-Do*Risk Domain*RPI	Subject ID	845.68	0.20
10	Age + Gender + IQ + Group + Social B-Do*Risk Domain + RPI	Subject ID	842.59	0.18
Hypothesis 3				
11	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Negative Evaluation	Subject ID	838.26	0.21
11b	Age + Gender + IQ + Group + Social B-Do*Risk Domain + Negative Evaluation	Subject ID	842.28	0.18
Hypothesis 4				
12	Age + Gender + IQ + Group + Social B-Do*Risk Domain*Victimisation	Subject ID	844.13	0.20
13	Age + Gender + IQ + Group + Social B-Do*Risk Domain + Victimisation	Subject ID	844.11	0.20
Hypothesis 5				
14	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Self Esteem	Subject ID	848.34	0.19
14b	Age + Gender + IQ + Group + Social B-Do*Risk Domain + Self Esteem	Subject ID	849.28	0.17
Hypothesis 6				
15	Age + Gender + IQ + Group + Sensation seeking	Subject ID	885.45	0.17
16	Age + Gender + IQ + Group + Social B-Do*Risk Domain* Sensation Seeking	Subject ID	829.88	0.23
17	Age + Gender + IQ + Group + Social B-Do + Risk Domain + Sensation Seeking	Subject ID	842.54	0.18

Table A2.4: Models predicting expected involvement in risky behaviours. Each model includes age, gender, IQ and group (TDS 1: child welfare sample and TDS2: community sample – TDS3 are included in the same group at TDS2 for these analyses given the extremely low sample size) as fixed effects. Social B-Do refers to the SARE scale measuring the perceived social benefit of engaging in the risk behaviour. Social B-Not refers to the SARE scale measuring the perceived social benefit of not engaging in the risk behaviour.

Fixed effects	**Estimate**	***SE***	***t***	***p***
Intercept	0.38	0.4	0.94	.35
Age	0.06	0.02	3.05	<.01
Gender	-0.06	0.07	-0.84	.40
IQ	-0.00	0.0	-1.54	.13
Group	0.00	0.07	0.01	.99
Social B-Do	0.24	0.08	3.05	<.01
Substance use	0.14	0.19	0.74	.46
Risky drinking	-0.19	0.19	-1.07	.68
Risky sex	0.65	0.23	2.83	<.01
Social B-Do*Substance use	-0.13	0.09	-1.38	.17
Social B-Do*Risky drinking	0.11	0.09	1.17	.24
Social B-Do*Risky sex	-0.30	0.12	-2.51	.01
Total Observations = 474				
Random effects	**Variance**		***S.D.***	
Participant (intercept)	0.048		0.22	
Simple slopes	**Estimate**	***SE***	***t***	***p***
Aggressive and illegal behaviours	0.24	0.08	3.05	<.001
Substance use	0.11	0.06	2.00	0.05
Risky drinking	0.35	0.05	6.57	<.001
Risky sex	-0.06	0.09	-0.61	.54

Table A2.5: Estimates for model 7, which included age, gender, IQ, group and an interaction between social benefit and risk domain.

Fixed effects	**Estimate**	***SE***	***t***	***p***
Intercept	0.70	0.49	1.41	.16
Age	0.05	0.02	2.82	<.01
Gender	-0.08	0.07	-1.26	.21
IQ	-0.00	0.00	-1.31	.19
Group	-0.02	0.07	-0.20	.86
Sensation seeking	-0.44	0.55	-0.80	.43
Social Benefit-Do	-0.01	0.19	-0.06	.95
Substance use	-0.12	0.40	-0.29	.77
Risky drinking	0.31	0.40	0.78	.43
Risky sex	-0.35	0.46	-0.76	.45
Sensation seeking*Social B-Do	0.43	0.31	1.34	.16
Sensation seeking*Substance use	0.34	0.75	0.53	.60
Sensation seeking*Risky drinking	-1.07	0.73	-1.47	.14
Sensation seeking*Risky sex	2.03	0.83	2.45	.01
Social B-Do*Substance use	0.08	0.22	0.35	.72
Social B-Do*Risky drinking	-0.10	0.21	-0.48	.63
Social B-Do*Risky sex	0.21	0.25	0.85	.40
Sensation seeking* Social B-Do*Substance use	-0.34	0.37	-0.85	.40
Sensation seeking* Social B-Do*Risky drinking	0.44	0.36	1.24	.21
Sensation seeking* Social B-Do*Risky sex	-1.01	0.44	-2.30	.02
Total Observations = 474				
Random effects	**Variance**		***S.D.***	
Participant (intercept)	0.046		0.21	
Simple slopes	**Estimate**	***SE***	***t***	***p***
Aggressive and illegal behaviours				
Social B-Do (-1 SD)	-0.5	0.26	0.19	.85
Social B-Do (Mean)	0.41	0.22	1.89	.06
Social B-Do (+1 SD)	0.77	0.40	1.92	.06
Substance use				
Social B-Do (-1 SD)	0.06	0.31	0.20	.84
Social B-Do (Mean)	0.14	0.20	0.70	.48
Social B-Do (+1 SD)	0.22	0.24	0.90	.37
Risky drinking				
Social B-Do (-1 SD)	-0.52	0.31	-1.66	.10
Social B-Do (Mean)	0.22	0.21	1.04	.30
Social B-Do (+1 SD)	0.95	0.21	4.47	<.001
Risky sex				
Social B-Do (-1 SD)	0.93	0.33	2.82	.01
Social B-Do (Mean)	0.44	0.23	1.89	.06
Social B-Do (+1 SD)	-0.14	0.38	-0.12	.91

Table A2.6: Estimates for model 16, which included the main effect of age, gender, IQ and group, as well as an interaction between sensation seeking, perceived social benefit, and risk domain.

A3. Appendix for Chapter 4

Variable	Sexual minority (SM)		Heterosexual		Difference test	
	Mean	SD	Mean	SD	t-test	Adjusted *p*-value
Depression (DEP)	8.97	6.71	3.95	4.41	-8.01	<.00001
Conduct problems (CP)	1.72	2.03	1.35	1.57	-1.97	>.05
Peer problems (PP)	2.66	2.17	1.59	1.73	-5.27	<.00001
Social support (SS)	0.72	1.13	0.50	0.86	-2.05	>.05
Victimisation (VIC)	7.70	3.58	5.85	2.89	-5.52	<.00001
Closeness to parents (PAR)	4.40	1.59	3.73	1.43	-4.46	<.0001
Smoking (SMO)	1.46	1.10	1.24	0.74	-2.15	>.05
Drinking (DRI)	1.51	0.90	1.31	0.68	-2.40	>.05
Drugs (DRU)	0.09	0.31	0.05	0.25	-1.15	>.05

Table A3.1. Results from t-tests conducted on each variable of interest between sexual minority and heterosexual male adolescents (Adjusted *p* value = Bonferroni corrected for multiple comparisons).

Variable	Sexual minority (SM)		Heterosexual		Difference test	
	Mean	SD	Mean	SD	t-test	Adjusted *p*-value
Depression (DEP)	13.21	7.35	6.64	6.11	-16.70	<.00001
Conduct problems (CP)	1.43	1.60	1.25	1.45	-2.03	>.05
Peer problems (PP)	2.11	1.97	1.40	1.61	-6.75	<.00001
Social support (SS)	0.94	1.21	0.44	0.87	-7.79	<.00001
Victimisation (VIC)	8.07	3.51	6.47	3.02	-8.50	<.00001
Closeness to parents (PAR)	4.60	1.54	3.99	1.53	-7.31	<.00001
Smoking (SMO)	1.63	1.21	1.27	0.81	-5.48	<.00001
Drinking (DRI)	1.44	0.71	1.32	0.67	-3.24	<.05
Drugs (DRU)	0.14	0.39	0.04	0.22	-4.99	<.00001

Table A3.2. Results from t-tests conducted on each variable of interest between sexual minority and heterosexual female adolescents (Adjusted *p* value = Bonferroni corrected for multiple comparisons).

A.3.1 Network comparison between males and females

We explored differences in the network structure between males and females. We compared the networks using the *NetwrokComparisonTest* (NCT) package in R (version 2.2.1). This is a permutation-based hypothesis test, which assesses differences in the structure between two networks. The test compares the network in three primary ways. (1) Network structure invariance: This test compares the difference in the maximal edge weight difference between the two networks and whether this differs from the largest edge weight difference of two randomly permuted networks. This is a measure of overall structural difference. (2) Individual edge differences: This test compares whether individual edge weight differences exist between the two networks (compared to two randomly permuted networks and Bonferroni corrected). The results of this test should be interpreted with cation if the network structure invariance test is non-significant. (3) Global network strength: This test compares the difference in the absolute sum of all the interrelations between the two networks (compared to two randomly permuted networks). This is a measure of overall network connectivity. NCT was not designed to handle mixed continuous and binary variables, therefore for these

purposes we treat all variables as continuous (as done by Sonmez, 2020: https://doi.org/10.7916/d8-bw9h-x816) – results should therefore be interpreted with this limitation in mind.

Results showed that the network structure was invariant (i.e., the networks did not significantly differ; p = .124). Further exploratory Bonferroni-corrected edge weight differences corroborate this finding showing that only one edge between depression and conduct problems was significantly different (p = .045). However, global strength invariance differed between groups (males = 3.11, females = 3.60, p=.003). This indicates that, whilst the network structure was the same across males and females, among females the variables in the network demonstrated greater connectivity.

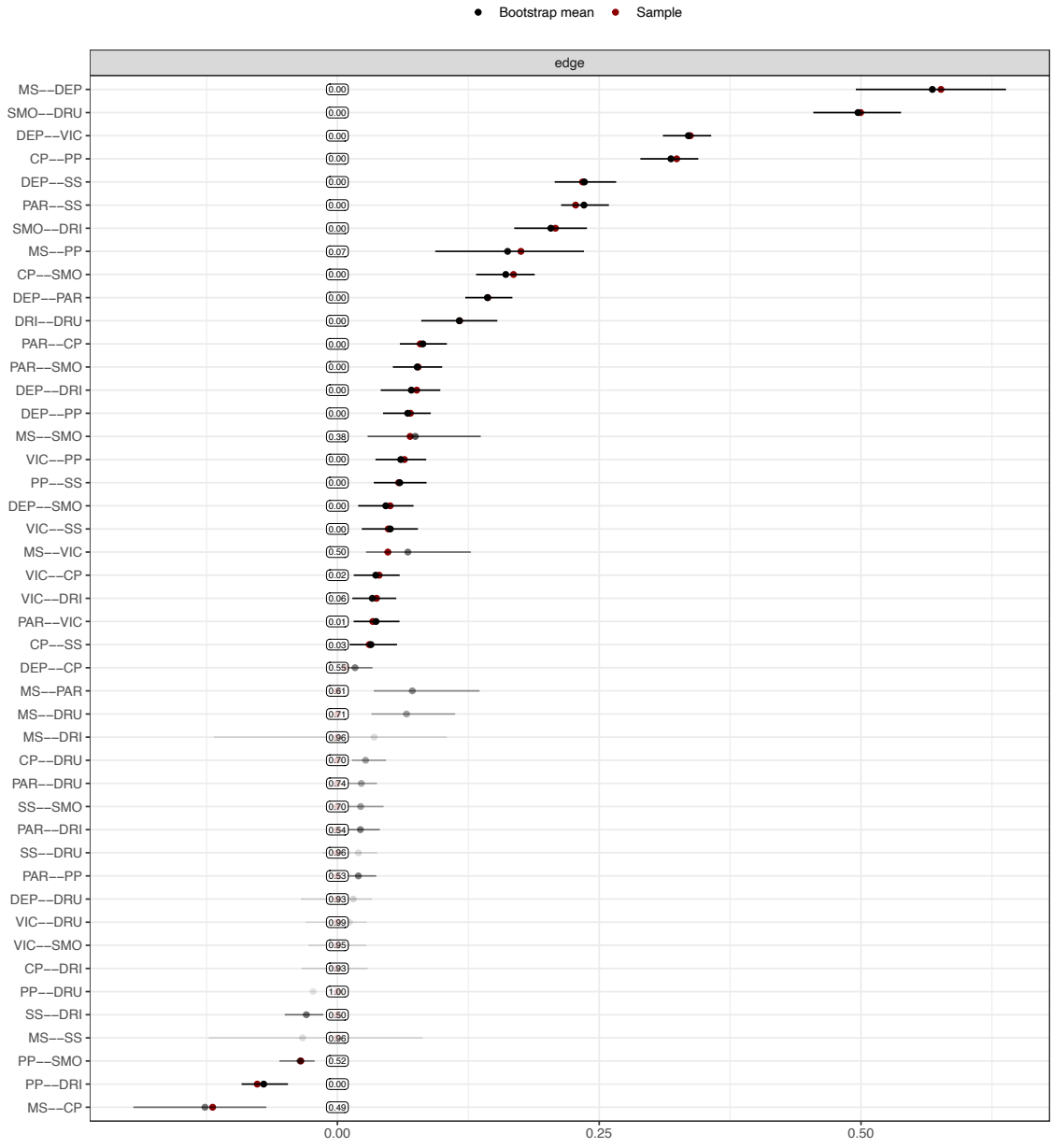

Figure A3.1. Edge weights for all edges in the network with bootstrapped 95% confidence intervals. The proportion of bootstrapped cases that were set to zero are shown for each edge. Grey lines indicate a zero-partial correlation (i.e. lack of an edge) between those variables. DEP = Depression, MS = Minority Status, VIC = Victimisation, SS = Social support, PAR = Closeness to parents, PP = Peer problems, CP = Conduct problems, DRU = Drug use, SMO = Smoking, DRI = Drinking.

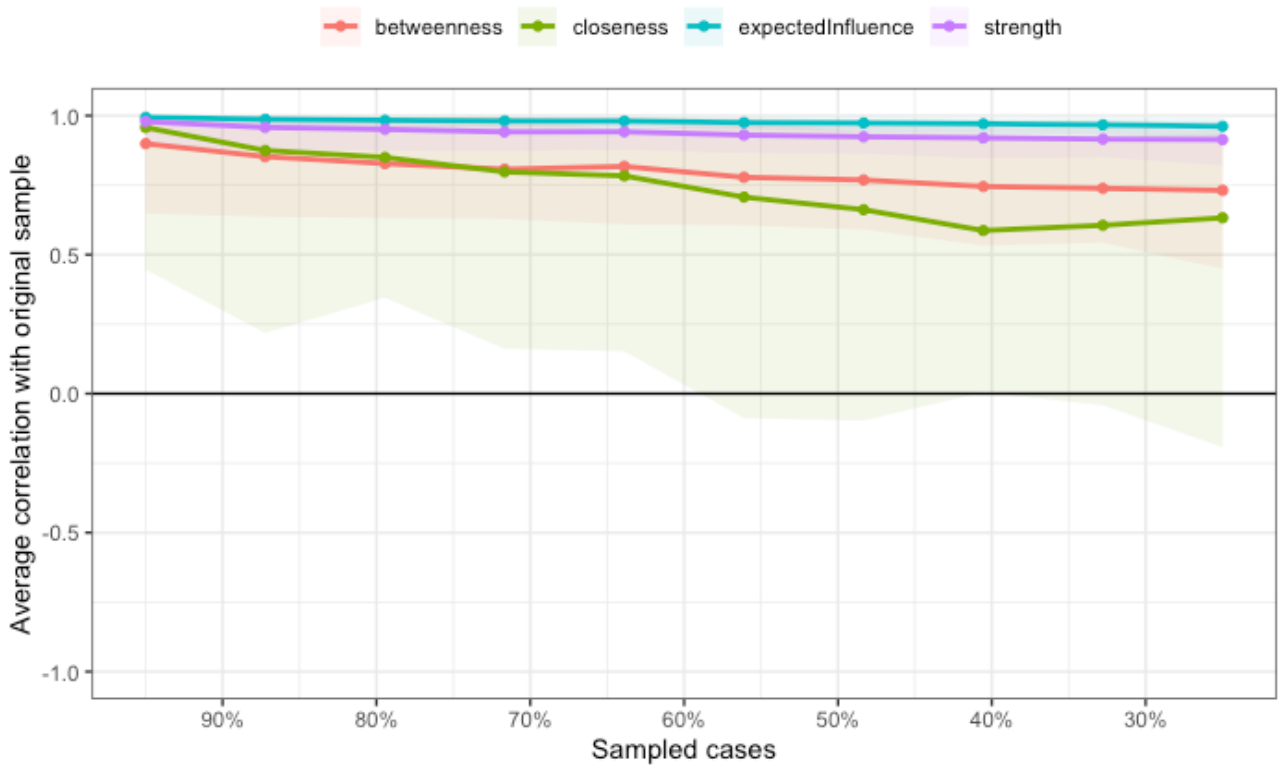

Figure A3.2. Bootstrapped stability of centralities measures. Stability scores are calculated by correlating the measures obtained from the full sample with those obtained after an increasing number of cases are systematically removed from the analysis [43]. The x axis refers to the percentage of persons dropped from the sample, and y the correlation with the original full sample. Shaded areas indicate 95% confidence intervals. We used the '*bootnet*' package for this and specified 1000 permutations.

A4. Appendix for Chapter 5

A4.1 Additional measures

I included additional questionnaires (see **Table A4.1** for means and standard error) to look at the relationship between performance on the task and measures of subclinical autistic traits (using the Autism-Spectrum Quotient (AQ). This questionnaire consists of 50 items and has good reliability for determining where any given individual sits on the autism spectrum. Measures of social reward were collected using the Social Reward Questionnaire – Adolescent Version (SRQ-A). This questionnaire consists of five subscales: enjoyment of admiration, negative social potency, passivity, prosocial interactions and sociability. This is a valid, reliable measure of social reward in adults and adolescents. Academic diligence is also related to 'grit', defined as perseverance and a passion for long-term and challenging goals. Therefore, I also included a standard questionnaire measure of 'grit', consisting of 12 items, where individuals are required to compare themselves to 'most people' on questions such as 'I have overcome setbacks to conquer an important challenge'. I predicted that the tendency to spend more time looking at social photographs might be inversely related to autistic traits and positively related to admiration, prosocial interactions and sociability. I also predicted that time spent doing maths would be positive related to higher grit scores. However, none of these measures correlated with task performance or self-reported enjoyment ratings (all p>.05).

Measure	Adolescents (mean, SD)	Adults (mean, SD)	p value, t test
WASI Matrices Raw	27.12 (2.86)	30.62 (3.86)	<.001
AQ	15.7 (6.08)	19.46 (6.90)	.008
SRQ Sociability	5.50 (1.04)	4.82 (1.23)	.007
SRQ Prosocial	6.5 0 (0.54)	6.13 (0.64)	.009
SRQ Admiration	5.73 (0.80)	5.79 (0.64)	.690
GRIT	2.89 (0.64)	2.69 (0.58)	.113

Table A4.1. **Questionnaire descriptive statistics.** Note: Max score for AQ is 50, for SRQ subscales is 7 and 5 for grit. Adolescents N=43, Adults N=46 (44 for WASI Matrices).

A4.2 Switches

I recorded the number of switches each participant made between the maths questions and looking at the show-reel of photographs, within each ADT condition. There was no significant main effect of age group (F(1,89) =0.581, p=0.448, η^2=.006) or condition (F(1,89)=.0.077, p=.782, η^2=.001) on the number of switches taken. There was also no significant interaction between age group and condition (F(1,89) =0.566, p=.454, η^2=.006). Controlling for autistic traits, social reward and grit did not affect the significance of these findings. In each case there were no significant effects (p<.05)

A4.3. Maths problems completed prior to switching

	Social Condition		Non-Social Condition	
	Adolescents	Adults	Adolescents	Adults
Mean	51.04	79.39	56.38	72.09
SD	68.72	88.01	70.06	101.6

Table A4.2: Mean and standard deviations of the number of maths problems completes before the first switch from maths to pictures, by condition.

There was no main effect of condition (F(1,89)=0.01, p=9.20, η^2= .00) or age group (F(1,89)=2.30, p=.133, η^2= .025) on the number of maths problems completed prior to the first switch to look at the pictures. There was no interaction between age group or condition (F(1,89)=0.42, p=.52, η^2= .01) (see table **A4.2** for descriptive statistics).

A4.4. Enjoyment rating for maths

All 45 adolescent participants provided an enjoyment rating for the maths in both conditions, but 4 of the 46 adult participants did not provide a rating in both conditions and were therefore not entered into the analysis. There was a significant main effect of age group (F(1,85)= 16.1, p=.001, η^2=.159) on maths enjoyment ratings. In the social condition, adolescents reported enjoying the maths significantly less than did the adults (t(85)= -3.723, p=.004). Similarly, in the non-social condition, adolescents reported enjoying the maths significantly less than did the adults (t(85)=-3.631, p=.004). There was no main effect of condition (F(1,85)= 0.689, p= .409, η^2= .008) on maths enjoyment ratings, nor was there was a significant interaction between age group and condition (F(1,85)= 0.03, p= .863, η^2= .001)

(Figure A4.1; **Table A4.1** for means and standard error). Controlling for autistic traits, social reward and grit did not affect the significance of these findings. In each case there was a significant main effect of age ($p<.05$) and all other effects were non-significant ($p>.05$).

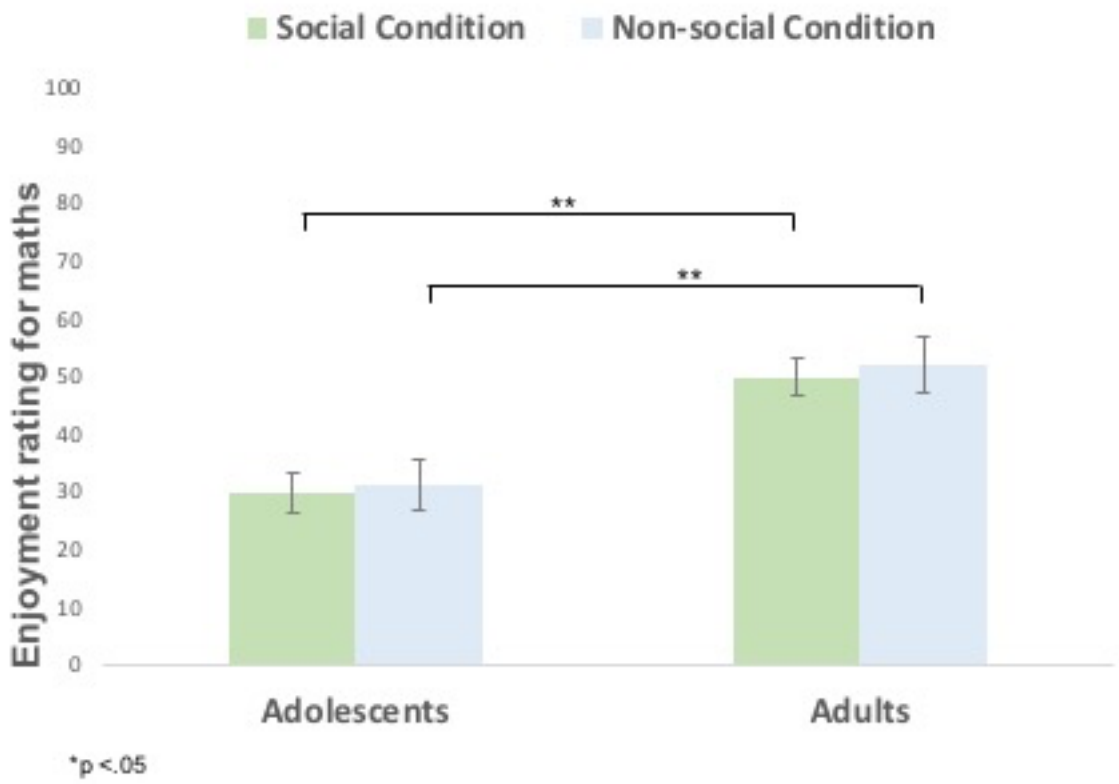

Figure A4.1. Enjoyment ratings

Mean enjoyment ratings for the maths in each condition, for adolescents and adults. Asterisks indicate Bonferroni corrected P values.

A4.5. Distributions of time spent looking at the pictures

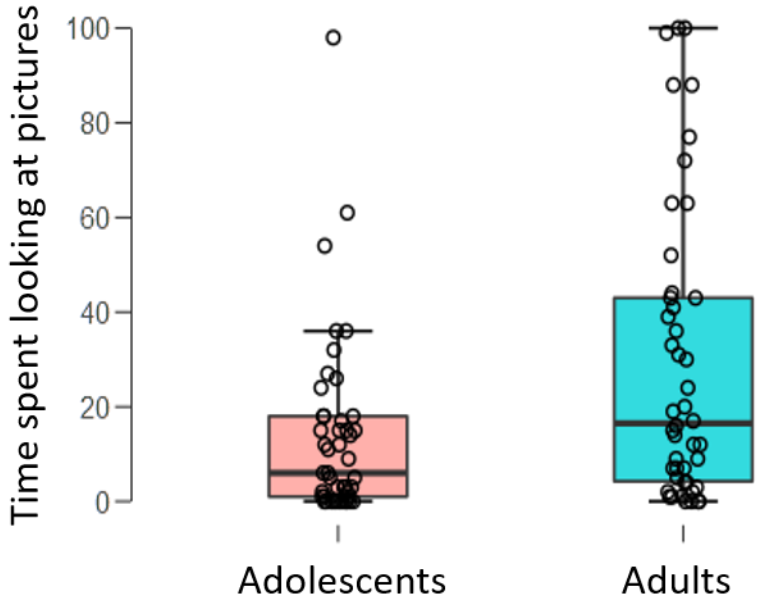

Figure A4.2. Distribution of time spent looking at non-social pictures in the non-social ADT

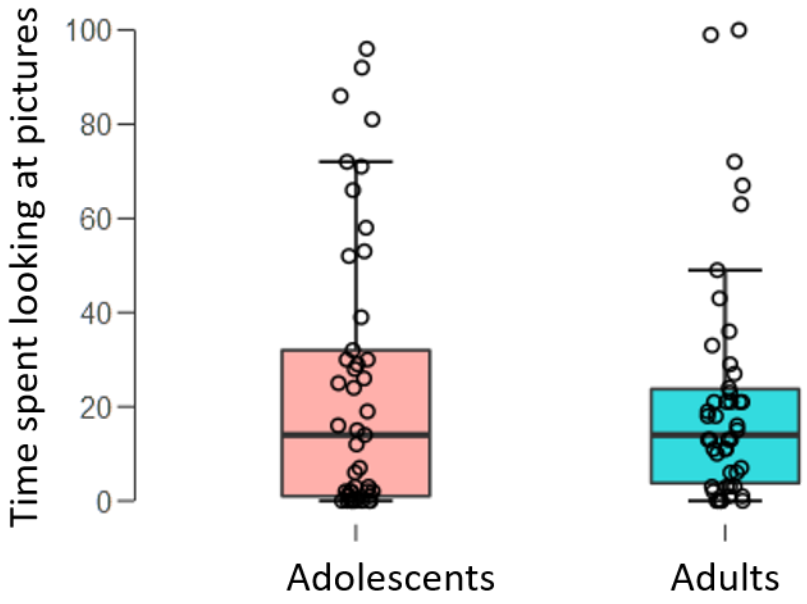

Figure A4.3. Distribution of time spent looking at social pictures in the social ADT